Feeding Status: A Comparative Study of Animal Foodways and Social Status in the Chinese Bronze Age (Guandimiao, Anyang, and Zhougongmiao, 13th-8th Century BCE)

by

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A dissertation submitted in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

Institute for the Study of the Ancient World

New York University

September, 2022

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ACKNOWLEDGMENTS

This dissertation would not have been possible without the guidance and support of many people to whom I am forever grateful.

I would first and foremost like to thank my advisor, Professor Roderick Campbell. His continued guidance at each stage of my study and kind support have helped me grow in every way. His many courses and discussions helped me to develop and expand my background in Bronze Age study and political economic theory, and it is from him that I began to understand anthropological archaeology and sinology in the West. It is based on his connections with collaborators in the Henan Provincial Institute of Cultural Relics and Archaeology and in the Institute of Archaeology in the Chinese Academy of Social Sciences that I was able to develop my dissertation study in Guandimiao and Anyang. His support and encouragement are a very important reason that I can finally finish my dissertation writing. His detailed reviews and edits (even to words and grammar) for each chapter and many invaluable comments help me to make the current form of the dissertation. To him, my gratitude is immeasurable.

I would like to thank my dissertation committee – Prof. Pam Crabetree, Prof. Lorenzo D'Alfonso, Prof. Katherine Brunson, Prof. Li Zhipeng 李志鵬, as well as my advisor Prof. Campbell. Their insightful and thoughtful comments are invaluable, and their generosity and encouragement give me much confidence to move ahead along the direction I have chosen in the dissertation.

I would also like to thank Li Suting 李素婷, Hou Yanfeng 侯彥峰, and Wang Juan (Luna) 王娟 in the Henan Provincial Institute of Cultural Relics and Archaeology, where I got a full permission to study the Guandimiao animal assemblage during 2015-2018. I really appreciate many valuable opportunities to communicate with Hou Yanfeng on questions about Guandimiao and the animal bone study. It is based on Hou's funding support that I can get the result of stable isotope analysis on domestic animals in Guandimiao (which was assisted by Zhou Ligang 周立剛 in the same institute). Li Suting introduced to me the main achievement of the field work in Guangdimiao, she was always nicely to answer my detailed questions on Guandimiao archaeology and gave me the access to work on the Guandimiao ceramic assemblage in the Xishan workstation. Luna was a very good colleague to help me solve problems on the use of the modern animal bone collections in the institute.

Thanks to Li Zhipeng and He Yuling 何毓靈 in the Anyang Workstation of the Institute of Archaeology in the Chinese Academy of Social Sciences, who made it possible for me to study the Xiaomintun animal remains in the winter of 2017. Li Zhipeng generously shared to me his study on the Xiaomintun assemblage and provided some very crucial background information to help me make a proper design of bone sampling. He Yuling granted me access to the workspace in Anyang Normal University where I studied the Xiaomintun animal bone samples and to the Anyang Workstation where I studied the ceramic collection from the same site. He Yuling also kindly showed me some unpublished data on ceramics at that time.

I owe many thanks to Lei Xiangshan 雷興山 and Chong Jianrong 種建榮 for allowing me to take part in the project of Zhougongmiao Archaeology, which was organized by both Peking University and the Henan Provincial Institute of Cultural Relics and Archaeology. Their kind attention and assistance in many ways had allowed me to finish my master's thesis in 2012 based

on this project, and I was also well treated during the beginning of 2018 to work on a sample of the Zhougongmiao animal bone assemblage for this doctoral dissertation.

I would like to thank Professor Pam Crabtree. It was from her courses that I systematically learned archaeological theory in the West and the basic situation and methodology of zooarchaeology in the West. I am also grateful to her for the guidance in developing this dissertation. Thanks to Professor Li Feng, Professor Adam Schwartz, and Professor Guo Jue, as well as Professor Campbell, from whom I received some basic training in Chinese epigraphy and Chinese texts by taking their courses.

Moreover, my dissertation would not have been possible without the help and counsel of a number of other people and institutions. Thanks to Professor Wang Ning 王寧 in the History and Culture and Tourism Institute, Jiangsu Normal University, who kindly shared to me some of his unpublished stable isotope data of human bones from Guandimiao; Dr. Li Nan 李楠 in Peking University, who offered me the unpublished stable isotope data of human and animal bones from Zhougongmiao; Dr. Zhang Yue 張樂 in the Institute of Vertebrate Paleontology and Paleoanthropology, the Chinese Academy of Sciences, from whom I got some very useful suggestions on the study of bone modification; Professor Cui Tianxing 崔天興 in the School of History, Zhengzhou University, who helped to duplicate a stone axe for my research; his colleague Zhang Li 張莉, who invited me to Zhengzhou University in the summer of 2016 where I had a very pleasant communication with professors and students about my dissertation work and it was a great encouragement for me to develop my research plan; Dr. Ma Xiaolin 馬蕭林 in Henan Museum, who offered me a chance to teach a zooarchaeology course in Henan University; the technicians, Li Yujie 李玉潔 and Wang Shufang 王書芳, and some intern students in the Henan

Provincial Institute of Cultural Relics and Archaeology, who were very good assistants for my staying in Zhengzhou during 2015-2018; Feng Wenli 馮雯麗 in the Zhougongmiao archaeological team and staff of Zhouyuan Museum, who helped me to push the work in Zhougongmiao smoothly; Professor Hu Hongqiong 胡洪瓊 and some students in the Faculty of History and Archaeology, Anyang Normal University, who kindly hosted me when I conducted my work in Anyang in the winter of 2017.

I am incredibly grateful to the experience studying at the Institute for the Study of the Ancient World. It provided me with wonderful research facilities and financial supports. And more importantly, it offered me a chance to obtain a much broad view to understand ancient China and ancient world. This leads to the current form of my dissertation, and it will definitely continue to benefit me. I also would like to thank the Chiang Ching-Kuo Foundation for International Scholarly Exchange who gave me a financial assistance for my dissertation writing during 2018-2019.

At last, I would like to thank my parents for their love and support, and for always believing in me, and my daughter for being a strength to keep me moving forward. And, finally, I would like to thank my husband Liang Tian – any words cannot be enough, and I am deeply grateful to every day we have spent together and everything he has done for me.

ABSTRACT

In the dissertation, I generally investigate how the analysis of animal bone remains, as well as ceramic vessels from residential contexts and correlated human skeletons from tombs, can shed light on the relationship between foodways and social status in the Chinese Bronze Age.

This study is based on archaeological work at three sites, Guandimiao 關帝廟, Xiaomintun 孝民屯, and Zhougongmiao 周公廟, which cover the core area of the Chinese Bronze Age in the Central Plains, extend from the late Shang period (13th-11th century BCE) to the Western Zhou period (11th-8th century BCE), and represent settlements of different contexts (rural vs. urban, Shang vs. Zhou). Animal remains of the three sites can roughly be attributed to daily food waste of local residents, the vast majority of whom are people of lower status and have long been neglected in received texts and by most historical and archaeological studies.

The main part of this dissertation focuses on solving the basic question of how animal food was prepared and consumed by non-elites in this period. A review and discussion of animal food production shows that meat consumption was based on a relatively stable structure of animal husbandry in this period, which offered reliable meat resources for both rural and urban settlements and also allowed the development of some degree of separation and specialization in production at the same time. Most of my work is on analyses of patterns of bone modification (bone breakage and butchery marks), as well as the regular skeletal element representation which reveals many details of cattle and pig butchering and meat cooking in communities of non-elites. It shows that large animal carcasses were processed following roughly similar procedures in the three sites. And, meanwhile, the rich evidence shows an interaction of butchery techniques, available tools,

butchery skills and butchers, preparation and consumption vessels and techniques, and possibly other cultural variables (such as gustatory preference) distinguish the three social groups. The comparisons prove that, in stratified Shang and Western Zhou societies, there was significant differentiation even between non-elites (urban vs. rural, and Shang vs. Zhou) and it was prevalent indeed in the details of daily life. It will be very interesting to further discuss the underlying causes and implications.

It should be pointed out that this study offers a chance to reconstruct the social life of communities of non-elites, especially that of the small rural settlement Guandimiao. Analysis of Guandimiao indicates the poverty and uniformity of the rural households and a relatively loose village-level organization. It suggests a degree of independence of the community as a unit in daily life, while it had to depend on outside powers and communities as previous studies have shown.

In addition, I would like to emphasize the methodological purpose of this dissertation, which aims to explore a possibility to excavate new information from animal bones in the study of complex societies in China based on studies of the most common animal bone remains from daily food waste. Following this method, close attention should be paid to evidence on bone modification and the analysis of taphonomic attritions. This dissertation demonstrates both the viability of this kind of approach in Chinese archaeology and its necessity.

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CHAPTER 1: Introduction

The study of foodways has long been a main topic in anthropology and archaeology, considering the nature of food to connect human beings with the outside world and to manifest and help construct social institutions and structure. For this reason, issues of foodways have also been actively discussed by zooarchaeologists. In my dissertation, I will investigate how the analysis of animal remains, as well as ceramic vessels from residential contexts and correlated human skeletons from tombs, can shed light on the relation between foodways and social status in Early China.

This study will be based on archaeological works at three sites, Guandimiao 關帝廟, Xiaomintun 孝民屯, and Zhougongmiao 周公廟, covering the core area of the Chinese Bronze Age in the Central Plains, and extending from the late Shang period (13th-11th century BCE) to the Western Zhou period (11th-8th century BCE).

To begin with, in this chapter I would like to roughly review the study of foodways in anthropology and archaeology (including zooarchaeology) in general, related studies in China specifically, and explain the purpose of this dissertation, as well as the arrangement of each chapter.

1.1 The Importance of Foodways: Related Work and Assessment

1.1.1 The Significance of Foodways in Social Study

People eat in order to live. However, food is not just for subsistence. As Andrew Sherratt wrote, "people don't eat species, they eat meals" (1991:221). More than providing simply nutritional value, food in human societies can be endowed with great social and cultural weight. On the one hand, food and the processes of food preparation, presentation and consumption are truly a combination of nature and culture. It is through activities of food processing that some natural resources are turned into an "edible" diet. It is also in this process that food becomes imbued with social and cultural values and can reflect the structure and function of social life. On the other hand, not only can food systems be structured in numerous ways in any given society based on specific social and cultural settings, but these food systems themselves and the construction of them can shape the social and cultural structures within which they are embedded. In other words, food and related activities have been fundamental in generating and sustaining social life (Curet and Pestle 2010; Dietler and Hayden 2001a; Graff and Rodríguez-Alegría 2012, Montón-Subías 2002; Twiss 2012).

In general, the process of interaction between people and food and the transformation of food from nature to culture can be divided into a series of activities: people acquire or produce (e.g., gather, hunt, raise, or trade for) food resources, they process it (e.g., butcher, thresh, and cook), they eat it, and they discard the waste, while activities like storage, distribution, and food sharing may happen between these steps (Twiss 2012:361-362). Goody summarized these activities to five phases as production, distribution, preparation, consumption, and disposal (Goody 1982:37). This whole interrelated system, which is composed of diverse ideas, habits and practices, are broadly termed foodways (e.g., Anderson 1971; Peres 2017; Twiss 2012). Taking a foodways perspective, it is possible to help archaeologists interpret the various social and cultural meanings of food (as mentioned above). However, these different stages of human-food interaction have not received the same amount of attention from archaeologists and scholars in other social sciences.

Since the early 20th century, anthropologists have intensively studied food systems of contemporary human societies, coming to see the significant role of food production and consumption patterns in broad social and cultural processes (e.g., Anderson 1988; Douglas 1984; Goody 1982; Harris 1985; Kahn 1986; Lévi-Strauss 1988; Mintz and Bois 2002; Radcliffe-Brown 1948; Richards 1932, 1939). Nevertheless, even in these cases, more efforts are given to the study of food for subsistence purposes or food as an essential for feasting and consumption, while food processing and specifically cooking practices have drawn less attention than other aspects in the study of food systems and, in many cases, are only seen as an accessory of consumption studies.

In archaeology, the development of food studies has lagged behind even its sister disciplines (Gifford 1981; Montón-Subías 2002; Parker-Pearson 2003). Since the 1970s, the topic of food in ancient societies has often been extended to the perspective of nutrition (i.e., diet and subsistence) or economic structure (i.e., food production and distribution), and, more occasionally, considered in the context of ritual. Food processing activities are, as Twiss (2012: 362) notes, often divided into two steps: 1) initial preparation of raw resources for storage, transport, and/or cooking (primary butchery or threshing and winnowing), and 2) pre-consumption preparation (cutting, grinding, soaking, cooking). For a long time, scholars were interested in subsistence and energetic systems, and were satisfied to take the first step as the main issue of food consumption study, especially in the study of animal-based foods. In this way, "food" production and "food consumption" in general were taken as the main components interacting with ecological context, while cooking was only "a dependent variable of other aspects" (Montón-Subías 2002: 8) and the details of preconsumption activities were treated as of little importance.

Fortunately, in recent years, with social and symbolic issues coming to the fore of archaeology and the study of agency becoming increasingly popular, more and more archaeologists have attempted to emphasize and study the meanings of food beyond its economic function (e.g., Crabtree 1990; Danforth 1999; deFrance 2009; Dietler and Hayden 2001b; Gumerman IV 1997; Miracle and Milner 2002; Parker-Pearson 2003; Spataro and Villing 2015; Twiss 2007). In this body of work, the practices of food processing and cooking have come to be seen not only as technological processes that make raw resources edible, but also as a key point in transforming raw matter from "nature" to "culture" (Lupton 1996) so as to further reflect and affect networks of personal relationships and social structures. Additionally, the political power of cooking with special stress on the definition and creation of identity and difference have already been noted. Last but not least, the study of food preparation brings those very people who were most often omitted from historical texts (and even from many archaeological discussions) to life. For all these reasons, the final stages of food preparation are an emerging focus of archaeology (e.g., Hastorf 2017; Klarich 2010).

1.1.2 The Study of Foodways in Zooarchaeology

Food is a necessity of life and is also imbued with social and culture meanings. In the case of animals, meat is a type of highly valued food in most societies. Therefore, food selection, especially the selection of meat, is particularly rich in social rules and meanings (Fiddes 1991: 5). While animal carcass processing and meat cooking contributes to the nutritional value of a diet, it also affects patterns of animal food acquisition/production and consumption, such as activities in which animal carcasses are transported and processed (e.g., Gifford-González 1993, Oliver 1993). The varied choices are always intertwined with different cultural and social contexts. Therefore, the existence of certain foodways associated with significant foods like meat should also be related to the expression and construction of networks of social relations and values (e.g., Isaakidou 2007; Stokes 2000).

Animal bones are among the most common remains in archaeological excavations. Most of them are results of human activities, and, especially in residential settlements, consumption events. Since the late 1960s, faunal analysis, or zooarchaeology, has become one of the fastest-growing subdisciplines within archaeology – continually growing and changing along with its parent discipline of archaeology. By a direct study of human-induced animal bone remains, zooarchaeologists make it possible to directly study human activities and choices, such as animal husbandry and hunting, a group's preference for particular meat cuts, and some butchering and cooking habits (Graff 2018). However, for a long time, the discussion of food production and consumption in zooarchaeology has been focused on patterns of economy and subsistence as well as animal use in some special contexts, such as sacrifice and feasting (although there were some exceptions, such as Crabtree (1990), and Schulz and Gust (1983)). This is partly because the evidence relevant to these activities is simply easier to see archaeologically, as it often involves special treatment of animal carcasses, and, in many cases, it needs only a collection of macro bone remains with little requirement of more advanced laboratory analysis. It has been only recently that the processing and cooking of meat in domestic contexts has become an independent and

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important topic (Gifford-González 1993; Isaakidou 2007; Jackson and Scott 2003; Oliver 1993; Pearce and Luff 1994; Russell and Martin 2012; Wandsnider 1997). Broadly speaking, the study of the processing and cooking of animal food is not only useful in understanding human society, but also helpful in refining the methodologies of zooarchaeology – such as those related to the identification and quantification of animal remains and the formation of zooarchaeological records.

1.2 The Importance of Foodways in China and Related Works

1.2.1 The Importance of Foodways in China

K. C. Chang once stated that "one of the best ways of getting to a culture's heart would be thorough its stomach" (Chang 1977: 4). Indeed, the importance of food in Chinese culture can never be emphasized too much – for Chinese people, "food is heaven" (民以食為天). Chinese food culture is closely intertwined with Chinese civilization.

In a famous introduction to Food in Chinese Culture (Chang 1977), K. C. Chang summarized some special features of Chinese food culture. Understanding these features should be a first step to interpret the Chinese preoccupation with food and eating. As Chang said, the Chinese food tradition is a complex of "countless food variables". On the one hand, the distinctive *fan*-*cai* (飯-菜) principle requires an interrelated and balanced use of multiple ingredients, including mainly *fan* (grains and other starch foods) and *cai* (vegetable and meat dishes) (as well as drinks), accomplished by a mixing of flavors in food preparation. Also, it leads to the parallel innovation of other features of Chinese food culture in food preparation, service and consumption, especially in the area of utensils and food rituals. On the other hand, the flexible Chinese way of eating – a relatively free combination of ingredients in each dish and dishes in each meal – allows for a great extent of adaptability. In this sense, "food and eating are among things central to the Chinese way of life and part of the Chinese ethos" (Chang 1977: 14). Within this tradition, it is not difficult to understand that "countless food variables are articulated in countless ways by subsegments of the Chinese culture and in various social situations" (Chang 1977: 14). At the same time, "the Chinese use or view food as symbols for the subsegment or for the situation" (Chang 1977: 14). As K. C. Chang mentioned, different food styles can reflect various cultural distinctions, such as those between regions, different economic classes, and diverse belief groups (based on religion, ethnic origin, occupation, etc.). Moreover, in many social interactions, food is also taken to express or construct the "minute and precise distinctions, and nuances of distinctions, in regard to the relative statuses of the interacting parties and the nature of the interaction" (Chang 1977:16). Thus, in some pre-Qin texts, a good ruler was analogous to a skillful chef, while governing a large state was like delicately cooking a small fish ("治大國若烹小鮮", from *Dao De Jing* 道德經 ch. 60); members of the nobility and officials had more opportunities to eat meat and were known as "meat eaters" (*rou shi zhe* 肉食者), while commoners were "bean leaf eaters" (*huo shi zhe* 藿食者); and bronze food vessels, especially the *ding* cauldron (which was used for cooking and/or holding meat food), were at the core of sacrificial rituals and taken as symbols of power.

1.2.2 The Significance of (Meat related) Foodways in the Construction and Maintenance of Social Hierarchy in the Chinese Bronze Age

The Chinese Bronze Age marks a highly stratified society in the Central Plains. According to K.C. Chang, "[t]he new societal realignment was essentially one based on the distribution of food resources" (Chang 1977: 20). In other words, it was a time when the Chinese population split along food lines. Considering that animal food was taken as the most valuable and precious food in the Bronze Age, it was more sensitive than any other kind of food to social distinctions and played a more important role in social reorganization.

In Shang and Western Zhou times, the whole social and political structure was based on kinship units, lineages and clans[1]. Each large lineage was a highly stratified society within itself and the whole society had a pyramid-like structure supported by lineages of different levels, while

[1] Though there are some debates about the degree of bureaucracy in Shang and Western Zhou, most scholars agree that kinship was still the most powerful factor in the formation of social and political order in this period (e.g., Campbell 2009; Chang 1980; von Falkenhausen 2014; Keightley 1983; Li 2008).

each person's political and ritual status was based on his position in the lineage system. The ruler was the high-lineage leader who occupied the largest urban center, together with his royal lineage members and officials. The capital city was surrounded by some small settlements, and the distribution of people/lineages in these settlements coincided with the segmentary lineage network. So too was the allocation of social wealth and resources. The ruler and his royal families were on the top; the subordinates were other lineages of a similar structure, with lineage leaders and their lineage members; slaves were at the bottom (e.g., Campbell 2007, 2009, 2018; Chang 1980; Keightley 1999; Zhu 2004).

Based on this hierarchical structure, we can see the potential interaction between meat food/resources and social status from multiple perspectives. a) As one of the high-valued resources for subsistence, animal meat resources were easily concentrated at the upper levels (elites and urban areas). Besides the many records from texts, studies show that a huge number of animal resources in the Shang capital, Anyang, were probably provisioned from outside (Li 2009, 2011a, 2011b), and the most precious exotic animals were only found in palace areas (Teilhard de Chardin and Yang 1936; Yang and Liu 1949). It leads to the possibility that meat consumption and status were closely related. b) Even in daily life, diverse foodways could also be a good medium to distinguish groups. According to many pre-Qin texts, elites enacted their status by emphasizing the special/complicated/ritual activities associated with cooking and consumption of meat, such as exotic/ rare/ labor-intensive ingredients; complex recipes, specialized production/ preparation/ service personnel, and elaborate etiquette. c) As mentioned above, meat is a wonderful tool to investigate the interconnection and separation of participants in various occasions of communal eating (Haapanen 2005). It has long been noticed that animals and meat, including also the relevant materials and activities, are some of the core elements in the system of ancestral worship. It was especially true in the Chinese Bronze Age, when the ideas and activities of ancestral worship functioned to maintain the pyramid-like social and political structure. Animals and meat were taken as offerings for ancestors and the powers of nature in some ritual activities, showing the hierarchical and reciprocal connection between the living and dead/nature. Sacrificial animals and meat were only allowed to be consumed in certain groups, and only some leaders held the right to decide the qualified persons who would receive the sacred meat, while the possibility that people could be present in certain occasions and would get meat later also became something over which these participants competed.

1.2.3 Previous Studies of Chinese Foodways

Considering this long-standing cultural tradition on food and associated rich materials, the study of food culture in China is far from sufficient. Much of the Sinological work remains merely descriptive and based on received texts written long after the Shang period, which, in addition to being frequently anachronistic, has focused on history and elite culture. Anthropology and sociology in China are both relatively new disciplines and the most extensive work on the subtopic of food has focused on food insecurity, eating and ritual, as well as eating and identity in general, and is especially focused on modern times (e.g., Chang 1973; Anderson 1988; Simoons 1991; Huang 2000; but see Sterckx 2005, 2011 for discussion of ancient China). For a long time, food in Chinese archaeology has been discussed under an economic or subsistence rubric, as well as taken as a component in ritual and sacrifice (e.g., Ye 1997; Yang and Ma 2010). In all these studies, food is roughly equated to food resources (plant and animal raw materials), or it is studied as an abstract symbol only. In other words, most of these topics are about food production, distribution and consumption in general, and the study of food in Chinese archaeology has been rather superficial and incomplete. The study of cooking, on the other hand, is largely derived from a discussion of vessels and vessel residues (e.g., Haapanen 2005; Jaffe 2016; Lanehart 2015) and, to a lesser degree, oracle bone inscriptions (e.g., Song 2005), and iconography.

It is the same case in the subfield of zooarchaeology. Zooarchaeology in China is a relatively young field, which was introduced from the West in the 1980s (Qi 1983; Yuan 1994). Following the trends of zooarchaeology in the West, Chinese zooarchaeology has some similar limitations, in addition to generally being years behind. Related research emphasizes topics such as domestication, husbandry, economic production, and sacrificial animals in some ritual contexts (tombs, foundations, palatial areas, etc.) (e.g., Campbell et al. 2011; Kim 1994; Linduff 2003; Li 2008; Li 2009; Mair 2003; Nelson 1998, 2003; Yuan et al. 2008; Yuan and Flad 2002, 2005). Even though we have known from both texts and material culture the importance and complexity of meat consumption in various ritual activities since at least the Chinese Bronze Age, very little research has gone beyond basic description and quantitative measures (mainly taxa and number), which can only have limited contribution to the understanding of political economic systems in that long period. Daily food practices are even less studied. While the topic of foodways is getting more and more attention in contemporary Anglo-American archaeology, it is still long overdue in Chinese zooarchaeology. However, recently, based on an improvement of methodology in field excavation and a gradual enlargement and shift of interests in study, some scholars are beginning to tackle issues of animal butchering, transportation, and distribution (e.g., Flad and Yuan 2006; Li 2008). This provides a context for a more advanced study of foodways in Chinese archaeology.

1.3 The Focus of My Dissertation

In this dissertation, animal related foodways in daily contexts, especially food preparation (including food processing, cooking and related activities), as defined by Goody (1982), will be a main concern (while taxa and quantity will also be included). The research will be based on three archaeological sites dating to the Bronze Age in China: Xiaomintun (part of Yinxu, a metropolitan center of the late Shang), Guandimiao (a Shang village site dating to the Yinxu period), and Zhougongmiao (a metropolitan center of the early Western Zhou -- the successive political power of Shang in the Central Plains). Animal remains of the three sites can roughly be attributed to food preparation and consumption of local residents, the vast majority of whom are people of lower status.

The basic question I am going to attempt to answer is how people, non-elites specifically, processed animal carcasses, as well as cooked and ate meat, especially large mammals, in the Chinese Bronze Age. Based on the traditional understanding (mainly from received texts, and some social models, such as the cultural historical model), as well as some archaeological and epigraphic evidence (such as houses, tombs, artifacts, and oracle-bone and bronze inscriptions), there is a vague belief that people of lower status were generally poor and were attached to those of higher status. However, little is actually known about the lifeway of people of lower status or residents of small settlements. Food and foodways are one of the direct lines of evidence into the lives of individuals and social groups. Via an examination of animal food and foodways in daily contexts, the three social groups, as represented by remains of the three sites, will be characterized. I will especially focus on the analysis of animal assemblage in Guandimiao, which is the first fully excavated Bronze Age village. Its complete animal bone collection enables a detailed study of animal processing before and, sometimes, during consumption. In addition, a sample of the Xiaomintun and Zhougongmiao assemblages will be utilized for comparison and discussion. (The detailed research questions are discussed at the end of Chapter 4.)

In addition, I am going to deal with the question how animal foodways were associated with status in Bronze Age. Specifically, I would like to explore to what extent the non-elite urban citizens are distinguished from those rural residents, and how the foodways can reflect the difference between different cultural groups. It has been clear enough that urban and rural settlements had significant differences in social and political structure. Some studies (e.g., Li 2009; Campbell et al. 2022) have also suggested that urban and rural settlements may have played different roles in the provisioning system of animal resources the Chinese Bronze Age, which can be expected to have affected meat consumption in some way. Also, specifically, according to evidence of excavated tombs and burial goods (Xiaomintun, Guandimiao), as well as some primary zooarchaeological results (Hou et al. 2018; Hou et al. 2019; Li 2009, 2011a, 2011b; Li et al. 2014), Xiaomintun (Shang capital) non-elite urban dwellers were generally richer than Guandimiao rural residents, and it can be expected that there were some differences between the two groups in animal butchering and cooking preparation, such as the degree of specialization and intensification, as well as possible meat consumption. In addition, considering foodways are an important reflection of cultural habitus and the geographical distance between sites, it is also anticipated that non-elite residents of Xiaomintun and Zhougongmiao could have different foodways.

1.4 The Structure of this Dissertation

Chapters 2-3 introduce the background of the study. In Chapter 2, the social and political structure of Late Shang and Western Zhou is introduced in order to clarify the social group (commoners) I am going to discuss in the dissertation. In Chapter 3 I introduce the archaeological work on the three sites included in the dissertation.

Chapter 4 gives a full review of previous research on animal foodways in the Chinese Bronze Age. Focus is given to the results of zooarchaeology and stable isotope studies which are most related to the present work.

Chapter 5 introduces various methodologies used in this dissertation.

Chapters 6-10 are detailed zooarchaeological analyses and discussion. Chapters 6-8 are for the animal assemblage of Guandimiao, Chapter 9 and Chapter 10 focus on Xiaomintun and Guandimiao assemblages separately.

Chapter 11 is the summary chapter. The three sites are compared to summarize the main patterns on meat food production and consumption for people of lower status (commoners). Then, some extra explanations are given to rethink about the development and meaning of the new methodology and also to raise questions for further studies.

CHAPTER 2: The Background of Late Shang and Proto-to-Western Zhou: Time Period and Social Structure

The Shang and Zhou dynasties were two sequential polities ruling much of north China during the second half of the second and early part of the first millennium BCE. During the late Shang dynasty, or Anyang period (around 1250-1050 BCE), the Zhou people were a minor polity located far to the West[2]. At some time around 1050 BCE the Zhou led a confederacy of western groups and conquered the Shang kingdom establishing a new hegemonic polity that lasted until the last Western Zhou king was driven out of the metropolitan region in 771 BCE. In brief, the Shang and Western Zhou kingdoms represented the most powerful polities in the Yellow River valley (in north China) in their times, and both are important cases of the early development of kinship-based royal power.

2.1 Late Shang

2.1.1 Time Period

It is generally believed that the Shang dynasty began around 1600 BCE and held sway over much of north China from its capital at Zhengzhou, even extending down to the Middle Yangzi. By around 1250 BCE, however, the Shang capital site had switched multiple times and was located

[2] The direct evidence of Zhou people in the late Shang period are records of oracle bone inscriptions (which recorded the situation of late Shang period) and some archaeological evidence, as well as a few words in the Western and Eastern Zhou texts, such as *Shang Shu* 尚書 and *Shi Jing* 詩經, and even later texts, such as *Shi Ji* 史記, *Zhushu Jinian* 竹書紀年, *Mencius* 孟子 and *Yi Zhou Shu* 逸周書. However, there are many debates about the early home of Zhou based on different understanding of the limited records (see Li 2006: 41 for summaries and references).

at Yinxu 殷墟, in modern Anyang 安陽 (Map 2.1). Since then, the late Shang period lasted around two hundred years (1250-1046 BCE).

At present, the main knowledge we have about the late Shang polity is based on archaeological discoveries and oracle bone inscriptions (as well as limited bronze inscriptions), which are the earliest definite written records in China. The core of the Shang polity, as represented by the Yinxu royal capital, was relatively limited to the Central Plains and Shandong, while the connection between Yinxu and other local communities and the nature of Shang society as a whole is controversial[3].

2.1.2 Social Structure

According to the study of material culture (mainly bronze and ceramic evidence), the influence of Shang culture extended over a large region of North, East, South, and Southwest China (e.g., IACASS 2003). Due to the reliance on archaeological discoveries and limited written sources, however, it is hard to determine the extent of the Shang kingdom's political domain, nor the social and political networks constructed between the core of the Shang polity and its neighboring communities. However, it is generally safe to say that these communities were bound together by the ritual-political hegemony of the Shang king (Campbell 2018: 174-176; Li 2003: 83). At the moment, scholars generally agree that complicated layered networks should be a more proper description of the interaction between the Shang court and its neighbors, which varied in different time periods and under different situations (e.g., Campbell 2009, 2018; Li 2003; Liu 2009; Thorp 2006)[4]. The power of the Shang king was based on a hierarchy of authority that placed the

[3] The summaries and references can be found in many publications, such as Campbell (2018: 15-50) and Li (2003: Chapters 4-5).

[4] This is different from previous Chinese Marxist (cultural-historical) scholars that aimed to simply put Shang society to one of the five stages of human society, or Western scholars (such as K. C. Chang and Keightley) that tried to focus

king in the position of crucial mediator between the people and the ancestors (Campbell 2018), and the relationship between royal court and local groups was a result of negotiation, which had to be affirmed and modified by the display of continuous sacrifice and frequent military campaigns (both of which could also include royal hunting and traveling).

Based on mainly oracle bone inscriptions (and some bronze inscriptions), most scholars agree that the Shang society was structured based on kinship relationships[5]. The royal lineage, including the ruling king and his sons were at the core of the structure. The social status of other elites/lineages was determined/manifested by their (real or fictional) genealogical distance to the kingly lineage[6]. These elites were leaders of their own lineages, while, at the same time, they (and maybe also some elites in the same lineage) took various positions in the royal court. Moreover, these individual lineages occupied and managed their own land, and they could maintain their relationship with the royal court via diverse approaches, such as divination, sacrifice and feasting, tribute and reward, marriage and warfare. Therefore, the Shang royal court only had limited control over other lineages and each lineage could potentially be largely autonomous.

The core of the Shang polity during the Anyang period was around Yinxu (in modern Anyang), in central and northern Henan along the middle reaches of Yellow River (IACASS 2003).

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on several characteristic features, so as to discuss the possible structure and nature of Shang polity and society based on the existing Western models and cases.

[5] There are some different opinions on the structure of Shang society (e.g., Qiu 1983), which are not discussed in detail here.

[6] The nature and approach of the connection between different lineages the Shang royal court is the core of many debates (e.g., Campbell 2018; Chang 1980; Keightley 1999, 2000; Zhu 2004). A summary and discussion of previous work, including the arguments of Chang, Keightley and Zhu, can refer to Li (2003: Chapters 4-5) and Campbell (2018). Campbell largely accepts the separation of Shang king’s lineage, allies, and enemies which is closer to Keightley’s model in terms of political landscape, while also, as I see it, denying a fixed or isolated description of each element, such as kinship, religions, and economy. With more archaeological evidence, as well as written resources, he emphasizes the different layers of social networks and tries to explain the interaction and modification of varying elements and networks. However, when the data is lacking, Campbell’s model offers a more general framework of interpretation.

Yinxu (the Ruins of Yin – another name for the Shang people), also known as the Great Settlement Shang (*Da Yi Shang* 大邑商), was located on the Huan River 洹河 and was the political, religious, and economic center of the late Shang kings. It was a giant urban center, over 3,000 ha at its zenith (Tang and Jing 2009) with a concentrated population of over 100,000 (Campbell forthcoming (a), Song 1991). Based on archaeological discoveries, Yinxu was the only super large settlement in the whole Huan River Basin during the late Shang period, and this whole area was its hinterland (Tang et al. 1998). Besides, there were numerous contemporary small settlements or hamlets around this region which represented the rural communities. Therefore, it is quite possible that most of the elites (including all the high-status elites) in the Yinxu neighborhood lived and were buried in the great settlement (Hwang 2016; Jing et al. 2013). The settlement includes two categories of neighborhoods generally. The core of the large settlement Yinxu is the palace-temple compounds and the royal (including the king) cemeteries in the center area (小屯 Xiaotun) which was likely occupied by people of royal lineage, and they were then buried in the northwest (Xibeigang 西北岡). There are several other residential areas and associated cemetery locations, as well as manufacturing workshops (for production of bronzes, jades, pottery, bone tools), scattered around the settlement. These areas are believed to be residential and mortuary areas of non-royal lineages and lower-status elite lineages. It is also believed that people of the same lineage lived together and were buried nearby (e.g., Tang and Jing 2009; Zheng 1995; Zhu 2004). Archaeological study of late Shang cemeteries at Yinxu gives support to the kinship connection and hierarchical separation between residents outside of Xiaotun[7] (Tang 2004). Therefore, to make such a

[7] Excavated Shang cemeteries have offered the most direct evidence of Shang social structure. Tang (2004) presents a most comprehensive study of Shang social structure based on more than 2,000 late Shang burials at Yinxu. He made the chronological and spatial analysis and separated the tombs to three level of clusters based on elements like the amount of labor, grave goods, sacrifice, symbols of authority. Considering also the clan/lineage insignia, he interpreted

composition of living areas and cemeteries as one neighborhood (small *yi* 小邑), each neighborhood should be sublineage- or lineage- based, and should have similar structure, where lineage members practiced their daily and social life (e.g., Campbell 2018; Jing et al. 2013; Tang and Jing 2004; Zhu 2004). The different neighborhoods are connected/separated by roads and canals, while, at the same time, the arrangement of different neighborhoods indicates interaction of different spaces, groups, and functions, which made Yinxu a giant and multi-faceted center (Tang and Jing 2009).

Based on both inscriptions and archaeological discoveries (clan/lineage insignia, the spatially adjacent relation between living areas, cemeteries, and workshop spaces), many researchers have suggested that some non-royal neighborhoods and lineages are identified by occupations, such as those of bronze-casting (e.g., Chang 1980: 232-234; Keightley 1969). As I will discuss in detail in next chapter, Xiaomintun is possibly such a neighborhood in Yinxu with a large bronze foundry, and the main residents were quite possibly involved in bronze-working, and were composed of lower elites and commoners. While most of the discussions of different neighborhoods in Yinxu are mainly based on tombs and artificial goods, a study of foodways, especially animal food remains of daily life in Xiaomintun enables another way to define a neighborhood. The issue of food production, distribution, and consumption refers to the degree of central control, regional autonomy, and specialization in the early urban center, and maybe also the application of advanced techniques and tools. While many scholars have assumed the concentration of material wealth in the Shang capital, little is known about the control of food

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these cluster as representation of separation of statuses and hierarchies, while the collection of various tombs in the same cemetery can reflect their close kinship connection. Campbell (2018) supports Tang's opinion by emphasizing "the importance of ancestor veneration, analogy from royal practice, the presence of sacrificial pits in some of the non-royal cemeteries, and later traditions of kin-based burial grounds" (2018: 158).

resources in a capital settlement. Therefore, based on the discussion of animal food in Xiaomintun, it is hoped that we can take one step further on this issue.

At the same time, without detailed written sources or systematic archaeological work, the nature or structure of local communities is even less clear[8], and prior to Guandimiao nothing was known about small settlements in late Shang period. The excavation of Guandimiao enables archaeologists to discuss in detail what a small village in Shang times was like and discuss the social status and function of a rural area in the Anyang period. By comparing with Xiaomintun, the preparation and consumption of meat is an especially meaningful way to investigate a rural neighborhood like Guandimiao.

2.2 Proto-to-Western Zhou[9]

2.2.1 Time Period

Compared to Shang, much more is known about the Zhou polity based on archaeological discoveries, bronze and oracle-bone inscriptions, and various texts. The Zhou people were once a small polity on the western edge of the Shang hegemony. Sometime in the later twelfth century BCE (the late Proto-Zhou period), the Zhou polity was relocated to the west part of the Wei River 渭河 Valley, which belongs to the middle reaches of Yellow River and is even further west of the

[8] Chang (1983) argues for a hierarchical structure of settlement distribution based on the later Zhou texts, corresponding to the social structure. The idea is accepted by Zhu (2004). Based on analysis of spatial patterns of settlements distribution in the core region of the late Shang polity, Hwang (2011, 2013) argues there may be a three- or four- tiered settlement hierarchy in late Shang: Yinxu is the only super large center, and, as for each lineage, there should also be a main settlement with several subordinate settlements. While Chang sees small settlements as basic units of production for wealth accumulation, Hwang treats these settlements as political or military locations. However, the evidence is still quite limited.

[9] Except notice specifically, the understanding of Western Zhou here is mainly based on Li Feng's work (Li 2003, 2006).

Shang, with a center of Qiyi 岐邑 (today's Zhouyuan 周原 site) (Map 2.2). Around 1046 BCE[10], after uniting the tribes and polities of the West the Zhou overthrew the Shang, and replaced them as the most powerful polity in the middle-to-lower reaches of Yellow River.

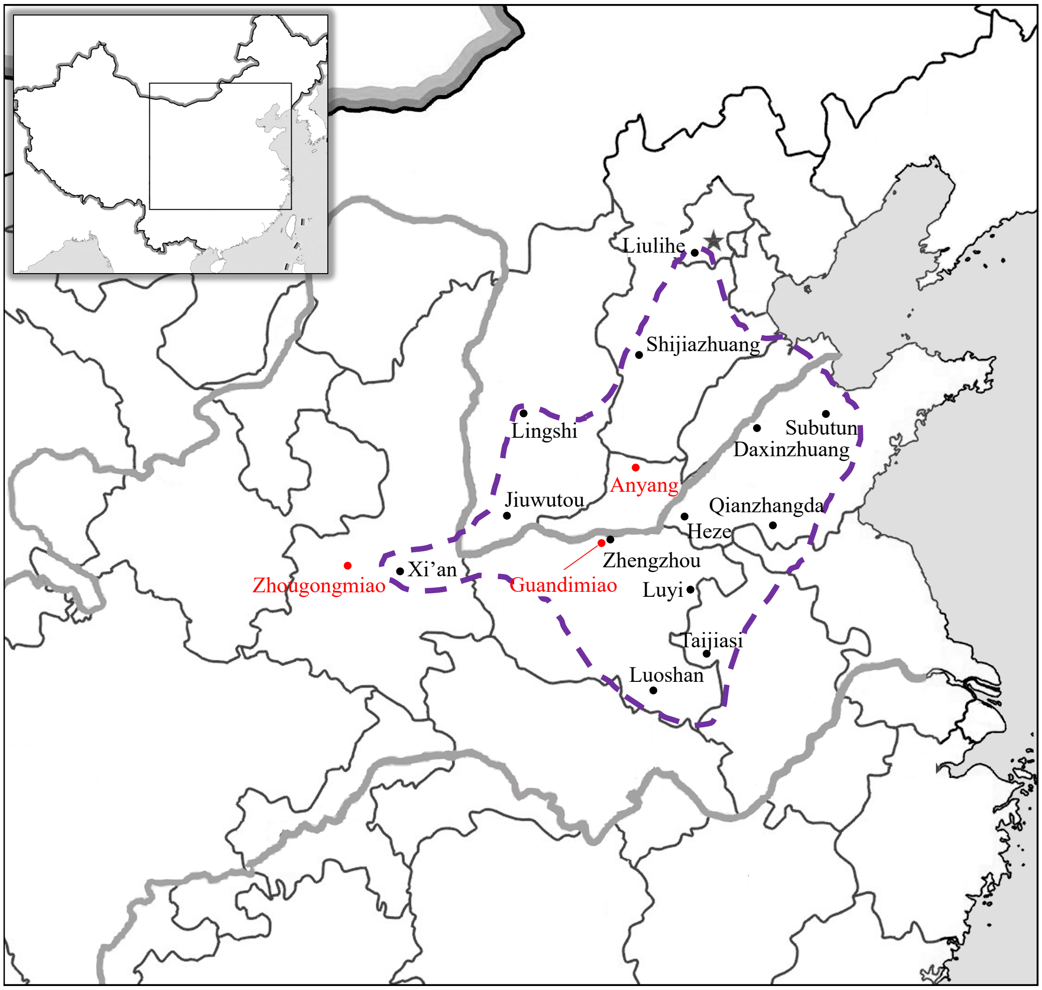
2.2.2 Social Structure

The Western Zhou polity formed two categories of structure between royal/local and west/east, in terms of the relationship between the royal court and local states, as well as their social, political and economic systems. Several royal centers were built on the Wei River plain, which served as the metropolitan area of Zhou royal power. The previous center, Qiyi, was included in this network as one center and continued to prosper during the entire Western Zhou period. Except the royal court, Zhou established several regional states in the newly conquered regions. The regional Zhou lords, together with some Zhou immigrants, were given the power to control the local land and local people, and, at the same time, they had to be agents of and support the royal court when necessary. The successfully implementation of this system largely relied on the kin relations between the local lords and the Zhou kings.

According to both written resources and archaeological discoveries, the arrangement of settlements was highly stratified in the Zhou royal domain in the Wei River valley and its adjacent regions. The major royal centers were at the top of the settlement hierarchy, which were the core of royal administration and had other social functions. They were occupied by elites and also some craftsmen in workshops. The secondary local centers, surrounding these royal centers, were estates of the elite lineages (some elites in the royal centers were also from these lineages). There were numerous small settlements or hamlets near the lineage centers, which represented the lowest

[10] There are some debates about the specific time, which have little impact for the discussion here. I follow Xia Shang Zhou Duandai Gongcheng Zhuanjiazu (2000).

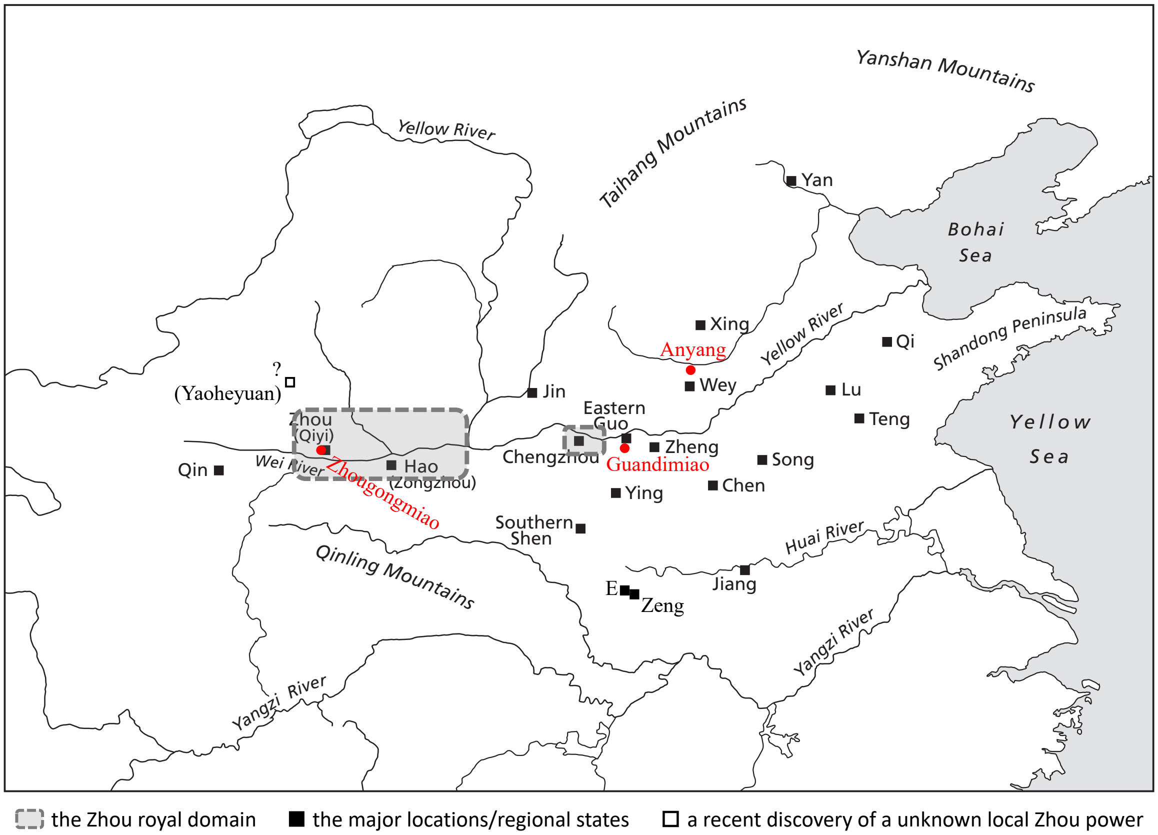
social units for agricultural production. Based on studies on the Zhouyuan site and its neighborhood, the Western Zhou settlements in this region can be divided into three or four tiers. In addition to the gigantic settlement cluster at Qiyi (Zhouyuan), there were a group of large settlements around every 10 km which are believed to be estates of elites (as well as elites' lineage centers), which may also include some small settlements around these large settlements (Zhang 2013; Chong 2010). Among the secondary settlements in the large Zhouyuan neighborhood, Zhougongmiao is the most comprehensively organized one, with palace areas, large four-ramp tombs (for the highest elites) and bronze foundries. Considering no zooarchaeological data of Western Zhou capital settlement has been reported so far, the study of such a high-level settlement can be a good reflection of animal resource production and food consumption in the core region of Western Zhou society.



Map 2.1 Late Shang ceramic tradition[11]

[11] This map is modified based on Campbell (2018: 70) and shows just the rough zone of late Shang ceramic tradition, which indicates the living regions of Shang people. Only a few of the important late Shang sites are listed in the map.

The base map is from the online database of the Ministry of Natural Resources of the People's Republic of China: the Biaozhun Ditu Fuwu Xitong (標準地圖服務系統, http://bzdt.ch.mnr.gov.cn/browse.html?picId=%274o28b0625501ad13015501ad2bfc0291%27).



Map 2.2 Distribution of the Zhou royal domain and the major regional states[12]

[12] This map is modified based on Li (2003: 122, 130 (Map 6.2 and Map 6.3)). The two regions covered by grey are roughly (not exactly) the Zhou royal domain, and other locations (labeled with ■) are the major regional states.

The locations of two regional states in the South, E and Zeng, have been confirmed since the publication of Li's book. A recent excavation in Yaoheyuan 姚河塬 (labeled with ☐) may indicate the existence of a Zhou power in the Northwest China while its detail is still unclear. The three locations are also shown on the map to indicate the possible boundaries of the Western Zhou polity. There were many other regional states within the Zhou extent that are not shown on this map.

CHAPTER 3: Archaeological Backgrounds of Guandimiao, Xiaomintun, and Zhougongmiao

The sites for which I have done research (Guandimiao 關帝廟, Xiaomintun 孝民屯, and Zhougongmiao 周公廟) are three of the most important sites of the late Shang to early Western Zhou period. All the three sites mostly or completely consist of the archaeological remains of commoners living in large and small settlements. All of them were systematically excavated and have seen basic zooarchaeological study. In this chapter, the archaeological background of the three sites will be discussed. The main purpose is to discuss the similarities of the three sites, as well as the particular nature of each site, in order to explain why the three sites can be comparable in terms of animal bone analysis and the study of foodways.

3.1 Guandimiao

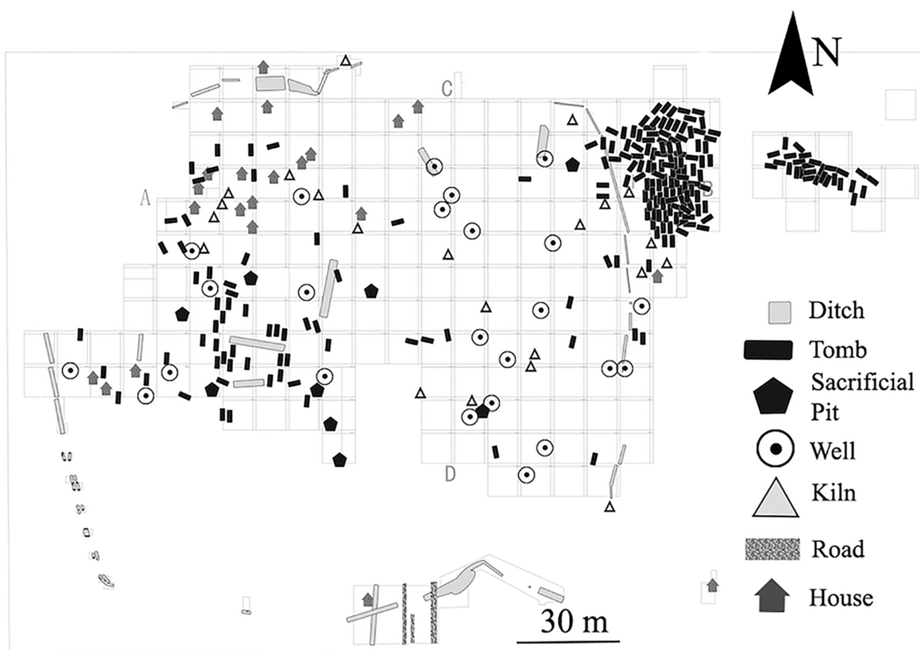
Guandimiao was a small rural site to the west of the modern city Zhengzhou 郑州 in Xingyang 滎陽 county. It is located at the edge of the core area of the Shang polity (see Chapter 2), approximately 200 km southwest of and contemporary with Yinxu in the late Shang period, and only around 50 km from the former center of the early Shang (Erligang period, around 1600-1400 BCE) in Zhengzhou.

Years of archaeological work indicates changes in Shang settlements and material cultures in the region around Zhengzhou (with the Yellow River to the north and the Mountain Song 嵩山 to the south, and are bound by several north-south small rivers) from the Erligang period to the Anyang period (Hwang 2011; Liu 2014; Liu and Zhang 2017). In the Erligang period, the region near Zhengzhou was definitely the core of the Shang polity, with the large walled settlements of Zhengzhou (Henan 1993, 2001) and Yanshi 偃師 (IACASS 2013), their palace-temple areas, and numerus other material remains related to elites and the royal court (such as bronzes and bronze foundries, large ceramic vessels, and sacrificial pits). After the Shang capital moved to Anyang, the amount and scale of settlements in this region decreased dramatically. To date, there have been only two cemeteries with typical late Shang bronzes (SACH 2007; Jia 2007), which indicate the existence of some local centers in this region. However, all the other settlements are rather small with thin layers of late Shang remains and daily-use ceramics only. Without systematic archaeological survey, it is not entirely clear at present how, in the late Shang period, these settlements were structured in this region. Nevertheless, it is likely that Guandimiao was under administration of a local lord and included in the extended hinterland of the Great Settlement Shang at Anyang[13] (Campbell 2018; Li et al. 2018).

The Guandimiao village is located in the lower Yellow River, lies in a small basin (Xingyang Basin), and is south of a low mountain (the Tan Mountain 檀山). An excavation of this site was done in 2006-2007 (Li et al. 2008a; Li et al. 2008b; Li and Zhu 2009; Li et al. 2018). It is the only well-preserved (about three-quarters of the whole site has been preserved) and well excavated Anyang period village site to date. The extant area of this site measures over 20,300 square meters, and most of it can be dated to Anyang Periods I-III (ca. 1250-1100 BCE) based on ceramic typology and archaeological stratigraphy. Totally, the archaeological remains include 22

[13] Based on archaeological evidence and bronze inscriptions, some scholars have argued that, in the late Shang period, this region around Zhengzhou is the territory of "She 舌" lineage, which is also seen in oracle bone inscriptions and was closely connected to the Shang royal court at Yinxu (e.g. Chen 2015; Miao 2010; Tang 2011). I happened to see a similar graph on one piece of Guandimiao ceramic sherd, when visiting the Xishan workstation of Henan Institute of Cultural Relics and Archaeology in Zhengzhou in the summer of 2014.

houses, 23 kilns, 32 wells, 1472 ash-pits, 17 sacrificial pits[14] and 228 tombs (Map 3.1). The layout of this Shang village is roughly clear. The occupation is surrounded by a ditch with an entrance in the south, and a main cemetery area with most of the burials is outside and to the northeast corner of the ditch. Most of the houses are in the northwest area, together with a great number of kilns and wells which may indicate multiple uses of this region. Other kilns and wells are scattered across the site, and there are even a cluster of kilns close to the cemetery in the northeast of the site. Many sacrificial pits are distributed in the southwest section, while others are seen all around the site. Tombs are also distributed all across the site but concentrated in two regions. A large number of tombs are in the cemetery region as mentioned above and many others are clustered in the southwest region.



Map 3.1 The layout of Guandimiao (Li et al. 2018:1516)

[14] This is a separation made in field during excavation. It is seen during the process of zooarchaeological analysis that some ash-pits were quite possibly for ritual use too.

All the houses are small and semi-subterranean and could not have been occupied by any group larger than a nuclear family (including 3-5 family members). Accordingly, the total population in its zenith cannot be more than 100, which is supported by a calculation of the number of tombs (Li et al. 2018). Based on the zooarchaeological data (Hou et al. 2019), many of the ash pits are rather small and may correspond to a small population. The large number of kilns indicate that this site may be specialized in ceramic production, and the many wells may also be closely related to these activities. The products include both sand-tempered and untempered potteries of typical late Shang styles. The rich sacrificial remains tell us much about ritual activities in this small village. All the types of domestic animals in Guandimiao, including cattle, pigs, dogs, and sheep/goats, were found in sacrificial pits. It is also the place that many oracle bones were discovered (Hou et al. 2018; Li et al. 2008a; Li et al. 2008b; Li and Zhu 2009; Li et al. 2018). In some sacrificial pits there were ash deposits and charcoal remains. All these things together indicate that ritual activities, including independent divination (Hou et al. 2018), were important activities in this small Shang village. Tombs in Guandimiao are of "rectangular shape" (similar to those defined by Tang 2004:48 in Anyang) and small in size (most of them are no larger than two square meters), and many of them include dog sacrificial victims inside (especially dogs in waist pits, which is typical of Shang tradition), while grave goods are scarce – only three tombs had a ceramic vessel and one had a bronze arrowhead and a small bronze bell. Generally speaking, tomb remains suggest that the Guandimiao villagers were of low status and they were poor or that their local burial customs did not encourage placement of burial goods (Li et al. 2018). All the ceramics in Guandimiao are typical of the Yinxu tradition, and stone and shell tools are also the frequently seen types for daily life in late Shang sites. Recent study on the bone artifacts at Guandimiao (Hou et al. 2018) suggests the Guandimiao bone hairpins were probably from Yinxu (the Great

Settlement). In addition, the discovery of agricultural tools (represented by stone and shell sickles) and the many animal remains (see Chapter 4 for details) prove that the production of crops and raising of domestic animals were part of their everyday life[15]. Furthermore, weapons were exceedingly scarce at Guandimiao, which also challenges the idea that the village-level settlements are both the basic social units of production and military organization (e.g., Hwang 2016; Tu 1979; Xiao 1981; Zhang 1951; Zhang 1988).

In summary, Guandimiao proves to be a small rural settlement of the late Shang period. On the one hand, people in Guandimiao roughly shared the same cultural traditions and ritual beliefs with that of the Great Settlement Shang, while at the same time, Guandimiao residents were apparently of low status. On the other hand, the small settlement was self-organized to some degree in terms of settlement organization, production activities and ritual practice, and the intra-differentiation in social status is minor even though there seemed to be some people of high status (as reflected by grave goods, tomb size and coffins and sacrifices). Moreover, the specialized ceramic production and the redistribution of hairpins show that Guandimiao was actively participating in the network of regional production and redistribution (Campbell 2014, 2018; Li et al. 2018; Liu 2009). That is, Guandimiao was not the sort of small village suggested in later texts which presented rural communities as self-sufficient, only supporting the government with agricultural products and labor (e.g., Twitchett and Loewe 1986; Yang 1992: 202).

Nevertheless, the arrangement of tombs and grave goods were usually highly formalized and may have more to do with social status, than economic conditions, while foodways, especially meat production and consumption, may cover both status and wealth and potentially be more

[15] Livestock production may have also involved in the regional resource organization and redistribution (Hou et al. 2019), which will be mentioned in Chapter 4.

revealing. In Guandimiao more than 10,000 animal fragments were collected and identified. While the published zooarchaeological report has generally broached the topic of animal production and consumption (discussed in Chapter 4), the further study of carcass processing in daily context is needed (Chapters 7-8). The overall study of foodways will offer much needed details to help characterize the lives of this group of rural residents and investigate the maintenance of social relations in a unit (lineage).

3.2 Xiaomintun

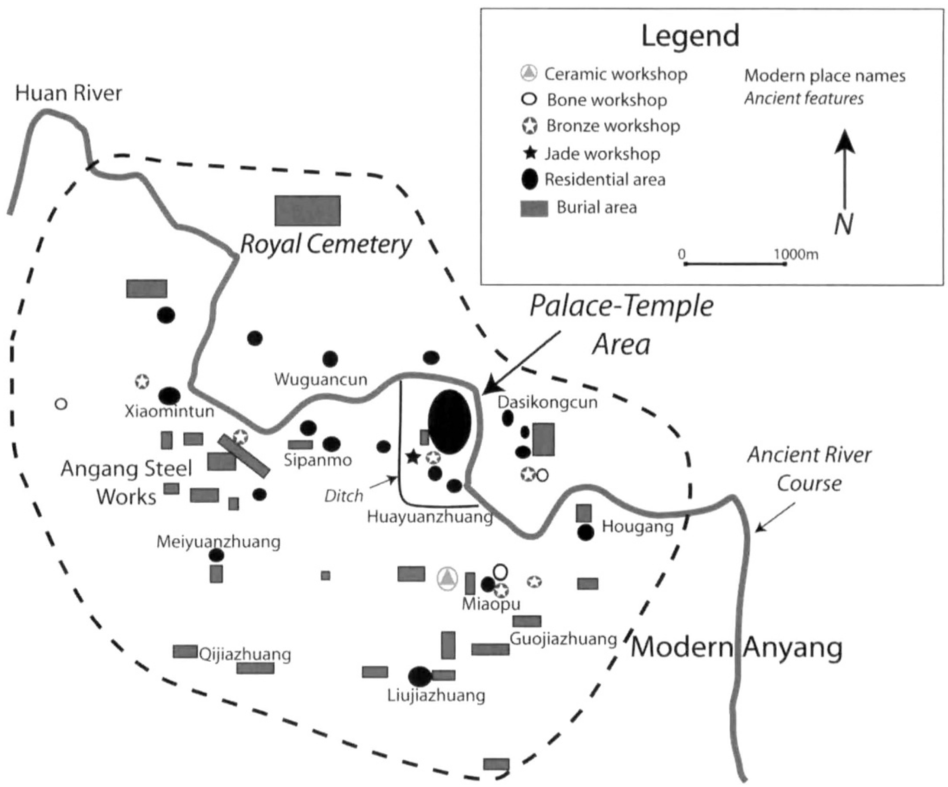
Xiaomintun is part of the Great Settlement Shang in Anyang (Map 3.2). It is located in the west region of the large settlement and very close to the south bank of the Huan River 洹河, which is 2 km southwest of the Shang kings' tombs in Houjiazhuang 侯家莊 on the north bank of the Huan River and 2.5 km west of the royal palace-temple compound in Xiaotun.

This area was excavated in 2003-2004, and limited information (mainly those related to large functional units) has been released based on preliminary reports (Wang 2005; Wang and He 2007; YXK 2007a, 2007b, 2007c; IACASS 2018)[16]. In total, an area of 60,000 square meters has been excavated. Shang remains from late Anyang Period I to Period IV (ca. 1250-1050 BC) were recovered in this region, including evidence of a large bronze foundry, more than 100 houses (for commoners), around 1,000 tombs, and a huge number of sacrificial pits and ash-pits.

Xiaomintun was firstly occupied by Shang people in the late Anyang Period I (ca. 1250-1200 BC) and its heyday as purely a residential region was quite possibly during Anyang Period II (ca. 1200-1150 BC). In Anyang Period II, the site was covered with groups of semi-subterranean

[16] This Xiaomintun site focused in this dissertation is in the south of the current Xiaomintun village, which was excavated in 2002-2003. In 1960 and 2000-2001, excavations were done in the west and southeast of Xiaomintun village separately (AYD 2006; IACASS 1987).

houses, which indicate a population in the hundreds. Based on the spatial distribution, there should be three neighborhoods. Inside each neighborhood, even though the structures of the houses varied, they were built with similar techniques and stood in lines, which indicate the existence of organization and the separation of social ranks. Considering the relative size and simple structure of these houses, as well as the artifact remains, excavators believe these were neighborhoods of lower status people. Nevertheless, the fact that no refuse pits related to or cemeteries around the house occupations have been found is an unsolved issue (YXK 2007a).



Map 3.2 The layout of late Shang Yinxu (Campbell 2009: 827)

In Anyang Periods III-IV (ca. 1150-1050 BC), the function of Xiaomintun was changed to bronze production. The Xiaomintun bronze foundry covered an area of about 40,000 square meters[17]. Rich discoveries include remains of different stages of bronze-casting, as well as many sacrificial pits which should also be related to bronze production. Judged by fragments of clay molds and cores, various bronze products were made in the Xiaomintun bronze foundry, and a large portion of them were ritual vessels (which were the bronzes of the highest value in Shang society). When combined with the nearby Xiaomintun Southeast bronze foundry remains (AYD 2006), the Xiaomintun bronze foundry as a whole, should be the largest (50,000 square meters) in Yinxu, assumed by some authors to be under direct control of the Shang royal court (YXK 2007b). In addition, there are also house remains, a huge number of ash-pits and ceramic fragments, indicating contemporary everyday activities in this region. Animal remains discussed in this dissertation were selected from bone assemblages excavated from these units.

Shang tombs are found inside and outside the bronze foundry region, and most of them have been dated to Anyang Periods III and IV. These tombs are divided into seven groups, which may be part of an even larger cemetery region to the west of Xiaotun (usually mentioned as "Yinxu xiqu 殷墟西區") (Wang and He 2007; YXK 2007c; IACASS 2018). Most of the tombs are of "rectangular shape", as Tang (2004: 48) defined, with waist pits and sacrificial dogs, and, in each group, they are distributed regularly. Except one tomb that is about 4 square meters with forty pieces of grave goods and possibly a chariot pit, the other tombs are 2-4 square meters with relatively few grave goods, indicating these tombs were mainly for people of lower status (commoners). Two of the cemeteries close to the bronze foundry are with bronze-producing related

[17] Excavators (Wang and He 2007; YXK 2007b) believe that the previous Xiaomintun West (Xiaomintun Xidi 孝民屯西地) bronze foundry remains (IACASS 1987) and those excavated in 2002-2003 in fact belong to the same bronze foundry. Calculating the two parts together, this bronze foundry covers an area of about 40,000 square meters. Besides, the Xiaomintun Southeast (Xiaomintun Dongnandi 孝民屯東南地) bronze foundry remains (AYD 2006) is geographically separate to some degree. However, the two locations are likely different parts of a large bronze foundry, which covers an area of about 50,000 square meters (Wang and He 2007; YXK 2007b).

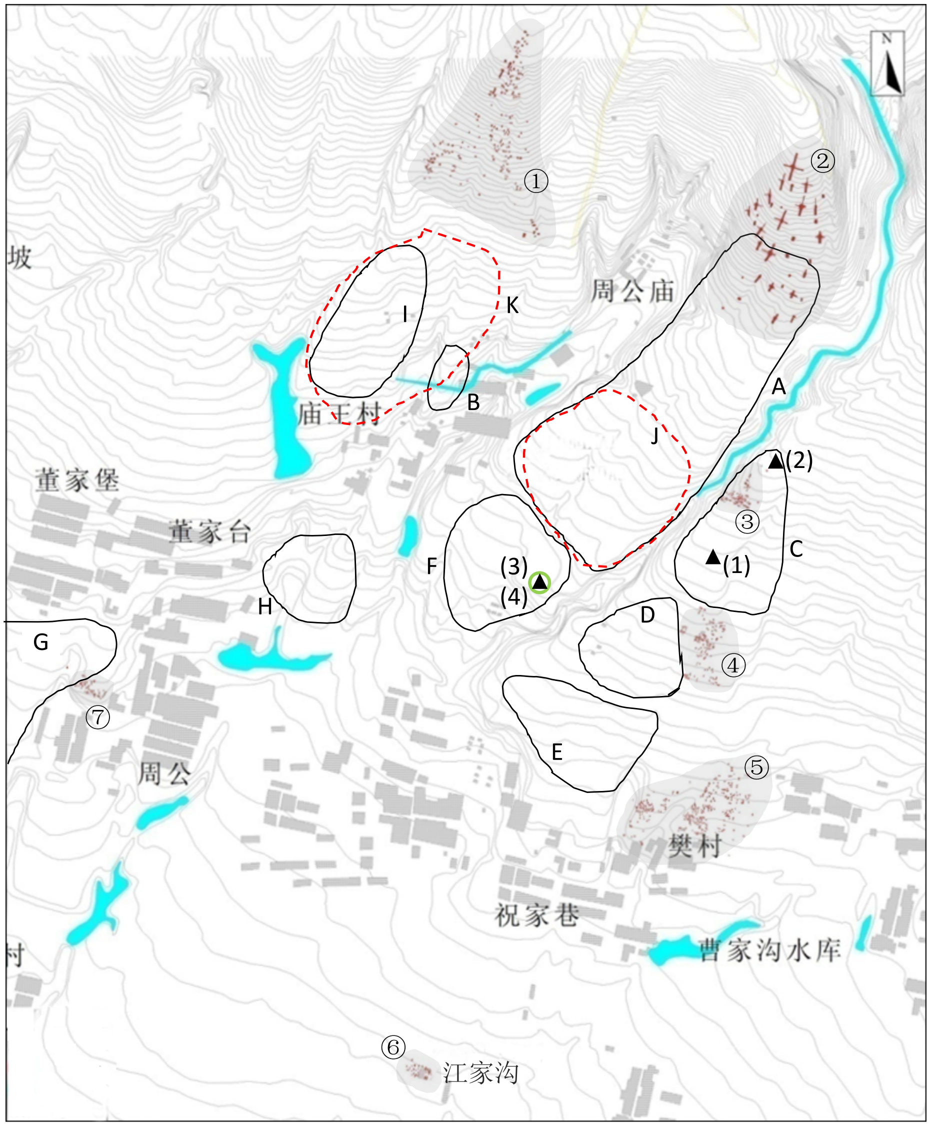
remains included in the burial goods, indicating at least tomb owners in the two cemeteries were very likely closely related to the bronze foundry (mostly workers?) (Wang and He 2007; YXK 2007c, IACASS 2018). In addition, there are even some human skeletons found in ash-pits and wells, which indicate people at the bottom of Shang society, such as slaves (Tang 2004).

Considering the large-scale transformation from a residential area to a neighborhood associated with a bronze foundry, the nature and scale of bronze production, and the types of bronzes produced, it is clear that the workshop was well organized with specialized workers in bronze production. A related question is how these workers gained and consumed everyday living resources. This is also part of a larger question of how urban citizens in Yinxu were supported. On this topic, the study of animal foodways has a great advantage. Li Zhipeng has made a first attempt based on the huge animal collection from Xiaomintun (Li 2009; 2011a; 2011b), which will be discussed in the next chapter. I will continue to pay attention to this in the following analysis.

3.3 Zhougongmiao

Zhougongmiao is about 780 km northeast of Anyang and 600 km east of Guandimiao. As mentioned in Chapter 2, it is an important high-level political site spanning Proto-Zhou (late Shang period) and Western Zhou (1046~871 BCE) periods, in the Zhou heartland and 18 kilometers to the west of Qiyi (in modern Zhouyuan, one center of the Western Zhou polity). Geographically, Zhougongmiao, together with Zhouyuan, is located on the loess plateau north of the Wei River and at the south foot of Fenghuang Moutain 鳳凰山. Based on archaeological discoveries and written sources, it is widely accepted that Zhougongmiao was an estate of a powerful Zhou lineage, the leader of which was likely among the most powerful aristocrats in the Zhou polity (possibly Duke Zhou and his lineage) (e.g., Dong 2006; Li 2004; Xu 2006).

The whole site covers an area of about 30,000 square meters. Archaeological fieldwork in Zhougongmiao lasted from 2004 to 2011. Archeologists have surveyed and cored all across the site and organized seven excavations. Most of the remains can be dated from late Proto-Zhou (Anyang Period IV) to the end of Western Zhou period (i.e., ca. 1100-871 BC) based on ceramic typology and archaeological stratigraphy, while its heyday was from late Proto-Zhou to the early Western Zhou period (ca. 1100-950 BC). The main field excavation on the site has finished, but the archaeological analysis is ongoing.



- Residential areas (for low elites and commoners): A, B, C, D, E, F, G, H, I (circled by real lines)
- Palace-temple compound areas (for high elites): J, K (circled by dotted lines)
- Cemeteries (for high elites): ①, ② (covered by grey)
- Cemeteries (for low elites and commoners): ③, ④, ⑤, ⑥, ⑦ (covered by grey)
- Bronze workshops: (1), (2), (3) (labeled with "▲")
- Pottery workshops: (4) (overlapped with (3)) (labeled with "o")

❖ Specimens discussed in this dissertation are from: A, C, D, E, F

Others:
- Modern constructions: unlabeled squares in grey
- Modern water surfaces: marked in blue
- Isolines: lines in grey

Map 3.3 The layout of Zhougongmiao[18]

[18] This map is made based on Map 13, Map 25, Map 26, and Map 31 in Chong (2010). The base map is modified based on a Zhougongmiao site map in an archaeological report of Zhougongmiao field work in 2011 (see Yuexin He, Unpublished Report: 6, Map 3), which is generated from the Zhougongmiao GIS system. Because the arrangement of Zhougongmiao was partly changed during the Zhou people's occupation, there are several overlaps between regions of different functions, as shown on Map 3.3(see Chong 2010 for details).

Excavators in Zhougongmiao have focused on identification of the layout of the settlement[19] in the first stage of their work (Map 3.3) and detailed information is limited. In total, there are two palace-temple compound areas, nine separated residential regions, more than 900 tombs in seven cemeteries and one rammed earth wall, four overlapped ditches, five bronze foundry locations, 6 kilns, and a huge number of ash-pits and some other remains.

The layout of Zhougongmiao is hierarchically arranged into separate areas for high elites and commoners. There are two adjacent palace-temple compound areas in the middle of the site, and two highest-rank cemeteries in the north of the site. The earliest cemetery of the two has one rammed wall and the highest-rank tombs. The nine residential areas are circled around the palace region and can be roughly paired with the five cemeteries to form separated neighborhoods, indicating intra-site groups (lineages?). The three small-sized bronze foundries are in inside the residential areas and were probably successively used (Chong 2010). Though there are some hints of bone artifact, stone tool, and pottery production, there is no evidence for mass production. Even in the regions of bronze foundries, farm tools take a similar percentage as those in other commoners' residential areas (Chong 2010). Therefore, the Zhougongmiao locals were mostly farmers and some of them were possibly part-time workers.

In a word, Zhougongmiao seems to be a well-planned high-ranking Zhou settlement. For a period, it coexisted with the Great Settlement Shang in the east. In terms of settlement ranks, Zhougongmiao should be considered a regional center during the late Shang period. The separation of Shang and Zhou communities is clear in material culture (e.g. Niu 2017). If this is so, then it should follow that foodways should also differentiate the two groups. Considering Zhougongmiao

[19] The distinction between residential areas of high elites and other residents (lower elites and commoners) and cemeteries was mainly based on a rough intra-site geographic division (by gullies) and archaeological contexts of each feature. However, it is not certain that there were clear-cut margins between different areas. Also, the functions of some areas may have changed throughout the period of occupation (Chong 2010).

is the only Zhou site around Zhouyuan that has completed systematic archaeological field work and has a zooarchaeological study, it is the best choice for comparison with Xiaomintun.

3.4 Summary

The three sites, Guandimiao, Xiaomintun, and Zhougongmiao, share many similarities. They are three roughly contemporaneous sites; they are all in the core areas of the pre-eminent polities of the Chinese Bronze Age, and even though they are about 800 km apart, the three sites share similar natural geographic environments and climates. Guandimiao, Xiaomintun, and Zhougongmiao are three of the best and most recently excavated sites in the Chinese Bronze Age – important not only for their multiple contexts allowing a more holistic archaeological perspective, but also for their differences from each other.

Each of the three has unique characteristics that together will reveal sets of contrasts, and by comparing the three sites yield an overall picture of meat consumption in the Chinese Bronze Age. Each of them has both contemporary residential and burial areas for lower-status which enable us to find possible evidence for meat consumption from both kitchen waste and human skeletons. Both Yinxu and Guandimiao are Shang settlements, but of very different sizes and ranks, so that a comparison of the Xiaomintun (a commoners' residential region in Yinxu) and Guandimiao can give us information about separation/similarity between a capital and a local small settlement in terms of daily meat consumption of lower-status. As representatives of urban settlements for Shang and Zhou people respectively, Yinxu and Zhougongmiao will allow us to compare the daily life of lower-status in metropolitan settlements, while also comparing Shang and Zhou food cultures popularized during commoners.

Moreover, the whole Guandimiao animal assemblage in domestic contexts[20] is included in my dissertation, which is a main focus in the discussion, aiming to give special attention to the study of small settlements and commoners. For comparison, a small number of animal bone specimens have been selected from the Xiaomintun and Zhougongmiao animal bone collections to reflect the situation of urban non-elite residents. More details can be found in the following Chapters 9-10.

[20] Three types of animal remains were identified from Guandimiao, as daily remains from domestic contexts, animal bones from ritual contexts, and animal victims in burials (Hou et al. 2019). It should be noted that the category of daily remains from domestic contexts is not a very definite group as people may see in other sites outside of China (such as animal remains from the inner space of a house), but instead, it broadly includes animal bone remains that were very likely related to household waste in daily life. Specifically, it includes all bone remains from deposits that didn't show any special phenomenon that may be related to ritual activities, and it is composed mostly of animal remains from ash pits of out-door regions around houses.

CHAPTER 4: Previous Studies on Animal Foodways in Late Shang and Western Zhou Times

4.1 Introduction

Goody (1982:37) summarizes the foodways-related human activities to four areas/phases: food resource production, distribution, preparation, and consumption. These four phases indicate possible directions of foodways study for archaeology. To date, the study of foodways in the Chinese Bronze Age has concentrated mostly on production (i.e., crop and animal husbandry), distribution (in terms of social-political structure), and consumption (including types of food consumed, containers, and ritual contexts of consumption). The purpose of this chapter is to review previous studies on animal foodways, especially in the period from late Shang to Western Zhou, which is also the starting point for my following analysis.

The various studies are roughly based on two types of evidence: written sources (contemporary oracle-bone and bronze inscriptions and later texts) and archaeological remains (mainly animal bone remains, as well as cooking and serving vessels and evidence of dietary analysis on human skeletons). Considering both the main research questions scholars are interested in and the different research materials/evidence they choose, the research history of animal foodways in the Chinese Bronze Age (mainly the Shang and Western Zhou periods) can be divided into two phases – those before and after 2000.

Before 2000, scholars mostly paid attention to the nature and form of early states, especially that of late Shang polity, and their discussions were largely based on written sources and some archaeological discoveries. In this case, animals were taken as an important social resource that should be managed and consumed based on certain social and political structures. In this way the many brief discussions written in this period only described an outline of animal use in the Bronze Age. A general review of such foodways studies for the Chinese Bronze Age, especially the late Shang period, has been made by Haapanen (2005).

Since 2000, archaeology in China has seen a period of rapid development[21], stimulating a new trend away from fitting the case of the Chinese Bronze Age to certain assumed evolutionary models, and instead focusing on the different factors playing a role in the process of social-political power construction (e.g., Campbell 2007, 2009, 2018; Liu and Chen 2000, 2001, 2003, 2012; Hwang 2011, 2013, 2016; Shelach and Yitzhak 2014; Underhill and Fang 2004). In this process, many newly published zooarchaeological reports, as well as the results of stable isotope analyses, have greatly enriched our knowledge of animal husbandry as well as meat distribution and consumption, both of which were important to the social economic structure of early China.

In this chapter, I will first briefly go over the framework of animal management and consumption which is largely derived from the study of written resources. Then, I will focus on more recent work on animal production, distribution, and consumption mainly based on updated zooarchaeological results from the past two decades - especially the results from the Guandimiao, Xiaomintun, and Zhougongmiao animal assemblages. In addition, the related results of human and

[21] The separation of Chinese archaeology into two phases before and after 2000 is triggered by several things. The rapid social and economic development in China started since 1990s have generated the needs of many field archaeological projects and have been a strong support for archaeological analysis and study and many of the effects have appeared after 2000. The academic exchange between China and the West, the importance of which was highlighted in the early stage by the practice and discussion of the multi-disciplinary Three Dynasties Chronology Project 夏商周斷代工程 at the turn of the 21st century, and the deepening international collaboration since then represented by the practice of international projects and the increasing exchange of students and scholars, have helped the scientization of Chinese archaeology (Wang 2002) in terms of the appearance and development of many subdisciplines in archaeology, including zooarchaeology.

animal stable isotope studies will be discussed as helping to explain the strategies of animal hunting and husbandry and the general situation of human diet. In addition, I will summarize the records of animal processing and meat preparation found in received texts, which will form the starting point of my zooarchaeological analysis of animal processing and meat preparation in latter chapters. At last, I will briefly discuss the studies of cooking and serving vessels which are also related to the process of meat cooking and consumption. In the following chapters, in order to better understand the patterns of bone breakage, one type of cooking vessels, *li* 鬲 tripods, will be discussed in more detail. As a summary, I will emphasize some specific questions I am going to deal with in the following chapters.

4.2 Studies on Animal Management and Consumption

4.2.1 A General Framework of Resource Control – Studies before 2000

For a long time, what we knew about Shang animal production and distribution was mainly based on limited information from the oracle-bone inscriptions[22]. Keightley's (1969; 1999:277-284) discussion of the allocation of laborers and the management, distribution, and utilization of animals is representative[23]. It was argued that the Shang kings controlled a huge amount of animal resources, including livestock owned by the royal family and other domesticated and wild animals received from allies and dependents and captured by hunting or in war (as gifts, tributes, game, and booty), and a great amount of animal resources came to the Great Settlement Shang (Yinxu)[24].

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[22] The situation of Shang animal management and meat consumption is also briefly mentioned in some later texts, especially those of the Warring States (477-222 BCE) and Qin-Han (221 BCE - 220 CE) period. However, most of these records are too brief to be useful or are just reconstructions based on the situation of their own time that cannot be relied on.

[23] A detailed review can be seen in Haapanen's dissertation (2005).

[24] Based on both oracle-bone inscriptions and archaeological discoveries, it is obvious that Shang kings were capable of controlling large quantities of domestic animals for ritual activities. Keightley (as mentioned in the body text) and many scholars (e.g., Wang and Yang 1999, Wang and Xu 2011, Yang 1992, Yang and Ma 2010) claimed that a huge

In addition, some elites and their lineages should also have kept their own livestock on their own lands, parts of which were sent to the royal court or received from the Shang king. According to oracle-bone inscriptions, a great part of these royal/elites-controlled animals, mainly livestock, were used in sacrifice and maybe the following feasts. In all these cases, cattle are especially important considering the great quantities mentioned in oracle-bones as tribute items and sacrificial victims in every major sacrifice, the use of cattle scapulae as a main media for royal divination and inscription, and cattle bones as the main source of bone artifact production (Li et al. 2014:72). This is supported by the archaeological discoveries in Yinxu. Compared to the large number of both sacrificial animal and human victims mentioned in oracle bone inscriptions, there are a great number of human skeletons but a relatively small number of animal remains found in ritual contexts (Campbell et al. 2011; Li 2003:103). The early zooarchaeological work on Yinxu also offers some details. In the palace-temple area (Xiaotun 小屯) and the royal burial and sacrificial area (Xibeigang 西北岡), the discovery of a large quantity of various indigenous wild species and exotic wild species (Fiskesjö 2001; Teilhard and Young 1936; Young and Liu 1949), demonstrates the flow of precious goods to Yinxu and supports the idea of elites' consumption of valuable meat resources.

The situation of animal management and consumption in Western Zhou is also ambiguous, based on limited information from some bronze inscriptions and later texts[25]. It seems the royal

number of livestock were raised and managed by king's laborers and officials. However, Campbell (forthcoming, 2022) recently has raised another possibility that animals were mostly levied from different places and centralized in Yinxu.

[25] The situation of Western Zhou related textual sources is summarized by Shaughnessy (1999: 293-297). Even though there are some texts which are seen as the first classical canon in ancient China and are assumed to be composed during Western Zhou period, records that can be dated to Western Zhou period are quite rare. Besides, the descriptions of Western Zhou events in the later texts are more or less idealized and "usually revealing more about the concerns of their own times than about the Western Zhou itself" (Shaughnessy 1999: 293).

family and other lineages owned landed properties, which were usually composed of the lineage centers (relatively large settlements) and their estates (multiple small settlements) (e.g., Li 2003:139-160; Zhu 2004), and lots of animal resources, mainly livestock, were concentrated at the large settlements[26]. A large amount of meat was likely consumed by diverse social groups in various ritual occasions and feasting activities[27]. According to received texts, the commonly consumed animal species were cattle, pigs, sheep/goats, dogs, chicken, rabbits, and fish, as well as some game species, and some authors (e.g., Hsu and Linduff 1988:357; Yang 2003:657-658) have supported the idea of different species being consumed based on rank as recorded in the *Liji* 禮記. Limited zooarchaeological data partly supported these claims with cattle and pigs providing the main source of meat in the large settlements, while other livestock were supplementary. However, there is little information about commoner meat acquisition and consumption[28].

Generally, it is probably true that people consumed more meat in Shang and Western Zhou times than farmers in later times (Hsu and Linduff 1988:356-357). However, as mentioned above, in the Chinese bronze Age, the use of the pictographic writing system was in its infancy and reliable sources were quite limited. As a result, knowledge of and discussion about foodways has been superficial. In addition, most of the records are about elites and special events (e.g., sacrifice, warfare, and feasting), which only cover a small part of Bronze Age activities. Since 2000, the

[26] According to bronze inscriptions, parts of the animals, especially large livestock, should be collected as tribute, rewards, and gifts between Zhou kings and elites. Elites and their families should also live on products from their lands. However, little detail is clear about the nature and process of livestock production and distribution.

[27] According to received texts (e.g., *Shijing* 詩經 and *Liji* 禮記) and limited archaeological discoveries (e.g., Luoyang 2015; Zhou and Shi 2011), in Western Zhou, the amount of animal victims used in ritual activities decreased greatly compared to that of Shang time. However, various feasts are frequently seen in the texts.

[28] Nevertheless, based on received texts, it has been traditionally believed that relatively small livestock (pigs, dogs, and sheep/ goats) and chickens, as well as fishes, were the main species bred and consumed by commoners (e.g., Hsu and Linduff 1988: 356-359).

rapid development of archaeology and zooarchaeology in China offers more material evidence for the study of foodways. However, before the work on the Xiaomintun and Guandimiao animal assemblage (Hou et al. 2019; Li 2009), little was known about the everyday meat consumption of non-elites (in either the royal centers or small settlements), who made up a vast majority of the Shang population.

4.2.2 Animal Husbandry and Animal Food Consumption – Studies Since 2000

Since the year of 2000, many published archaeological reports (especially those of zooarchaeology, paleobotany, and isotope analyses) are making the early development of agriculture in the Central Plains of China more and more clear from the late Neolithic to Bronze Age (Chen 2017; Li et al. 2014; Yuan 2010; Yuan et al. 2007; Zhao 2005, 2014).

Various archaeological evidence has proved that, in the Central Plains, a transformation in agriculture happened during the second and third millennium BC. In this trend, various new species, including sheep and goats, cattle, horses, wheat, and barley, were gradually brought to the middle reaches of the Yellow River (the Central Plains), and changed the local millet-pig-dog system to a more complex and diverse system of agricultural practices. By the late Shang period (Anyang period), after the introduction of horses, all the main livestock we can see today (the six farm animals, including horses, cattle, pigs, dogs, sheep/goats, chicken) had been domesticated and raised. Domesticated horses played an important role in the Bronze Age and were mostly controlled by elites, even though they were a small portion of the total livestock. Since their appearance in the Central Plains, the number of cattle, sheep, and goats steadily increased during this period, especially cattle. Besides primary products (mainly meat), it is also possible that cattle, sheep and goat secondary products, such as milk, wool, and traction were also used in some sites. All these new factors should have had a great impact on the development of animal husbandry and significantly changed the whole system of production and consumption of animal source foods (Li et al. 2014).

4.2.2.1 Zooarchaeological Progress

Li (2009) has summarized and discussed animal husbandry and subsistence in times before and during the late Shang period, which is largely based on animal collections from large settlements. Now, based on the published reports, including mainly reports from Xiaomintun (Li 2009, 2011a, 2011b; Li et al. 2014), Guandimiao (Hou et al. 2019), and Zhougongmiao (Zhang 2012), as well as that of Tianma-Qucun (Huang Y. 2000), it is possible to explore the situation between the late Shang and Western Zhou[29] and even later periods of the Chinese Bronze Age. (Except where noted, all the data referred in the following discussion are from reports of the four sites mentioned here.)

Table 4.1 Main mammals in Xiaomintun, Guandimiao, Zhougongmiao, and Tianma-Qucun (calculated by the Number of Identifiable Specimens, NISP)

Period (BCE)	Site		Cattle	Pig	Sheep /Goat	Dog	Horse	Deer	SUM
Yinxu (1250-1046)	Xiaomintun		16046	17149	5939	1020	963	540	41657
		%	38.52	41.17	14.26	2.45	2.31	1.30	100
	Guandimiao		1684	1659	180	1441	4	104	5072
		%	33.2	32.71	3.55	28.41	0.08	2.05	100
	Zhougongmiao		1290	1700	385	50	42	367	3834

[29] Concerning the Western Zhou royal domain, from the Wei River plain to the east boundary of the middle reaches of Yellow River, there are only two sites with zooarchaeological study – Zhougongmiao and Fengxi 灃西. There is only one brief zooarchaeological report on Fengxi site (Yuan and Xu 2000), which is believed to be the location of Feng 灃 and one of the Western Zhou royal centers. In the Fengxi report, based on 655 bone fragments, it is roughly known that domestic livestock, especially pigs and cattle, take a large part in the assemblage.

Huang's work on animal remains of Tianma-Qucun 天馬-曲村 site has been the only systematic zooarchaeological study on a Western Zhou regional state (Huang Y. 2000). This site is about 250 km west of Anyang (Yinxu), 200 km northwest of Guandimiao, and 380 km northeast of Zhougongmiao. It was part of an early capital of the State of Jin 晋 probably in a time from Western Zhou to early Spring and Autumn periods (see Xie (2009) for a review of related researches and debates). Considering Tianma-Qucun is close to the royal domain of Zhou geographically, environmentally, and culturally, results of the two reports can roughly be discussed together in order to review the situation of animal husbandry in the Central Plains.

		%	33.65	44.34	10.04	1.30	1.10	9.57	100
Western Zhou (1046-771)	Zhougongmiao		1857	743	410	221	77	400	3708
		%	50.08	20.04	11.06	5.96	2.08	10.79	100
	Tianma-Qucun		1627	882	1409	505	240	169	4832
		%	33.67	18.25	29.16	10.45	4.97	3.50	100
Spring and Autumn (770-435)	Tianma-Qucun		1068	608	650	192	93	186	2797
		%	38.18	21.74	23.24	6.86	3.32	6.65	100

Table 4.2 Main mammals in Xiaomintun, Guandimiao, Zhougongmiao, and Tianma-Qucun (calculated by the Minimum Number of Specimens, MNI)

Period (BCE)	Site		Cattle	Pig	Sheep /Goat	Dog	Horse	Deer	SUM
Yinxu (1250-1046)	Xiaomintun		324	639	207	108	8	50	1336
		%	24.25	47.83	15.49	8.08	0.60	3.74	100
	Guandimiao		42	136	11	83	2	14	288
		%	14.58	47.22	3.82	28.82	0.69	4.86	100
	Zhougongmiao		31	33	21	5	3	20	113
		%	27.43	29.20	18.58	4.42	2.65	17.70	100
Western Zhou (1046-771)	Zhougongmiao		29	36	23	14	7	24	133
		%	21.80	27.07	17.29	10.53	5.26	18.05	100
	Tianma-Qucun		103	126	87	47	26	84	473
		%	21.78	26.64	18.39	9.94	5.50	17.76	100
Spring and Autumn (770-435)	Tianma-Qucun		22	75	43	35	5	11	191
		%	11.52	39.27	22.51	18.32	2.62	5.76	100

It has been pointed out that, compared to earlier times, by the Anyang period, the exploitation of cattle reached its peak and the portion of cattle was comparable to that of pigs (Li 2009; Li et al. 2014). After this, the scale of cattle husbandry maintained this level fluctuating slightly in the Western Zhou and later times while correspondingly the proportions of pigs became even smaller. The trend can be clearly seen in Zhougongmiao, and the situation of Tianma-Qucun also supports the changes, based on calculations of both NISP and MNI (Table 4.1, Table 4.2). It is clear that the main livestock of cattle, sheep, goats, pigs and dogs dominated in Shang and Zhou societies, although there was always a small portion of deer, which are believed to be hunted[30]. Cattle in this period were especially important. Even though the final zooarchaeological results may contain some taphonomic bias as mentioned in the reports above, a great quantity of cattle were certainly raised, not just in large centers, but also in small villages like Guandimiao (though the situation of small Western Zhou settlements is not clear yet). This is likely a reflection of cattle's multiple roles in society – in addition to being a main source of subsistence, cattle were the main non-human sacrificial victims especially in large events (e.g., Ma 2009; Yuan and Flad 2005, 2008), their bones were the main resource used in bone workshops (e.g., Campbell et al. 2011; Zhao 2017), and even though we still lack a systematic study, cattle were likely used for traction (but probably not ploughing) (Li et al. 2014; Song 1986). Pigs, comparatively, were for meat mainly and played an important dietary role[31]. Though they may have been consumed on occasion, the main discoveries of horse bones are in royal or high elite-involved sacrificial or mortuary contexts. In addition, sheep, goats, dogs and deer played a supplemental dietary role.

[30] Some scholars tried to argue the early domestication of deer by the late Neolithic period in the Central Plains based on a result of stable isotopic analysis (Zhang and Zhao 2015). However, there is no further evidence.

[31] It is not so easy to compare the importance of cattle and pigs in diet in late Shang and Western Zhou. Compared to cattle bones, pig bones, in general, have suffered more serious taphonomic attrition according to the reports, which include mainly dogs' damage to bone waste before deposition and bone fragment lost by hand selection during the retrieval process in the field, in all the four sites discussed here. Therefore, pig's NISP and MNI values are relatively more underestimated than those of cattle. Based on the portions of MNI, more pigs were raised than cattle, while the difference narrowed significantly in Western Zhou sites. On the other hand, a cow usually has a higher meat yield than a pig.

Though the meaning of meat weight estimates based on skeletal mass allometry is limited (Barrett 1993; Casteel 1978; Jackson 1989; Reitz and Wing 2008: 237-242), a calculation of meat yield based on animal remains can still give us some idea about the dietary use of cattle and pigs in the Chinese Bronze Age. According to Yang's (2007) ethnoarchaeological study in the Central Plains, a cow is 312.5 kg on average, with a meat yield of 125 kg (= 312.5 × 40%), and a pig is 140~200 kg, with a meat yield of 98~140 kg (= (140~200) × 70%). If a standard, based on studies of Western sites, is taken, a cow can produce even more meat and the meat yield of a cow can be 3-4 times of that of a pig (see Lyman (1979), Reitz and Wing (2008: 237-242) for a review).

Considering all these factors, it is safe to argue that both cattle and pigs were important in late Shang and Western Zhou.

As the only example of a small settlement in the period discussed, the Guandimiao assemblage is unsurprisingly slightly different from those of large settlements. There are only a very small portion of sheep/goats, and high-status related horses are quite rarely seen, while the proportion of dogs is relatively high (though partially this is due to their frequency in sacrificial and mortuary contexts). In fact, the Guandimiao fauna is almost entirely composed of cattle, pigs, and dogs, with only a rather small number of deer. In addition, compared to that of the contemporary non-elite residential area of Xiaomintun, in Guandimiao, the amount of animal fragments per unit is much smaller (roughly three-tenths of the Xiaomintun assemblage[32]), which is likely to suggest that residents of Guandimiao did not consume as many medium-to-large size domestic animals as those in Xiaomintun did (Li et al. 2018; Hou et al. 2019). (This issue is further discussed in the next section of this chapter when talking about results of stable isotope analyses in paleodietary study.)

The analysis of kill-off profile and sex ratio can be used to study the potential exploitation of secondary products and possible existence of livestock transport and redistribution. According to the study of Xiaomintun, Guandimiao, Zhougongmiao, and Tianma-Qucun, meat production

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[32] The ratio of fragments per unit area (as calculated by NISP) of Guandimiao to Xiaomintun is different from that published in Li et al. (2018). The ratio published in that paper was based on preliminary results. It is necessary to update the results:

(a) The Guandimiao Shang site dates to Anyang periods I–III. The total number of identifiable specimens (NISP) of Guandimiao animal fragments is 11,069, including 10,253 mammals.

(b) The Xiaomintun Shang site dates to Anyang periods I–IV. The total NISP of Xiaomintun animal fragments included in Li's dissertation is 63,907 (Li 2009:20); and, in Anyang periods I–III, the NISP of Xiaomintun animal fragments is 48,532, including 48,027 mammals. This is no less than 90% of the total animal bone collection in the part of Xiaomintun that was excavated by the Institute of Archaeology, Chinese Academy of Social Sciences (IACASS) (Li 2009:6).

(c) The total excavated area of Guandimiao is approximately 2 ha, while the area of Xiaomintun excavated by IACASS is approximately 3 ha.

(d) Therefore, the amount of animal bone fragments per unit area is about 1/4~3/10 of that of Xiaomintun.

was the main concern for livestock raising in this period, especially for cattle and pigs. The situation of sheep and goats, however, is more complicated. While there is no strong indication of milk or wool production in Xiaomintun since the majority of the sheep/goats were slaughtered relatively young, the Zhougongmiao and Tianma-Qucun results suggest that some elder individuals were kept, which is a possible indicator of secondary products production. More work is required to see if there is a real differentiation between late Shang and Western Zhou in terms of secondary products.

The strategies of pig husbandry and consumption can more or less be distinguished between Xiaomintun, Guandimiao, and Zhougongmiao[33]. According to the mortality profiles based on eruption and wear of teeth, in Xiaomintun, over 93% pigs died before 3-years old and over 60% are between 1.5-3 years, which represents a pattern of meat consumption and holds the possibility that some pigs may be transported from somewhere else (Li 2009). In Zhougongmiao, the proportion of pigs died before 3-years old is higher than 94%. However, in Guandimiao, the survivorship curve is gradual and there are a relatively high proportion of older individuals (38.3% surviving past the 30-52 months category) showing that pigs were either consumed in Guandimiao without an optimized strategy of meat production or they were not all consumed there but partly (mainly those between 1-3 years) delivered to other places. The female dominated sex ratio (judged by the morphology of canine teeth, about 96.92% of the pigs are female) supports the latter hypothesis[34]. The differences between Guandimiao (a rural settlement) and two large settlements

[33] The comparison lacks data from Tianma-Qucun because of the small sample size.

[34] It has been discussed in Chapter 3 that Guandimiao is a small site in a group of settlements in a region around Zhengzhou, all of which should also belong to the large hinterland of Yinxu. Therefore, if Guandimiao is a producer site, there are several directions that the animal products could have gone.

may be a result of early specialization of meat production and consumption, even though we still need more evidence from other sites to further deal with the question.

The age profiles of cattle from Xiaomintun and Guandimiao are relatively similar in that about two thirds of the cattle died before 4 years. It is argued that the pattern of cattle culling in Xiaomintun is closer to a strategy of meat optimization since only a few cattle survived through 4-5 years based on the situation of vertebral epiphyseal fusion (Li 2009; Li et al. 2014), while Guandimiao kept about one third of old cattle (Hou et al. 2019). On the other hand, Zhougongmiao kept a higher portion (over 45%) of adult cattle (Zhang 2012). Generally, more work is needed to further understand these differences.

4.2.2.1.1 Summary

To summarize, it seems that, in late Shang and Western Zhou, the structure of animal husbandry had been relatively stable[35]. That is, when new livestock (mainly cattle and sheep/goats) were gradually introduced to and adopted by residents of the Central Plains in an earlier period (between the third and second millennium BCE), the species and ratios of livestock in late Shang and Western Zhou were relatively stable (with slight fluctuations), while in later times (roughly after the second half of the first millennium BCE), animal husbandry and meat consumption were gradually restricted[36]. In addition, the systems of animal management and consumption were

[35] It is necessary to clarify that the word *stable* used here is to emphasize the composition of livestock species and ratios during the late Shang and Western Zhou times didn't change a lot, which can be seen as one stage in the long history of animal husbandry. As I have mentioned, this structure of animal population should have been a result of the promotion and negotiation of various social and economic factors. In other words, this is one evidence to argue the commonality between the late Shang and Western Zhou society.

[36] Around and after the Warring States (roughly after the second half of the first millennium BCE), the scale of animal husbandry and the various approaches of animal use were quite different from those of Bronze Age largely because of the greater needs for plant agriculture and the higher frequent use of livestock in the war. Farmers in later times didn't eat as much meat as common people in Bronze Age did. However, it doesn't mean that animal husbandry in Bronze Age was highly developed to offer enough meat resource for consumption.

complex. With the exception of horses and dogs, domestic animals were mainly raised as a source of meat and other primary products while secondary products, such as milk, may have been introduced but were far from prevalent in diets. It should be noted that cattle in this period were not consumed only by elites in some high-level social activities. In fact, both cattle and pigs were the main sources of meat in the diet of both large and small settlements. In addition, wild animals did not play a large role in subsistence[37], though deer were still often seen in different sites.

Distinctions in the status of sites is shown in the form of differentiation of settlements in strategies of animal husbandry and meat consumption. As rulers of the unique mega-settlement in its time, Shang kings in Yinxu (the Great Settlement Shang) were able to collect rare and exotic species (e.g., Teilhard de Chardin and Young 1936; Young and Liu 1949) that were not seen in either Xiaomintun (the non-elite locus) (Li 2009) or Zhougongmiao (a large non-capital settlement) (Zhang 2012). There is a tendency of specialization in animal production and consumption. Both Xiaomintun and Zhougongmiao (large settlements) focused on animal consumption, while Guandimiao was self-sufficient or an animal production site. Therefore, it can be seen that, in this period there was a system of animal husbandry and exchange in existence, connecting large settlements and rural settlements. The construction of this system was based on characteristics of different livestock species. In this system of animal husbandry, a large number of cattle mainly, as well as some sheep/goats possibly, were produced and possibly distributed in the urban-rural network (while they were also largely consumed locally), while pigs were generally a good choice for local meat production and consumption[38]. However, the distinction between late Shang and

[37] There are many records of royal hunting in oracle-bone inscriptions. However, the big game hunting was mostly a royal sport, and thus was probably not a significant source of meat for daily consumption or for commoners (Chang 1980: 136-157; Fiskesjö 2001; Keightley 2012).

[38] I believe both large and small settlements raised pigs. Meanwhile it is also possible that some pigs were fed in small sites but consumed in other places (e.g., Li 2009, 2011b; Hou et al. 2019). However, as I see, the evidence is not

Western Zhou is not quite clear based on current evidence, even though there are some differences between Xiaomintun and Zhougongmiao.

The basic distinction between Xiaomintun/Zhougongmiao and Guandimiao is that of consumer sites and producer sites. There should be several contrasts in the ideal consumer-producer-sites model (e.g., Crabtree 1990:158-169; Zeder 1988, 1991). Some differences between Xiaomintun/Zhougongmiao and Guandimiao can be noted. 1) Species range and ratios: In Yinxu/Zhougongmiao, there is a broad spectrum of both low- and high-prestige animals, even when the majority are those commonly seen domestic animals. As a high-status meat source, a great number of cattle were consumed. While most of the livestock may have relied on external suppliers, people in the two large settlements also kept a number of animals as an important supplement. In Guandimiao, there were only very limited animal species (livestock mainly). In addition, a large portion of cattle were also consumed in this small settlement, which has challenged the traditional understanding of rural life in ancient China in general. 2) Kill-off pattern and sex ratio: Guandimiao kept both cattle and pigs of broader age ranges, while the majority of the two species in Yinxu and Zhougongmiao were concentrated to a narrow age range with the maximum meat yield. The uncommonly imbalanced sex ratio of pigs in Guandimiao is also an evidence of pig provisioning. 3) Body part distribution: although there are some differences, there is no obvious evidence of purpose selection/concentration of certain body parts in middens of food

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enough to discuss the scale of pigs' local production and consumption, or the exchange between rural and urban sites in the Chinese Bronze Age. At present, the analysis is mainly based on pigs' the age profiles and kill-off patterns as shown by tooth eruption/wear and epiphyseal fusion. It is only in Xiaomintun, Guandimiao, Zhougongmiao, and Tianma-Qucun that a large sample is available and pigs' age profile has been analyzed. That is, there are quite limited sites for comparison, not to mention the extensive collection of animal remains by hand during excavation. Therefore, even though there have been some clues of exchange and consumption, more sites and studies should be included to better understand the system.

waste in any of the three sites[39]. At last, butchery and food processing related bone modification have never been treated specifically in Chinese zooarchaeology but are possibly useful for the study of differentiation as discussed here.

4.2.2.2 Carbon and Nitrogen Stable Isotope Analysis

In the last ten years, stable isotope analysis has become an increasingly common tool to help understand past human diet and the strategies of food production in the Chinese Neolithic and Bronze Age.

After the introduction of sheep/goats and cattle into the Central Plains (the middle reaches of Yellow River) sometime in the latter half of the third millennium BCE (Yuan 2010), a comprehensive but relatively stable agricultural system was established gradually, the process of which can be seen based on reports of carbon and nitrogen stable isotope analyses on a series of

[39] However, several things should be noticed and given more attention in the future research.

Compared to other cattle bone elements, cattle scapula fragments are much less seen in either of the three sites, which is actually a common phenomenon in sites of the Chinese Bronze Age. It is widely accepted by scholars that this should be related to the needs of oracle-bone divination.

According to Li (2009: 37-38), in Xiaomintun, less cattle cranial and mandible fragments have been identified than other bone elements of cattle in the residential area. Li raises two possibilities: (a) cattle were butchered in elsewhere and carcasses with no head were brought to Xiaomintun, or (b) based on the discoveries of many cattle mandibles in sacrificial pits in the bronze workshop of Xiaomintun, cattle mandibles were possibly imbued with special meanings and collected for ritual events.

The deer cranial bones and mandibles are not as common as other bone elements in Xiaomintun and Zhougongmiao, while antler fragments are often seen. Considering deer were likely hunted from the wild, a reasonable explanation is that deer were usually slaughtered, and the carcasses were dressed in the field and their heads, as well as some other elements possibly, were not brought back to settlements; or, on the other hand, antlers were purposely collected for tool production (Li 2009:38; Zhang 2012:43-44, 63-64). In the Guandimiao animal bone collection, the sample size of deer bones in total is very small.

In addition, the situation is different in bone workshops. For example, there is obvious selection of certain taxa and elements at Tiesanlu bone workshop in Yinxu (late Shang period) and Zhouyuan bone workshop (Western Zhou period) (Campbell et al. 2011; Zhao 2017).

sites (see Chen 2017 and Yuan et al. 2020, for a review of recent progress in China; Zhang et al. 2003 for an introduction of early work[40]).

Based on studies on a series of sites in successive time periods (as cited in the above paragraph), there has been a clear pattern of animal husbandry in the Chinese Bronze Age (Chen 2017; Yuan et al. 2020). Both pigs and dogs are omnivores, and their $\delta^{13}C$ and $\delta^{15}N$ values are usually clustered together, which, in many cases, are close to those of humans. Thus, it is understandable that they ate kitchen scraps and waste, which were mainly composed of millet crops (C4 plants). Cattle and sheep/goats, however, are both herbivores yet their $\delta^{13}C$ values show that they were raised in different ways. Cattle largely ate C4 plants as indicated by relatively high $\delta^{13}C$ values, which indicate a diet of millets, millet waste and C4 weeds in the farmlands. It is quite possible that cattle were grazed around the farmlands or even on the fallow lands which should be near the settlements, and they may also be fed with harvested millet hay especially in winter times. On the other hand, the $\delta^{13}C$ values of sheep/goats are more similar to those of deer, the latter of which represent animals eating wild plants. Thus, sheep/goats were likely pastured in areas further from the settlement and with mainly wild grasses and leaves (C3 plants), while sometimes they

[40] Specifically, studies on several sites are significant: Chen et al. (2017) for Wadian 瓦店 study; Dai et al. (2016), Zhang and Zhao (2015) for Xinzhai 新砦 study; Si et al. (2014), Zhang et al. (2007), Zhao and Zhao (2018) for Erlitou 二里頭 study; Chen et al. (2012), Zhang et al. (2007) for Taosi 陶寺 study; Hou et al. (2009) for Zhangdeng 鄣鄧 (proto-Shang period) study; Cheung (2015), Cheung et al. (2017a, b, c), Si and Li (2017), Yan (2010), and Zhang et al. (2017) for Yinxu study; Hou et al. (Forthcoming), and Wang (Unpublished work) for Guandimiao study; Li et al. (Forthcoming (a)) for Zhougongmiao study, Li et al. (Forthcoming (b)) for Zhouyuan study.

were also raised with millet residues or on/near the farmland[41]. Therefore, diverse domestic animals were integrated into the agricultural regime and people's life in different ways[42].

In terms of human diet, based on stable carbon and nitrogen values of human and animal samples, most groups/sites[43] studied in the Central Plains from the late Neolithic period to the Bronze Age were characterized by a C4-dominated diet, which was supported by a millet-based crop system[44]. This is consistent with the results of paleobotanical studies (e.g., Guo 2013; Li et al. 2008; Yang et al. 2017; Zhao 2014; Zhao and Xu 2004).

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[41] The clear separation of cattle and sheep/goats by the $\delta^{13}C$ values are seen in studies of several sites which claimed to have found the earliest cattle and sheep/goats in the Central Plains (Dai et al. 2016, Zhang and Zhao 2015 for Xinzhai site; Chen et al. 2012, Zhang et al. 2007 for Taosi site; Si et al. 2014, Zhang et al. 2007, Zhao and Zhao 2018 for Erlitou site). So, it is quite possible that the different diet treatments of cattle and sheep/goats were introduced from the West.

[42] Comparing the results of Yinxu (Cheung 2015; Cheung et al. 2017a; Yan 2010), Guandimiao (Hou et al. Forthcoming, and Wang Unpublished work), and Zhougongmiao (Li et al. Forthcoming (a)), it seems that the late Shang data of Yinxu and Guandimiao are more similar, especially in that the $\delta^{13}C$ values of cattle are quite close to those of pigs, dogs and human while clearly separated from those of sheep/goats, while in the case of Zhougongmiao, the $\delta^{13}C$ value of cattle is relatively closer to that of sheep/goats. That is, there is a possibility that cattle in Zhougongmiao may be fed with more wild grasses than those in the two late Shang settlements and the strategies of cattle husbandry may be different. However, since there are only limited data we can rely on and there may be more issues to be considered, it is still too early to reach any firm conclusion.

It is still unclear if and how animal fertilizers were used in fields in the Chinese Bronze Age. However, compared to those of deer, the relative higher $\delta^{15}N$ values of cattle and sheep/goats in some cases (e.g., Hou et al. Forthcoming; Li et al. Forthcoming (a); and Yan 2010) may indicate the possibility of manure use for the maintenance of soil fertility.

[43] Details of the studied sites are based on: Chen et al. (2017) for Wadian 瓦店 site; Dai et al. (2016), and Zhang and Zhao (2015) for Xinzhai 新砦 site; Chen et al. (2012) and Zhang et al. (2007) for Taosi 陶寺 site; Si et al. (2017), Zhang et al. (2007), Zhao and Zhao (2018) for Erlitou 二裡頭 site; Cheung 2015, Cheung et al. (2017a, b, c), Si and Li (2017), Yan (2010), and Zhang et al. (2017) for Yinxu 殷墟 site; Hou et al. (Forthcoming) and Wang, N. (Unpublished work) for Guandimiao 關帝廟 site; Li nan et al. (Forthcoming (a)) for Zhougongmiao 周公廟 site, Li et al. (Forthcoming (b)) for Zhouyuan 周原 site.

[44] As ancient people in the Central Plains rarely had access to marine resources (which are with the range of $\delta^{13}C$ values similar to that of C4 plants), it is safe to assume that the high $\delta^{13}C$ values should reflect the consumption of terrestrial C4 plants (Boutton 1991). It is this case in Yinxu, Guandimiao, and Zhougongmiao, which are the main focus of this chapter.

The $\delta^{15}N$ value is mainly taken as evidence to estimate an individual's animal protein intake. However, the complexities of nitrogen transformations among soil-plant-animal systems make the explanation of meat consumption based on nitrogen stable isotope analysis (as well as carbon stable isotope analysis) not entirely straightforward[45]. By looking over the several published works on carbon and nitrogen stable isotope analyses in the Chinese Bronze Age (mainly studies of Yinxu, Guandimiao, and Zhougongmiao), as well as referring to other archaeological evidence (which have been discussed above), it is possible to get some idea about people's meat diet. Since the C and N isotopic baselines of the local fauna varied between the three sites, in the following, the situation of each site will be discussed separately, and a summary will be made then.

4.2.2.2.1 Yinxu

Cheung (2015; Cheung et al. 2017a, b, c) has reconstructed the ancient diet in Yinxu based on human samples from five localities (most of the samples are from Xiaomintun North-South and Xin'anzhuang, both of which were residents of commoners/lesser lineages)[46], and several sacrificial pits in the royal cemetery.

The same environmental background makes it possible to discuss the subsistence of spatially separated groups of people in Yinxu. It turns out that there are no observable differences in $\delta^{13}C$ and $\delta^{15}N$ values between the Shang population in the five localities, which indicates a similar subsistence pattern of Shang people; while the carbon and nitrogen values of the sacrificial

[45] A summary of the possible factors that may affect the $\delta^{15}N$ value explanation and relevant references can be found in Cheung's dissertation (2015:11-13).

[46] Except the Xin'anzhuang (59 humans) and Xiaomintun North-South (two humans from Xiaomintun North, and 17 humans from Xiaomintun South), there is only one human individual from Liujiazhuang North, a ceramic workshop near the royal palace-temple area of Yinxu, and two human individuals from Huayuanzhuang, a ritual and burial region of the royal household. Besides, the C and N isotopic baseline of the local Yinxu fauna are from published research (Si 2013; Yan 2010), including 29 cattle, 20 sheep/goats, 34 pigs, 12 dogs, 1 horse, and 16 deer.

victims formed another group[47]. Meanwhile, the mean $\delta^{15}N$ values of humans from the five localities are much higher than that of cattle and higher than that of pigs[48], and is in agreement with the zooarchaeological evidence. So, Cheung has argued that the Yinxu locals, even the local commers, consumed a considerable amount of animal protein in their diet, especially from domestic animals (though a high proportion of animal protein does not necessarily mean a high-quality diet) (Cheung 2015; Cheung et al. 2017c). Comparatively, the sacrificial victims may have had more restricted access to animal protein. In addition, based on the Xin'anzhuang samples, Cheung's study of the potential correlation between dietary patterns (in terms of $\delta^{13}C$ and $\delta^{15}N$ values), mortuary practices, and tomb owner's sex (the latter two are potentially related to social status) inside a commoner group indicates a further separation: a tendency for, even among commoners, higher status individuals to have higher animal protein intake. However, as Cheung has pointed out, the sample size is still too small while the chronological framework is too general to make a convincing conclusion.

In a word, the study of human and animal samples of the residential neighborhoods in Yinxu (mainly Xin'anzhuang and Xiaomintun) shows the typical Shang dietary pattern -- mostly millet-based but containing a large amount of animal protein (primarily from livestock). On the

[47] Based on an analysis of $\delta^{34}S$ values, these sacrificial victims were non-Shang origins. A small group (eight individuals) of these individuals were taken to study the dietary practices of these victims' last few years of life. The $\delta^{13}C$ and $\delta^{15}N$ values show that, when living in Yinxu, these sacrificial victims had similar diet to residents of Xin'anzhuang (Yinxu's typical lower class) and took millet as the main crop, while consumed less animal protein (Cheung 2015; Cheung et al. 2017b). Compared to Xin'anzhuang residents, the $\delta^{15}N$ values of the sacrificial victims are on average 1.9‰ lower (Cheung 2015:91).

[48] Generally, stable nitrogen isotope ($\delta^{15}N$) values can elevate about 3‰~5‰ from one trophic level to the next along the food chain, and, for human, the diet-to-collagen δ15N enrichment can be up to 6‰ (O'Connell et al., 2012). As for the Xin'anzhuang human group, the mean $\delta^{15}N$ value of the humans (9.97‰) is very close to that of Xiaomintun (9.71‰), and is 3.5‰ higher than that of cattle (that is, about one trophic level above cattle) and 1.8‰ higher than that of pigs, 1.7‰ higher than that of dogs (Cheung 2015:50). The three samples from the other two localities show a similar trend.

other hand, sacrificial victims, who were spatially separated from Shang locals, were treated as a lower category and not afforded much meat. Moreover, there is some evidence that subsistence patterns and dietary practices were also varied depending on intra-group social status even among commoners. However, because of the small sample sizes, there is no statistically significant correlation between diet and social-cultural differentiations[49].

4.2.2.2.2 Guandimiao

The Guandimiao Shang residents' dietary practice is reconstructed based on the analyses of human samples from tombs (Wang, N., Unpublished work)[50] and animal samples from residential, sacrificial, and burial contexts (Hou et al. Forthcoming)[51].

As discussed in Chapter 3, Guandimiao residents are representative of rural low-status Shang commoners and there is little difference in mortuary status. The mean $\delta^{15}N$ value of the humans is 3.3‰ higher than that of cattle, 2.3‰ higher than that of pigs, and 1.4‰ higher than that of dogs. The range of distinction between human and animals is quite close to that of Yinxu, as discussed above. However, the amount of animal bone fragments per unit is smaller than that

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[49] Zhang et al. (2017) studied the carbon and nitrogen isotope compositions of humans in a Yinxu tomb (M54), which is a high-ranking Shang elite's burial with both tomb owners and human victims. The $\delta^{15}N$ value of the tomb owner is higher than $\delta^{15}N$ values of all the humans mentioned in Cheung's dissertation. Nevertheless, M54 is the only high-ranking burial in Yinxu with published isotopic results and little further explanation can be made at present. More results of high elites are expected.

[50] The carbon and nitrogen stable isotopic data of humans in Guandimiao is offered by Ning Wang (王寧, in the History and Culture and Tourism Institute, Jiangsu Normal University 江蘇師範大學歷史文化與旅遊學院, who is running a large project focusing on a comprehensive study of Guandimiao human remains by approaches of stable isotope analysis), and the data used in the dissertation belongs to his further publications.

37 human samples from tombs have been included in the first stage of this project, including 12 males and 25 females. Based on that, the mean $\delta^{13}C$ value of humans is -8.0±0.6‰, the mean $\delta^{15}N$ value of humans is 9.0±0.9‰, and there is little difference between males and females (personal communication with Wang, N.).

[51] The mean $\delta^{13}C$ and $\delta^{15}N$ values of 16 dogs are -7.2±0.6‰, 7.6±0.6‰; the values of 16 pigs are -8.5±1.5‰, 6.7±0.8‰; the values of 13 cattle are -9.5±1.2‰, 5.7±0.7‰; the values of 11 sheep/goats are -16.6±2.3‰, 6.7±1.1‰; the values of 7 medium-size deer are -16.2±3.5‰, 5.9±2.2‰ (Hou et al. Forthcoming).

of Xiaomintun (as discussed above). Thus, there is a discordance when comparing the two types of data. Some factors may have influence on the result[52]. I am inclined to think that, in terms of animal protein intake, residents in Guandimiao may not be so poor as farmers in later Chinese history, and, even though Guandimiao residents may have consumed less meat than people in Xiaomintun, the difference was probably not significant enough to be seen by the stable isotope

[52] There are several possibilities that may have caused the different results:

(a) The complexity of the trophic level model has not been totally understood, since we do not know exactly Guandimiao's environmental or ecological contexts, or the effect of human activities.

(b) The densities of population were not the same. The estimated Guandimiao population is about 50-100 for 2.5+ ha based on both houses and tombs (Li et al. 2018). Song (1991) estimated that Yinxu had a population of 140,000-230,000 (in Anyang Periods III-IV, the zenith) for 3,000 ha based on tombs, and Campbell (forthcoming (a)) also got a very similar minimum population of 112,500-120,000 based on houses and tombs separately for 3,000 ha, while Hwang (2016:199) doubled this number to 227,000-450,000 for 3,600 ha based on size of the settlement. If a population of 140,000 is accepted (since it is calculated in the same standard as Guandimiao and it is a population specifically for Anyang Period III when Guandimiao was occupied) and an area of 3,000 ha is taken (based on the most recent archaeological work (Tang and Jing 2009)), Yinxu could be 1~2 times the population density of Guandimiao. Therefore, based on collected animal bone assemblages, it is possible that the Xiaomintun residents consumed more meat than people in Guandimiao did (3/10~3/5, based on the number of specimens collected, as discussed above).

(c) Guandimiao residents' diet may have contained some animals which were not well represented in the bone collection. For examples, small animals (e.g., chickens and other wild birds, rabbits, and rodents) may take a part in diet, while their bones were easily missing during excavation (as shown in the report). Milk may also be taken. (Freshwater fish was not common according to my additional work on a small sample of water flotation.) As mentioned above, the proportion of animal protein and the quality of diet can be separate issues. However, considering the small standard deviations across all C and N measurements of humans, the portion of wild game (which ate more C3 foods) should be small.

(d) The taphonomic impact of dogs at the site was very serious and they may have destroyed a great number of skeletal elements or element portions. Based on body part frequency, it is very clear that there was a disproportionate quantity of taphonomically robust elements at Guandimiao (such as pig mandibles, cattle metapodials, etc.) (Hou et al. 2019), while evidence of carnivore damage at Xiaomintun is relatively weak (Li 2009; it will also be discussed in chapter 9). The relatively high mean $\delta^{15}N$ value of dogs at Guandimiao also supports this assumption, which indicates that they consumed higher portion of animal protein than dogs in Xiaomintun.

In summary, there is probably no single explanation for the discrepancy between the two types of data. However, I am inclined to think that, in terms of animal protein intake, the difference between villagers in such a small settlement and urban residents in Yinxu was probably not that significant. This conclusion is also supported by the low intensity of bone fat and grease extraction at Guandimiao (which I give detailed analysis in Chapter 7), suggesting that animal food resources were not scarce.

analysis. Moreover, the analysis shows that there is almost no difference between males and females in diet (Wang Ning, personal communication).

4.2.2.2.3 Zhougongmiao

Li's analysis of human and animal samples from Zhougongmiao has made a good start to the study of dietary practice and subsistence in the royal domain of Western Zhou (Li et al. Forthcoming (a))[53].

In general, based on the stable carbon and nitrogen isotopic compositions of human and animal remains, residents in Zhougongmiao had a millet-based diet, which can be supported by the study of plant crop remains. The human and animal nitrogen values, however, are much more complicated to interpret[54]. Considering the large animal remains collected, the Zhougongmiao

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[53] Bone samples from 20 humans, 3 cattle, 4 pigs, 7 sheep/goats, 6 deer, and 4 dogs have been taken to study the Zhougongmiao residents' dietary pattern.

Cheung (2015) has also included a few human samples from the expanded Zhouyuan, without clear archaeological context, which is not considered here.

It is also reported in Li's another paper the dietary reconstruction of Shang remnants in Zhouyuan based on isotopic evidence (Li et al. Forthcoming (b)), which will not be discussed here.

[54] The result of isotopic studies on Zhougongmiao is different from that of other sites mentioned in this chapter:

(a) In terms of the mean δ15N values, it shows an order of deer (4.1‰) < sheep/goats (6.0‰) < cattle (6.7‰) < human (8.2‰) < pigs (8.4‰) < dogs (9.0‰).

(b) The difference in mean δ^{15}N values of the human and cattle samples is 1.5‰, and this is much less than those of Yinxu (Xin'anzhuang and Xiaomintun), Guandimiao, and the even earlier Erlitou, Taosi, and Xinzhai. However, the result of zooarchaeological study on Zhougongmiao suggests that residents consumed lots of meat. As discussed earlier in this chapter, it includes a larger portion of herbivores (mainly cattle, sheep/goats, and deer) in this Western Zhou site compared to the earlier sites. Therefore, there exists a possibility that the more frequently consumption of herbivores, as well as some wild species, affected the δ^{15}N values of human samples.

(c) The mean values of dogs and pigs are very close to that of human. It is usually believed that pigs and dogs were fed with human's kitchen leftovers in this period. So, the 2.0‰ difference between mean cattle and pig δ15N values suggests the inclusion of some animal protein in pig diets, which were quite possible from kitchen leftovers, even though both cattle and pigs may be affected by manured crops and their by-products. So was the case for dog possibly. However, the isotopic result seems to indicate that the dog and pig protein had contributed little to human diet. It is possible for dogs considering its small portion in the whole animal assemblage (Zhang 2012), while low consumption of pig protein is extremely unexpected and unlikely to be true. The reason for this discordance is not residents, mainly commoners, consumed at least moderate animal protein in their diet, which should include a large quantity of herbivores (mainly cattle, sheep/goats, and deer) compared to late Shang period[55]. On the other hand, a wide range and the high standard deviation of humans' $\delta^{15}N$ values ($\delta^{15}N$ values ranged from 5.2‰ to 11.2‰, with the mean as 8.2±1.6‰,) indicates the Zhougongmiao residents had great variability in animal protein intake. This makes some sense when considering the archaeological and mortuary background of these human samples. – As Li has tried to argue, the mean $\delta^{13}C$ and $\delta^{15}N$ values of the higher-ranking group (elites) are larger than those of the low-ranking group (commoners), even though there is no statistically significant correlation[56].

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clear yet. It may arise from the bias of small sample sizes – only four pigs. So, further work with more samples may help to explain this strange result.

(d) Beside the possible effects of animal species component and sample size, chronological contexts of the selected tombs may also be noted in order to better understand the isotopic data. Zhougongmiao had its heyday in a time from the proto-Zhou (Anyang Period IV) to the early Western Zhou, and the settlement decayed greatly in the later middle-to-late Western Zhou time with fewer residents and the damage of palatial-temporal area (Chong 2010). Most of the human samples in Li's study are from tombs of middle-to-late Western Zhou period. Based on zooarchaeological evidence, only about 16% (=3815/23320, based on NISP) of the whole animal assemblage are from middle-to-late Western Zhou contexts. So, the social and economic status of residents in Zhougongmiao should also be discussed in the future.

[55] In Zhougongmiao, the total area of several localities of excavation has not been reported yet. It is known that about 5,000 m^2 residential areas (and bronze workshops) have been excavated, with several associated cemeteries. According to unpublished reports, this is a very strict calculation based on ArcGIS and was done by students during field training. So, if the excavated area of large high-ranking elite tombs and some scattered pieces are also included, the total could be 1-1.5 ha. In Zhang's thesis (2012), 20,000 animal fragments are reported from proto-Zhou to early Western Zhou (around 1100-950 BCE, the heyday of Zhougongmiao), the amount of which is about half of the whole collection. In Xiaomintun, during Anyang Period II-IV (around 1200-1050 BCE, a time for the bronze workshop), about 60,000 animal fragments were collected in an area of 3 ha. Therefore, in Zhougongmiao and Xiaomintun, the density of animal remains are very close.

[56] There are 8 samples from middle-to-low-ranking elites' tombs, including a unique one of a middle-ranking elite which has the highest C and N measurements, and 6 samples from commoners' tombs. The sample size is too small to make a statistically meaningful comparison, and, in fact, there is great overlap in the scatter chart.

In addition, Li also tried to show the separation of males and females as indicated by $\delta^{15}N$ values. However, the small sample sizes and the distribution of data in the scatter chart made the argument unconvincing.

4.2.2.2.4 Summary

Even though it is not so straightforward to reconstruct paleodiet relying on stable isotopes of carbon and nitrogen, by referring to other archaeological and zooarchaeological evidence of Yinxu, Guandimiao, and Zhougongmiao, it is possible to get some information on subsistence strategies and dietary practices in late Shang and Western Zhou times, which has especially focused on the remains of commoners[57].

Generally, Shang and Zhou people subsisted on a millet-based agricultural system, and also consumed a great amount of meat (mainly from livestock). Though there may be some difference between urban (Yinxu) and rural (Guandimiao) settlements (as discussed in the earlier section of this chapter based on zooarchaeological evidence), as for the portion of animal protein intake, there seems no great difference between rural residents of Guandimiao and urban citizens of Xiaomintun. The situation of Zhou people in Zhougongmiao is even less clear, despite the huge animal bone assemblage indicating frequent meat consumption. Furthermore, compared to farmers in later Chinese history, meat may have taken a larger part in commoners' diet in the Bronze Age (Hsu 1993:242), and, therefore, the clear distinction between commoners (as "bean leaf eaters", *huo shi zhe* 藿食者) and elites (as "meat eaters", *rou shi zhe* 肉食者) seen in Eastern Zhou and later texts had probably not yet come into existence. For this reason, it is meaningful to study the approaches of animal butchery and meat food preparation in the three sites – even if residents in rural settlements also ate a substantial amount of meat, they may not have processed meat in the same ways as people in large settlements did.

[57] The very practical reason is that there are more tombs of lower-ranking than those of higher-ranking and, usually, human skeletons in tombs which have few burial goods (usually of lower-rank) are less likely to be looted and thus better preserved than those with rich burial objects, and with coffin chambers which trap air and offer poor preservation conditions for bone.

In addition, the published results have pointed to the possibility that the patterns and degrees of (both intra- and inter-group) social separation in the Bronze Age may be reflected in human dietary patterns. However, current work is still too limited to discuss the diversity and variations of human diet.

4.3 Meat Food Preparation and Consumption

Since there is little contemporary written evidence, most of what we conjecture about food preparation in the Chinese Bronze Age is derived from post-Zhou texts. According to records in later texts, cooking methods in Shang and Western Zhou times included steaming, boiling, broiling, and roasting, as well as baking, drying, salting and pickling (Hsu and Linduff 1988:358-359; Huang H. T. 2000:67-76). It can also be inferred based on these texts that Western Zhou meat dishes could be made of the whole carcass, bone-in meat, purely meat (as well as viscera and fat), or meat with bone particles[58], and so these are all possibilities for Shang times as well.

Records of cooking vessels in received texts are not as common as those of food description. Based on archaeological studies, the most used cooking vessels in Shang and Western Zhou were the ceramic *li* 鬲 tripod, as well as the ceramic *yan* 甗, which was a combination of a *li* tripod and a *zeng* 甑 steamer (Haapanen 2005; Huang H. T. 2000; Reinhart 2011; CCS 1982:51-93). Though bronze cooking vessels, especially *ding* 鼎 cauldrons, were important for elites on ritual

[58] For example, various meat dishes are mentioned in the *Liji, Quli, Part I* (禮記·曲禮·上): meat cooked on the bones (*yao* 殽), sliced big pieces of meat (*zi* 胾), thin fine slices or strips of meat (*kuai* 膾), roasted meat (*zhi* 炙), dried meat squares (*fu* 脯), dried meat strips (*xiu* 脩), meat sauces (*hai* 醢). In *Yili, Gongshi dafu li* (儀禮·公食大夫禮), there is also minced meat with bone particles (*ni* 臡). According to *Liji, Neize* (禮記·內則), meat can be consumed in various forms, such as separate dishes, be placed on top of cooked rice or millet, and be cooked together with rice as porridge. (A detailed summary is made by K. C. Chang (1977:23-52).) Although these texts are idealized ritual regulations for elites written hundreds of years after the Western Zhou they may supply a helpful starting point for a reconstruction of meat preparation in the Chinese Bronze Age.

occasions[59], they weren't widely used. Currently, the study of ceramic vessels is one of the main ways to understand foodways in this period. Haapanen (2005) studied the ceramic remains from two bronze-manufacturing sites at Yinxu, which represented the remains of commoners, and discovered that the late Shang *li* tripods were manufactured in three different size categories. Considered together with the results of use wear analysis, she argued that the specific size categories may reflect the size of the social unit defined by eating-together (one to little over two people; three to nearly four people; over four people), while they may also be used to cook diverse dishes. In addition, her research has reconfirmed the importance of boiling and stewing using *li* tripods as the prevalent methods of food preparation during this time. Reinhart (2011) compared the ceramic remains from the palace region and one commoner residential area at Yanshi Shangcheng (the capital of early Shang period in around 1600-1435 BCE). She argued for the separation of cooking and serving ceramic vessels in both vessel types and dimensions between the royal ritual area and the commoners' residential region. Generally, her analyses show a wider array of vessel types and important vessels of larger size in the palace area than in commoner residential areas which may suggest frequent large-scale feasts in the royal palace.

While the current state of knowledge about food preparation is limited, the study of animal bones can partially fill the blank, since both breakage patterns and marks on the bone surface contain information of human activities such as butchering, pot-sizing (based on studies of cooking vessels), filleting, and roasting, and the differences may also be indicators of certain eating occasions.

[59] For example, it is often found in the Western Zhou tombs at Zhouyuan animal bones in bronze vessels, which should be offerings to the deceased (e.g., Zhao 2017:119; Zhouyuan Kaogudui 2016).

4.4 Summary of Previous Studies and Some Specific Questions for This Dissertation

To summarize, in the past several decades, especially in recent years, based on both written evidence and archaeological discoveries, there has been much progress in the study of animal foodways in the Chinese Bronze Age, especially the latter half of this period (late Shang and Western Zhou periods). It is generally clear that, in this period, a complicated system of animal production and consumption took shape, which relied on the stable development of animal husbandry.

It is quite possible that, while livestock farming was a widespread activity in society, the king and other high-elites controlled parts of livestock management and distribution. Based on zooarchaeological studies of Xiaomintun (in Yinxu), Guandimiao, and Zhougongmiao, there was a degree of specialization in animal production and consumption between settlements of diverse levels. That is, there was more or less a separation of consumer and producer centers between large and small settlements as shown by quantitative proportions of different species, age and sex groups[60], as well as the number of medium-to-large livestock taken in daily life. However, meat consumption patterns between commoners in rural and urban sites seem similar, so that cattle were as important a meat source as pigs in both large and small settlements even though cattle have long been regarded as more valuable and status related. In addition, isotopic results also suggest there may be no great separation of urban (Xiaomintun) and rural (Guandimiao) residents generally in terms of animal protein intake, though many variables exist in understanding of carbon and nitrogen isotope patterns. In summary, when talking about foodways and subsistence strategies of late Shang and Western Zhou, especially those of commoners, the dichotomy between urban and

[60] The situation in the palace-temple region of Yinxu (in Xiaotun) is an extreme example that there is a concentration of a large amount of valuable, exotic, unusual species.

rural settlements seems to be less clear than in later history, and so was that between elites and commoners.

In order to further understand animal foodways in Early China and discuss the potential difference and relationship between settlements of different levels, animal butchery and carcass processing deserves study. This is based on a consideration that both political economic factors and gustatory and symbolic factors can separate foods among different groups of people (Curet and Pestle 2010, Goody 1982). The study of animal butchery can provide evidence for specialization of butchery and exchange of animal products, since issues like the separation of butchering/consuming populations and locations and the distinction in butchering techniques and tools may also mark differences between large and small settlements in complex societies. Meanwhile, the approach and intensity of animal processing, which may be greatly influenced by social economic status and cultural customs, can also be discussed based on butchery studies. In addition, other factors, like diverse tastes and varied ritual/political/social criteria for occasions such as public feasts, may also affect the final pattern of food preparation and consumption and can be discussed based on the study of animal food processing.

Therefore, in the following chapters of this dissertation, animal butchery and carcass processing will be discussed, and patterns of bone modification (bone breakage and butchery marks) will be the main focus.

Several layers of questions will be discussed. To begin with, I will deal with the very basic question of how non-elites prepared and ate meat, especially cattle and pigs, in this period. This will be the first time such a study has been done in Chinese zooarchaeology. What is the evidence of carcass butchery and cooking preparation (by which I mean the patterns of bone breakage and the types of butchery marks)? How were animals butchered and dismembered and how were large pieces of meat processed for cooking based on the evidence? How do cooking vessels (*li* tripods) effect and reflect the preparation of meat (pot-sizing)? In addition, some deeper issues can be discussed. How can we reconstruct the daily life of commoners based on the animal remains, such as the pattern of resource allocation (e.g., self-sufficient, government- or market-reliant) and the social scale of meat consumption (e.g., a household, an enlarged social unit)? To what degree do the patterns of animal food consumption reflect and distinguish the social economic status of commoners in Shang and Western Zhou societies? Or do they? It is also possible that even in a stratified society food itself is not stratified (Curet and Prestle 2010).

CHAPTER 5: Methodology

5.1 Introduction

This chapter outlines the methodology that is adopted in the following chapters of this dissertation for studying animal butchery and carcass processing, in order to discuss animal food preparation and consumption. In the second section of this chapter, considering the diverse purposes and different approaches/techniques of carcass processing and bone modifications during steps of carcass and meat preparation butchery and cooking-consumption, as well as the potential separations between small and large settlements, I summarize the potential purpose, processes, products of each stage, and the possible evidence left on the bones. The arrangement of analyses and discussions in the following chapters of this dissertation is largely based on this model. Then, I summarize a model proposed by Halstead (2007), which aims to study the social scale of meat consumption based on the general situation of the animal assemblage at the site (including the archaeological contexts). Its high requirement for the completeness of archaeological information makes it of limited application in this dissertation – I only apply this model roughly to discuss the Guandimiao case. However, since similar work has not been attempted in China, it deserves an attempt. In the third section of this chapter, I generally describe the logical steps of analysis for each site. I borrow a framework from Orton (2008, 2012) where changes are made based on an understanding of human activities of animal food preparation and consumption (summarized in section 1 of this chapter), as well as their connection with the taphonomic background. Lastly, detailed methods and techniques used in this research are illustrated, including especially those for specimen identification and bone-modification observation, information recording, and data analysis.

5.2 General Outline of Models Used in the Dissertation

5.2.1 Models for Studying Carcass Processing for Food Preparation-Consumption

The process of animal butchery and carcass modification related to food preparation can roughly be broken down into at least two steps (Twiss 2012: 362): A) initial preparation of raw resources for storage, transport, allocation, and/or cooking, and B) preconsumption preparation which includes actual activities of preparing a meal (e.g., cutting, soaking, cooking). The first step involves the initial slaughter and carcass dressing, including activities such as blood extraction, removal of hides/hairs and viscera (and their contents), as well as potentially the removal of the head, extremities, and/or other non-major meat bearing parts. This stage also includes the initial division of the carcass into major portions (the division of which can refer to the "primal cuts" of livestock in the modern butchery, such as rounds, loins, ribs, chucks), which may happen in either separate venues or some temporary areas close to households, and may also be divided to two steps, as "primary butchery" and "secondary butchery" (e.g., Landon 1996:59; Lyman 1978:5, 1987, 1992:247; Rixson 1989:49) if activities of slaughter and dismemberment are in different locations. Some animal secondary products, such as hide, hair, teeth, horns/antlers, some special bones for bone working or ritual use, may also be extracted. The second step includes the final division of meat and bone into smaller pieces for cooking and consumption (also known as "final or tertiary butchery" (e.g., Landon 1996:59; Lyman 1978:5, 1987, 1992:247; Rixson 1989:49)), finishing all the preparation before cooking. Finally, the second stage includes cooking, which may be done by butchers in special locations in some relatively developed societies or in domestic contexts. A general model is shown in Table 5.1 and details are further explained as follows.

In the primary butchery stage, if butchery is a separate activity conducted some distance away from the consuming households, the slaughter waste, including heads and extremities and/or other non-major meat bearing parts, as well as viscera and their contents (which are rarely preserved) may be concentrated in certain areas, and some animal secondary products such as hide, hair, teeth, horns/antlers, some special bones for working or ritual use may be extracted, while meal remains should be in other locations.

If the butchering activity is locally conducted near the consuming households, almost all body parts from both the slaughter waste and food remains (except those which have been extracted purposely) should be in local garbage dumps. Considering the different purposes of animal slaughter, carcass dressing, and initial dismemberment/disarticulation, distinctions should be discernable in butchery marks and breakage patterns.

During the stage of preconsumption preparation, considering different requirements of various dishes and the limitation of cooking vessels, it can be expected that those original large body portions may be affected in roughly three ways. A) The requirements for elaborate cuisine or nutrient extraction may cause further fragmentation of meat parcels and bones. For example, boiling and roasting may require meat and bone parcels of different sizes in order to fit into certain cooking vessels (so called pot-sizing) or facilities, and grease and marrow exploitation can also cause the breakage of bones. B) Filleting (the removal of meat from bones) is a common practice and can leave marks on the surface of a bone. C) Heating treatment (boiling and roasting mainly) in cooking may change the physical and chemical states of animal bones, which may change the color of a bone and can affect bone fragmentation afterwards[61]. For example, "bone-in" roasting

[61] Temperature is one of the factors that may affect bones when cooking. However, it is shown that cooking has little distinguishable effect on bones in a short term and its effects are difficult to discern at present.

or grilling may cause burning marks on the ends of joints (with little meat covered) and even further fragmentation of bones. I mainly consider the breakage patterns and bone marks related to A) and B).

In addition to these main steps discussed above, meat storage and preservation should also be included in the process of preconsumption preparation, though it is not always a necessary step and the related remains may not be easily identified. Meat storage and preservation may focus on either raw meat resource or processed meat, they may occur after any stage of animal carcass processing, and these activities can take place in locations of animal butchery, food cooking, and even specialized food processing locations. For example, a whole animal carcass or joints of meat may be hung up, roasted, smoked, or cured for preservation before further processing. The requirements of meat preservation may affect people's choice of butchering in some way and can also cause special bone modification sometimes, such as holes and/or cuts related to hanging and burning of bones for roasting/smoking.

However, in terms of bone modifications during food processing and consumption, some cases during food consumption should also be considered. Though marrow can be extracted from bone fragments (especially those of long bones and vertebrae) during the process of cooking (e.g., by boiling and/or roasting), if the whole bone element has been cooked, marrow can also be removed after meat consumption by breaking the cavity of the bone directly or after reheating the

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It has been shown by some researchers that bones cooked while still insulated from the heat by the meaty tissue surrounding them behave differently from bones cooked without this cushioning effect. When meat was cooked, the temperatures bones suffered can be much lower (Alhaique 1997; Roberts et al. 2002). Some scholars have studied the physicochemical effects on cooked bones (e.g., Ellingham 2015; Roberts et al. 2002; Solari et al. 2015). These studies show that roasting and long-period boiling may make bones easily broken in later taphonomic context. However, such work is still in process, and I will not add related scientific analysis in my dissertation.

bone. Besides, activities such as cutting off meat from ham or roast meat joints may leave marks on bone.

Table 5.1 Stages of animal butchery and food preparation-consumption

<table>
<tr><th></th><th>Stage</th><th>Purpose</th><th>Process</th><th>Products</th><th>Locations</th></tr>
<tr><td rowspan="6">Animal butchery and food preparation</td><td rowspan="3">(STAGE I) Initial preparation</td><td rowspan="3">Preparation for storage, transport, distribution, and/or cooking</td><td rowspan="2">Primary butchery -- initial slaughter and carcass dressing)</td><td rowspan="2">Raw animal food resource (most of the carcass, blood?, viscera?); secondary products (hide, hair)</td><td>Separate butchery venues (e.g., hunting camp, production site, shambles or slaughterhouses, and sometimes butcher shops)</td></tr>
<tr><td>Temporary areas close to households</td></tr>
<tr><td>Secondary butchery -- initial carcass division into major proportions</td><td>Raw animal food resource (large body portions); secondary products (certain bones (e.g., teeth, horns/antlers, special bones for working or ritual use)</td><td>A) separate butchery venues, which may or may not be the same places as those for initial slaughter; or B) temporary areas close to households</td></tr>
<tr><td rowspan="2">(STAGE II) preconsumption preparation</td><td rowspan="2">Preparation for consumption and fat extraction</td><td>Tertiary butchery -- division of large body parts into units of meat</td><td>Raw animal food resource (main muscle parts, small meat joints, blood, viscera, brains, sinew (tendon and ligament), fat (marrow and grease)); secondary products (bones, teeth, sinew, fat)</td><td>A) households, or B) separate places (such as butcher shops)</td></tr>
<tr><td>Cooking</td><td>Cooked animal food</td><td>A) households mostly, or B) butcher shops sometimes</td></tr>
<tr><td></td><td></td><td>(OTHER STEPS) e.g., storage and preservation</td><td>A) almost the whole carcass, or B) joints of meat (being hung, roasted, smoked, cured, etc.)</td><td>--</td></tr>
<tr><td>Meat food consumption</td><td></td><td>Animal food consumption</td><td></td><td>A) animal food, B) food waste, C) secondary products (bones, fat)</td><td>Households</td></tr>
</table>

Table 5.2 Possible evidence of animal butchery and food preparation-consumption

	Process	Locations	Evidence		
			Skeletal element representation	Breakage pattern	Bone surface modification (marks)
Animal butchery and food preparation	Primary butchery	Separate butchery venues	Separate discards of slaughter waste (head/extremities mainly, or other non-major meat-bearing parts; visceral contents) and meal remains (primary meat-bearing body remains)	Mostly whole elements	Marks of slaughter, severing the head, skinning/hide removal, etc. (cut marks, chop marks/shear surface)
		Temporary areas close to households	Almost all body parts in local garbage dumps		
	Secondary butchery	A) separate butchery venues; or B) temporary areas close to households	Primary meat-bearing body parts (except those abandoned/extracted in the stage of initial slaughter)	A) mostly whole elements, B) breakage of some articulation joints	Marks of carcass dismemberment/disarticulation (cut marks, chop marks/shear surface)
	Tertiary butchery	A) households, or B) separate places	A) several anatomically articulated elements (e.g., rib-vertebrae, proximal femur-ischium-pubis-acetabulum); or B) several bone fragments of the same element/bone category (e.g., ribs and/or vertebrae, long bones)	Small joints of meat; diverse bone breakage patterns	Marks of subdivision of meat joints, filleting, bone extraction, marrow extraction (cut marks, chop marks/shear surface, scrape/scoop marks)
	Cooking	A) households mostly, or B) butcher shops sometimes		Further fragmentation sometimes (for bone grease extraction, etc.)	Heat treatment: burning marks, and other physicochemical changes on bones
	(OTHER STEPS) e.g., storage and preservation			E.g., a hung scapula: holes on the blade	E.g., A) a hung carcass: tool marks on foot bones; B) smoked bone-in meat: burning marks on the ends of joints

Meat food consumptio n		Household s			E.g., marks of bone breakage, meat cutting

Therefore, considering all the general steps summarized above, it is clear that three aspects of a bone assemblage should be the core of a study of animal butchery and food preparation-consumption via bone remains: (a) skeletal element representation, (b) bone breakage patterns, and (c) bone surface modifications (mainly butchery marks) (Table 5.2). However, in this dissertation, for reasons discussed latter in this section, most of the attention is given to (b) and (c), and (a) is only occasionally mentioned.

Nevertheless, it must be emphasized that the above framework is just a very brief summary, while the processing of animal carcasses as well as the cooking and consuming of animal food can vary greatly depending on a broad range of natural and cultural variables (e.g., Gifford-González 1989; Lyman 1987; Morales-Muñiz 1988). Natural factors, such as taxon, size, age, sex, and body parts, may easily affect human treatment of animal carcasses. Some common situations are that different elements with diverse muscle and sinew attachments may be processed separately, animals of different species, sizes, and/or ages tend to show differences in the number of fractures of the same element, and element attachment can have an obvious impact on ways carcasses are dismembered and joints of meat are subdivided. The many cultural variables, such as tools and techniques, gustatory preferences, limitations of cooking vessels and other facilities, customs and beliefs, the organization of people, and social economic status, also have significant effects on each stage and the whole process of animal food preparation and consumption. A few frequently discussed issues are listed here. Compared to activities of early humans, the appearance of specialized butchers and advanced metal tools have increased the efficiency and standardization of animal butchery while producing different patterns of bone modification. The development of urban and rural settlements enables a separation of animal production, meat preparation and food consumption which can be shown by traces like different taxa, ages, and sexes of animals, and variant skeleton element representation. The available cooking vessels (form, texture and size) and relevant tools can help to determine the pattern of bone fracture and ways of cooking, and so do the social context and social scale of meat consumption, for example. The intensity of animal resource extraction may have close connection to factors like people's economic status and social customs, which can be reflected by some evidence, such as the taxa diversity of animals, and the degree of bone fragmentation. All of these factors/variables make the study of animal processing and meat consumption a very fruitful direction in the study of complex society and will be the main topic discussed in this dissertation (see the last section of Chapter 4).

5.2.2 A Model for Studying the Social Scale of Meat Consumption

Considering the animal assemblage of a settlement as a whole and specifically paying attention to animals too large to be eaten fresh by a single household in a short time, Halstead (2007) has developed some relatively simplified standards to distinguish three pathways of meat preparation, distribution, and consumption, which refer to meat sharing in two types of social groups in terms of their scales (that is, single household vs. several households). Although Halstead's study focuses on Neolithic-EB Greece, his model raises most of the commonly discussed occasions of domestic animal consumption in complex societies. Thus, I think his model is suitable for investigating the situation of settlements in other regions and cultures. Specifically, in this dissertation, I would like to refer to Halstead's model in order to think about how domestic animals, especially cattle and pigs, were consumed in the local community of Guandimiao.

In Halstead's model, a precondition of human selection of domestic animals for processing and consumption on different occasions is carcass sizes, which is identified on the basis of taxon, age and, to a limited extent, sex. This model concentrates mainly on large domestic animals which are too large to be eaten fresh by a single household. It is based on the consideration that large carcass processing and consuming is more sensitive to various social and cultural contexts and the scale of people than small ones, while it is natural that some small (and very young) animals are suitable for domestic consumption in a short period.

Halstead's three ways of large carcass consumption are distinguished from each other by interpreting the complicated combinations of two groups of independent variables -- collective vs. domestic consumption and cooked/cured vs. raw distribution -- in different contexts.

(1) A large domestic animal was partially and wastefully consumed, as a fresh carcass, within a domestic unit.

This is elaborated by comparison to a relatively common way of meat consumption in a single household. With other things being equal, if large and small carcasses are processed and cooked in the same way, large carcasses should be butchered more intensively with more frequent cut marks than small ones and possibly a higher portion of long bone fragmentation (for marrow removal). However, when a large fresh carcass is partially and/or wastefully consumed within a domestic unit, the intensity of carcass exploitation should be low and meat consumption can quite possibly gain a high priority compared to bone marrow and grease exploration, and body parts with more meat may be first processed. In this case, one or more of the followings should be expected: (a) the incidence of butchery marks declined with increasing carcass size, (b) the degree of bone fragmentation, which represents the intensity of marrow and grease extraction, is low, and (c) there are more meaty body parts butchered than those of lower utility. (d) In addition, it is also possible that there is a high percentage of fragments from the same carcass around the household.

(2) A large domestic animal was preserved for consumption over an extended period, potentially within a domestic unit.

The specific food preservation practices are always closely related to local natural environment and social-cultural customs. Some relatively universal rules of meat preservation in the domestic context can be summarized. When meat is preserved for consumption over an extended period within a household, some special treatment (salting, smoking) is needed. Therefore, it can be expected that a peak of slaughter might be during the cold winter in order to have time to preserve and process the greatest amount of meat. The scale of curing varies. It can be a mostly whole/a portion of whole carcass, a chunk of bone-in meat, or the meat only (after filleting). The available cooking vessels and other facilities may affect some of these choices. The dumped bone fragments should also be around or near the house. However, since meat is consumed in multiple occasions, there may be bone elements from the same individual which have different taphonomic damage because of a delay in bone discard.

(3) A large domestic animal was consumed by several households (large numbers of people), whether collectively at a large social gathering or as joints of meat distributed for domestic consumption.

Halstead explains the complexity of this category. It in fact includes at least three types of events. Large carcasses may be presented and processed during collective ceremony with meat joints distributed to and consumed in domestic contexts; they may be consumed during large social gatherings; or they may also be processed for reciprocal exchanges between a group of people/households (e.g., among neighbours or kin) to be a substitute method of meat preservation. In different situations, two activities - collective meat processing and consumption by several households and distribution of joints of meat to individual households - may either happen together or separately. Also, activities, such as carcass butchery, meat-joint sharing, cooking and consumption, debris discarding, may happen together in one locus or in different places (e.g., collective vs. domestic contexts).

In order to describe and compare these different situations, two groups of variables, collective vs. domestic consumption and cooked vs. raw meat distribution, are summarized and analyzed by Halstead. Then, following the order of discarded bone fragments, processed bones for cooking, and other details for butchery, he makes several pairs of comparisons.

i. The distribution of skeletal elements and bone fragments under certain archaeological contexts can help tell the nature of meat consumption. Remains of collective ceremonies may be very special and are possibly easily identified[62]; however, it may also not be the case. Some of these activities may take place in one ritual event together with collective feasting and/or meat distribution to individuals/households (the details are similar to discussions of the other two types of events in this section). After collective consumption of some carcasses, there are usually a great number of bones discarded quickly and together in one or several nearby loci, which means some fragments may be identified as articulated or paired elements and some may be pieced together as portions of one element. Also, several elements (such as those meat-rich parts) may be preferred in collective feastings. Nevertheless, if meat joints are received via reciprocal exchanges and consumed in domestic units, it is quite possible that each household would get relatively equal meat parts on average and over the long term, and skeletal elements of an animal may be dispersed across the site with no special pattern with little or no element bias.

[62] Halstead's (2007) description is based on Greek examples where low-utility elements (such as heads and feet) were left in the ceremonial butchery locus while meat-rich parts were distributed and consumed.

ii. Cooking vessels (e.g., pots, ovens) can have impact on animal butchering, that is, the intensity of butchery (mainly in terms of the degree of bone fragmentation and the frequency of butchery marks) may be varied based on the size of cooking vessels. The general rules are that with cooking vessels of similar size, the intensity of butchery should be higher for larger carcasses than smaller ones, while, with large vessels for cooking large carcasses, the intensity of large carcass butchery should be similar to (or lower than) that of small individuals. Therefore, if meat joints (of large carcasses) during a large gathering were cooked with a large pot or oven (larger than regular cooking vessels), or if raw meat joints (which may be prepared for or received from reciprocal exchange with other households, or received from some collective activities) were cooked in large vessels in domestic contexts, the intensity of dismembering and/or filleting of large carcasses may be similar to (or lower than) that of small carcasses. However, if standard cooking vessels are used in either gatherings or households, large carcasses should be more intensively processed than small carcasses. Thus, the availability and actual choice of cooking vessels can make a great deal of difference to bone fragmentation patterns.

iii. In addition, compared to domestic activities, different butchery tools and procedures may be chosen during collective butchery and cooking for a variety of reasons, such as prestige display, specialization, and efficiency. For this reason, the analysis of butchery marks can be potentially very informative.

Halstead has noted some practical limitations of this model. He describes ideal and sometimes detailed situations, which can help people understand the complexity of meat consumption but may not be clearly differentiated in the zooarchaeological record. The analysis of an animal assemblage may be faced with equifinality or be disturbed by taphonomic attrition, especially dog related damage and human activities. Cultural variation is another factor that poses a barrier to the universal adoption of this model to other studies. However, Halstead's model has suggested the main factors in an assemblage to be focused on for such a study (such as body part abundance, bone fragmentation, and butchery marks; cooking vessels and butchery tools) and listed many possible clues. Moreover, in the model, there are different layers (from general to detailed) of analysis and related evidence on possible meat-consuming types and social scales of meat consumption. For these reasons, it is in fact a rather flexible approach for those doing related research. For this reason, I adapt Halstead's approach to the Guandimiao materials (see Chapter 8).

5.3 Framework/Logical Order for Analyses

In order to distinguish the possible sources of taphonomic attrition so as to choose qualified samples for the study of human behavior, I broadly follow Orton's (2008:60-77, 2012) framework, especially in the study of Guandimiao animal assemblage. The strength of this model is that it can separate analyses on different taphonomic agents (mainly carnivores and human) into several steps and makes it possible to first describe and evaluate the impact of some non-human agents during and after deposition so that the following study can focus on the anthropogenic modification of animal carcasses during the butchery-to-consumption process.

5.3.1 A General Discussion on Orton's Framework

Orton's framework aims to make a comprehensive and quantitative understanding of practices of animal consumption and bone deposition[63]. The five-step analytical framework

[63] At present, for archaeological studies of complex society, mainly three types of frameworks have been proposed in order to reconstruct contexts of animal treatment during and after human processing, as well as to analysis the approaches of carcass processing and consumption ((a) Marciniak 2001, 2005; (b) Bar-Oz and Munro 2004; Munro and Bar-Oz 2005; (c) Orton 2008, 2012). Comments and critiques of the three can be found in Orton (2008, 2012) and Norman (2018).

separates the assemblage formation process and discusses diverse taphonomic variations in groups. It enables descriptions and comparisons of many sub-groups of the assemblage in order to clarify the impacts of different taphonomic agents.

Firstly, in Stage 1 of Orton's framework, the preservation of the bone assemblage is described by a comparison of element frequencies (by bone survivorship) with bone structural density in order to figure out the possible correlation between bone abundance and density-mediated attrition, which is a starting point and reference to think about the degree of the possible natural attrition (mainly destructions caused by carnivores) and of the impact of human activities in general and to avoid jumping easily to any inferences regarding human selection, since both non-human processes and human activities may generate a pattern similar to that of density-mediated damage[64] (details can be found in Appendix I). In Stage 2, the frequency and severity of gnawing and weathering of bone fragments is investigated, together with a study of fragment size, in order to figure out the possible types and degree of non-human taphonomic damage during and after deposition (mainly to confirm the impact of carnivore damage) and to reconstruct the scene of refuse disposal. Then, from Stage 3 to Stage 4, patterns of anthropogenic bone breakage and fragmentation as well as those of bone surface modification (burning and butchery marks) are analyzed so as to provide information on human-induced bone modification which were possibly caused by food practices. Finally, taking into consideration all of the possible sources of attrition/bias in animal assemblage formation, in Stage 5 the nature of body part profile can then be relatively objectively interpreted, which can be related to issues like selected transport during

[64] Simply speaking, if the skeletal part frequency of an assemblage is strongly correlated with bone density, the composition of this assemblage is likely greatly affected by some density-mediated destruction which can be engendered by either non-human (mostly carnivores) or human damages (as separately discussed in Stage 2 and Stages 3-4), while purposeful human selection can only be a secondary consideration (in Stage 5).

hunting or exchange, different treatment of body parts during butchering, food preparation and/or waste disposal. In addition, an assessment of possible biases during and after excavation is also recommended if applicable in the very beginning of analysis (Stage 0).

Orton's framework can be applied to interpret animal assemblages with various recovery standards or limited information concerning archaeological contexts. This approach separates the taphonomic history and human effects on the assemblage into different stages, while also enabling feedback between the stages. Moreover, even though Orton has given an example of how to do quantitative analysis at each stage, there is still much flexibility for users to adapt analytical methods and parameters. For these reasons, it offers a usable framework for animal butchery and food culture study in complex societies.

5.3.2 A Modified Framework for This Dissertation

I broadly take Orton's framework and follow its analytical steps while at the same time making some modifications appropriate to my assemblage.

Generally speaking, the analysis of the retrieval process, which is only mentioned by Orton as Stage 0, is included in this dissertation to assess possible biases caused by excavation, curation, and recovery. In addition, much attention is given to Stage 3 and Stage 4 since I am mainly interested in bone modification related to food processing. Some of the specific methods are also modified to suit the goals of this dissertation and the specific conditions of the data.

The detailed steps of animal assemblage analysis are as follows:

Stage 0: Possible excavation, curation and recovery biases. The purpose is to assess the possible bias caused by excavation, curation and recovery.

The archaeofaunal assemblage is investigated in three ways. (a) Fragment size distributions are analyzed. The measurement of fragment length is discussed in the next section of this chapter (see “Maximum length”). (b) For cattle and pigs, the frequency of small compact bones and that of the adjacent large limb bone portions are compared since the two groups of bones/portions usually stay together for use, discard, or deposition (Halstead 2011; Payne 1985; Russell and Martin 2005). To be specific, carpals can be compared with distal radii and proximal metacarpals, tali and calcanea can be compared with distal tibia and proximal metatarsals, and phalanges 1-3 can be compared with distal metapodials. The two comparisons can avoid biases toward some body parts, especially some small bones, which can be generated by butchery methods, transport strategies, and even dog damage. (c) In addition, the ratio and severity of newly broken specimens (“new break”) is calculated.

Stage 1: Rather than making a series of statistical tests as in Orton (2008, 2012), I have chosen a simple way to compare frequencies of some elements/portions so as to confirm the degree of human and non-human destruction in general.

(a) The pattern of body part distribution is observed, and special attention is given to survival rates of some high-survival elements so as to confirm a density-mediated pattern. Such high-survival bones include mainly mandibles, all the long bones (humerus, radius-ulna, femur, tibia, as well as metapodials for ungulates; referring in particular to midshafts of these bones), and some cranial portions such as petrosals (part of the temporal bone), which may vary based on body size and taxa. It is argued that high-survival elements are those most likely to resist destructive taphonomic processes (e.g., Marean and Frey 1997; Marean and Cleghorn 2003; Faith et al. 2009). On the other hand, bone elements of both high and low economic utility are included (e.g., cranial vs. long bones) in order to avoid the possible equifinality since there is a “weak but significant negative correlation between density and utility between density and utility for some species” (Orton 2012: 323). Therefore, frequencies of these bones may inform treatments (such as selective transport, patterns of killing behavior, and certain cooking and consuming customs) of some elements which are not density mediated.

(b) The degree of long bone end destruction is calculated as a measure of density-mediated attrition. For humerus, femur, radius, and tibia, unlike midshafts, long bone ends are generally of low density and highly sensitive to destructive processes[65]. So, ideally, with long bone shaft fragments included, a calculation of long bone end destruction compared to the minimum number of long bone elements (MNE) can be an indicator of degree of density-mediated attrition. This is also a necessary step in understanding body part profile patterns. Following Faith and Thompson (2018), the percentage of long bone end attrition is calculated as:

$$\frac{\sum(long\ bone\ MNE \times 2) - \sum(long\ bone\ end\ MNE)}{\sum(long\ bone\ MNE \times 2)} \times 100.$$

It deserves to be emphasized that, by making the two types of comparisons, not only the completeness of animal skeletons as a whole, but also the completeness of individual elements (especially long bones) should be assessed. The result is closely related to further analyses, relating to issues such as selection of specimens and interpretation of human behaviors in Stage 3-5.

Stage 2: Peri-depositional damage. The frequency and severity of animal gnawing is emphasized.

In my experience, weathering and rodents caused little serious attrition to the three assemblages discussed in this dissertation and so that the degree of bone destruction caused by dogs is my main focus. The frequency of animal gnawing is calculated as a ratio of gnawed

[65] This may be not so sensitive for all cattle limb bone. However, based on my experience, some of the articular portions of cattle long bones are less dense than and not as well preserved as other portions/elements, such as the proximal end of a humerus, the distal end of a femur, and the proximal end of a tibia. Therefore, the method adopted here can work well in general.

specimens to the whole assemblage. Also, the severity of gnawing can be assessed by referring to the degree of long bone end attrition (as mentioned above)[66].

Stage 3: Breakage and Fragmentation. Two types of analysis are covered. (a) By qualitatively assessing the pattern of element breakage (including element completeness and fracture types), together with the study of butchery marks (see Stage 4), the manner of animal butchery can be analyzed. (b) The fragment size of specimens is measured and grouped, which may be related to pot-sizing.

Stage 4: Bone surface modification. Since burning, as a result of roasting meat, is not common in any of the three sites, only butchery marks are emphasized in this stage in terms of "visible human modification". Differing from Orton's (2008, 2012) simplification of all marks to "cut marks", four types of butchery marks are recorded based on the morphologies of marks observed (see Section 5.4.1.3).

Based on many actualistic experiments and ethnographic observations (e.g., Abe 2005; Binford 1978, 1981; Gifford-González 1989; Seetah 2006), types and locations of butchery marks often can be related to activities of animal slaughter, carcass dismemberment, and preconsumption preparation (primary, secondary, and tertiary butcheries). Thus, types, locations and frequencies of butchery marks are summarized and compared.

Stage 5: Assessment of element representation and animal butchery and processing. This is discussed based on models mentioned above (Table 5.1, Table 5.2).

These study steps are followed mainly in the study of Guandimiao for which I had full access to and could offer the most complete information needed for a taphonomic discussion.

[66] Some scholars (e.g., Binford 1981; Todd and Rapson 1988) take a slightly different measurement that compares the ratio of proximal and distal ends of humerus and tibia. The basic logics of these approaches are the same.

5.4 Methods of Identification, Recording, and Quantification

In order to meet the needs of a meat preparation and consumption study, three types of information were collected and recorded for each piece of bone fragment, in addition to basic information: information that A) helps to calculate the body part frequencies, B) describes the approach and degree of bone fragmentation, and c) records the situation (e.g., morphology, location, and amount) of butchery marks. Accordingly, there are two priorities in developing the methodology. Firstly, locating bone fragments to their position on elements as a basis for all further identifications and analyses. I will illustrate the procedure in this section. Secondly, evaluating and even controlling the bias caused by taphanomic attrition in order to develop a way of sampling to ensure that most of the specimens for study were the result of human behavior, and to understand to what degree the studied bone specimens can reflect the original situation when the bones were discarded. The method for collecting taphonomic attrition information will be included in this section and the discussion of dealing with relevant bias will take place in the following chapters.

5.4.1 Bone Identification and Recording[67]

5.4.1.1 Basic Information

Generally, all the bone fragments were associated with features (such as ash pits, tombs, wells, houses, layers) and identified by species, body part, and portion. Observation of taphonomic attrition and bone surface modification was done on all qualified specimens. All the results were recorded in a standardized excel database used by the Henan Institute of Cultural Relics and Archaeology, which was developed based on Meadow's BONECODE system (1978).

► Comparative samples and several bone catalogs

[67] The methods of bone retrieving in the field can be seen in previous studies of Xiaomintun, Zhougongmiao, and Guandimiao (Hou et al. 2019; Li 2009; Zhang 2012). Generally, animal remains from the three sites were all recovered through hand collection.

The whole Guandimiao collection was sorted and identified in the zooarchaeology lab using its comparative collections and several bone catalogs (e.g., Hillson 2016; Schmid 1972; Zeder and Lapham 2010; Zeder and Pilaar 2010), while the Xiaomintun and Zhougongmiao specimens relied mainly on the bone catalogs, as well as identified samples from the same site. All bone fragments were studied.

► Bone recovery

All the fragments were washed in water before recovery. Fragments of the same unit were examined together. According to condition of broken surface, these fragments were recorded as whole, old break (with an original broken surface and were broken before excavation), and new break (with a new broken surface that may be introduced during and/or after excavation). Fragments with old breaks were treated separately, while those which proved to be from the same animal individual or even the same element were noted in the database. Those newly broken fragments from the same element were put together, glued if necessary, and recorded as one piece in the database.

► Initial identification - Body parts

Considering stages of carcass processing and various bone attritions, all specimens were identified first to body parts and then to specific elements and portions. In the beginning, four anatomical groups are classified: (a) cranial skeletons – craniums, mandibles, loose teeth, and horns/antlers; (b) axial skeletons – vertebrae, ribs, sternum, as well as innominate and scapulae; (c) limbs – long bones and metapodials[68]; and (d) extremities – hand and foot bones; (e) while some unidentifiable fragments were recorded according to their textures and morphologies, as long

[68] These are elements with a marrow cavity. Although pig's metapodials are different in this sense, they are relatively easy to be identified even as fragments. Therefore, it is roughly reasonable to put metapodial fragments to the long-bone category.

bone fragments (including mainly small long bone and phalanx fragments), flat bone fragments (including fragments of cranial bones, mandibles, blade portions of scapulae, innominates, sternums, ribs, and vertebral laminae and apophyses), and articular bones/fragments with abundant spongy tissue (including carpals, tarsals, and sesamoids, as well as some epiphyseal fragments and unidentified cranial and vertebral bodies). In addition, quite a few very small fragments (<10 mm) were grouped together as unidentified.

► Elements and portions

Bone fragments were further identified to elements and then, portions. Element portions were described with information of side (right/left/medium), position (e.g., proximal/distal, medial/lateral), and completeness of the element/portion.

i. The portion of an element was identified according to the following rules: (a) Limb bones were divided into four parts: proximal and distal ends, and proximal and distal shafts, while one fragment may include one or several parts. (b) Scapulae were divided into two portions: proximal blade (those with acromion portions are specially recorded) and distal articular joint. (c) Innominates were divided into five portions: wing of ilium, shaft of ilium, acetabulum, ischium, and pubis. (d) Mandibles was as five portions (specifically for specimens of cattle and pigs): incisors-diastema, premolars, molars, mandibular angle, and rising ramus. (e) Maxillae were as two portions (specifically for specimens of cattle and pigs): premolars and molars (a few premaxilla fragments are included in the "cranial bone" category). (f) Vertebrae were divided into two portions: centrum and the dorsal parts. (g) Ribs were divided into two portions: head and body. These rules were mostly implemented in cattle and pig bone identification and were much simplified for other animals.

ii. Completeness was recorded for limb bone fragments. (a) The lengths of long bone fragments were measured as: complete, three-quarters, half, one-quarter, or less than one-quarter of a whole limb (some tiny breaks were accepted so long as the length evaluation hasn't been interrupted). (b) The completeness of the fragment was further recorded as: whole or portion for a bone end, and cylinder (with full circumference) or splinter for a bone shaft. (Note that several newly broken fragments were treated as one if they can be pieced together, while they were separately counted if they were with old fractures.)

► Animal species and size class

Most of the fragments were identified to species if possible or to size class, and almost all of them were counted (except those very small unidentified fragments, as mentioned in "Initial identification - Body parts" above). In consideration of commonly seen animal species in the three sites discussed, specimens attributed to large mammals and sizes were compared with domestic cattle, medium-size-1 mammals with medium dogs, domestic sheep, and small deer, medium-size-2 mammal with domestic pigs, domestic sheep, and sika deer, and small sized taxa smaller than medium dogs.

► Maximum length

Measurements were done on most specimens larger than 10 mm except fragments of antlers and horns and isolated teeth or teeth fragments. Among them fragments with a maximum dimension of or larger than 40 mm were measured with a ruler, while those within 10-40 mm range were taken roughly as one group. This is based on studies of bone grease extraction – breaking bones smaller than 40-50 mm does not improve efficiency of grease extraction (e.g., Church and Lyman 2003; Janzen et al. 2014; Outram 2005). The maximum length of a bone fragment, as well as the above description of the portion of an element, is an important factor for studying bone fragmentation.

► Age information

All information on age-stage evaluation, including dental eruption and wear, epiphyseal fusion, bone size and texture, were observed and recorded. When necessary, bone fragments were also recorded as infant, or juvenile, or adult. The main results can be found in the following publications (Hou et al. 2019; Li 2009; Zhang 2012).

► Other information

Other information, such as pathology, some hints of bone working and inscription, were also observed and recorded if any. Pathologies are few in number and are not further discussed in later chapters. Nevertheless, it shows the animals were in relatively good health with a stable animal raising environment (consistent with my argument in Chapter 4).

Observations of taphonomic attritions (including weathering and burning damages, and bone surface modifications mainly), bone fragmentation, and butchery marks are also done in the process of bone identification and database construction. They are discussed separately in the following section.

5.4.1.2 Taphonomic Observation

► Weathering and burning observation

For all the specimens with a maximum dimension of/larger than 40 mm, the degree of weathering was examined based on Blumenschine's six-level categories (1995) and burning marks[69] were recorded based on Meadow's nine-level categories (1978). Other traces, as plant-root etching and concretion, were kept in notes.

► Bone breakage and fragmentation

Information can be found in Section 5.4.1.1.

► Bone surface modification

Bone surface modifications, including mainly butchery and animal gnawing marks (caused mainly by dogs and rodents[70]), were only evaluated on specimens with the bone surface relatively well preserved. A strong light (60w), and sometimes a 10× hand lens when necessary, were used for observation (following Blumenschine et al. 1996). Marks were identified using the criteria outlined by Binford (1981: 105-106), Choi and Driwantoro (2007), Fisher (1995), Greenfield (1999, 2002), Lyman (1994: 190-215), Noe-Nygaard (1989), Seetah (2006), and West and Louys (2007)[71].

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69 Some fragments were darkened by mineral staining, especially in the Xiaomintun assemblage, which may bias the observation. However, it was not a severe problem in general.

70 However, it is not impossible that some gnawing marks were caused by other animals, such as human, pigs, deer, most of which are similar to dogs' or rodents' gnawing marks (e.g., Brothwell 1976; Domínguez-Solera and Domínguez-Rodrigo 2009; Saladié et al. 2013). Most of these gnawing marks may be mistaken for dog's chewing marks. However, this cannot be a big enough issue to affect the later understanding of human activities.

71 Fisher (1995) gives clear descriptions and typical drawings of various marks (of both human- and unhuman-attrite), while Binford (1981) and Lyman (1994a) add many clear images of examples (especially those of chewing marks) from archaeological sites and detailed explanation, in addition. Binford (1981: 105-106) distinguishes the macro-morphologies of marks on bones left by stone and metal tools, while Greenfield (1999, 2002) is one main researcher to use SEM to separate the two types of marks. Noe-Nygaard (1989) connects five types of butchery marks with butchery practice and shows clear figures of impacts on animal bones. Seetah (2006) classifies, assesses, and interprets butchery marks based on modern butchery activities, which are caused by metal tools. Choi and Driwantoro (2007) describes the morphology of cut marks generated by shells, and West and Louys (2007) reports the morphology of cut marks by bamboo tools.

I also consulted Dr. Zhang Yue 張樂, who is a specialist in the study of early human behavior and zooarchaeology in the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), the Chinese Academy of Sciences (CAS), for help when necessary.

5.4.1.3 Butchery Marks

► Types of butchery marks

Five types of butchery marks were defined for the convenient discussion of the actual function and intentions of the butcher: cut marks, chop marks, scoop marks, and shear marks (Figure 5.1)[72]. (a) Cut marks are generally straight, narrow, incised lines, which can be caused by stone, metal, and even shell knives. (b) Chop marks are similar to but wider than cut marks, which may be the result of some heavy tools, such as cleavers and axes. (c) Scoop marks are defined following Seetah (2006: 128-129). A shallow layer of surface bone has been removed, indicating the insertion of a blade along the length of the bone. (d) Shear marks are defined by Crader (1984: 547) and focus on the breakage surface of bones. They "are straight-walled planar surfaces where the bone has been split apart, probably by a powerful blow with a cleaver or ax-like implement". When both cut and chop marks can indicate the activities of the separation of joints or meat removal, scoop marks can more clearly indicate the butcher's purpose to try to "remove small remnants of meat, or to detach a portion of muscle from a particularly tight attachment to the bone" (Seetah 2006: 128), and shear marks, as well as chop marks, can suggest the purpose of carcass disarticulation (separating joints or splitting of bones) and/or bone fragmentation during culinary processing for marrow extraction or for pot-sizing[73]. To identify these marks, both morphological characteristics and the redundancy and purposiveness criteria have to be considered (Lyman

[72] A few specimens also displayed evidence of blows from or against blunt objects on the fracture surface of the bone (not the bone surface), but these are difficult to detect and interpret. For this reason, such marks are not included in the following calculation and discussion.

It is true that sometimes traces may be left on bones even in the process of food consumption. However, it is generally believed that such marks caused by consumption is rare, since, once boiled or steamed, the cooked meat can be rather soft to be moved off the bone (Russell and Martin 2005). So, unless mentioned specifically, it is assumed that all the tool marks are related to the various activities of carcass processing before consumption.

[73] Shear marks can generally be included in chop marks (e.g., Seetah 2006). It is separately listed in my study to emphasize the purpose of bone dismemberment.

1987:260-270). The recording of butchery marks and some other bone modifications were realized by drawing the individual butchery marks/modifications on a set of whole-bone templates and, in order to show the frequencies, locations, orientations of marks/modifications, a composite drawing of marks on each element will be presented in the dissertation. I mainly used the bone templates published by Popkin (2005)[74]. Some specimens have also been photographed.

► Quantification of butchery marks

As mentioned above, the process of butchering an animal for storage or consumption is usually composed of slaughtering, skinning, disarticulation, filleting, fragmentation, and grease and marrow extraction (Binford, 1981: 106; Lyman 1987). Some scholars have summarized patterns of various butchery marks (including frequencies, locations, orientations, and morphologies of marks) which correspond to different activities and steps of butchery (e.g., Binford 1981; Bunn 2001; Galán and Domínguez-Rodrigo 2013; Landon 1996; Nilssen 2000; also see Table 5.2). The development of these patterns is based on a general assumption that the repeated appearance of butchery marks within a skeleton portion and an anatomical reason for the marks arenecessary to identify a butchery pattern (Reitz and Wing 2008: 126-127). Although butchery marks of different functions may be overlapped in one location and the final presence of butchery marks in certain location can be affected by many factors, this assumption is correct in a general sense. Therefore, I will make an effort to explain the function of some typical butchery marks in certain locations and to describe the pattern of animal butchery by referring to a previous

[74] Popkin's templates are drawn based on a goat skeleton, and he has argued that the templates can be used for artiodactyl species such as sheep, goats, cattle and deer that have similar skeletal morphologies. I have also used most of the templates (mainly those of long bones, general vertebrae, ribs, and innominate) to record marks of pigs, since many pig bones are roughly similar to those of other artiodactyl species and Popkin's templates are usable, while some new templates of pigs (those of cranial bones, mandibles, atlas, and axis) are made based on drawings of an unpublished work (IACASS Unpublished).

study by Binford (1981: 87-181), with supplemental consideration of the works of Galán and Domínguez-Rodrigo (2013), Landon (1996), Nilssen (2000)[75]. Some regular patterns can be expected. Marks of skinning and tendon removal may appear on distal ends of radius and tibia, metapodials or phalanges and they should also be on the cranial bones and mandibles. During the stage of disarticulation, butchery marks are usually clustered on/near joints of elements, such as long bone ends. Filleting usually happens in the stage of secondary butchery and should be common on the bone shafts. Bone fragmentation may sometimes be confirmed directly by a tool-inflicted flat sheared fracture surface and/or chop marks near the fracture surface. On the other hand, a lack of butchery marks in some expected locations can also indicate information such as the situation of carcass during butchery and the special butchery purpose. Finally, in order to calculate the frequency of different types of butchery marks, butchery marks are calculated based on fragments(following Domínguez-Rodrigo and Yravedra 2009, Egeland 2003, Lyman 2005). That is, for a certain type of butchery marks, it is calculated as “1” when shown on a specimen no matter how densely scattered the marks are on the bone surface.

[75] Nilssen’s (2000) and Galán et al.’s (2013) works are based on Binford’s early study (1981), and all the three mainly pay attention to herbivores. Landon’s (1996) study mentions pigs as well which is also partly based on Binford (1981).

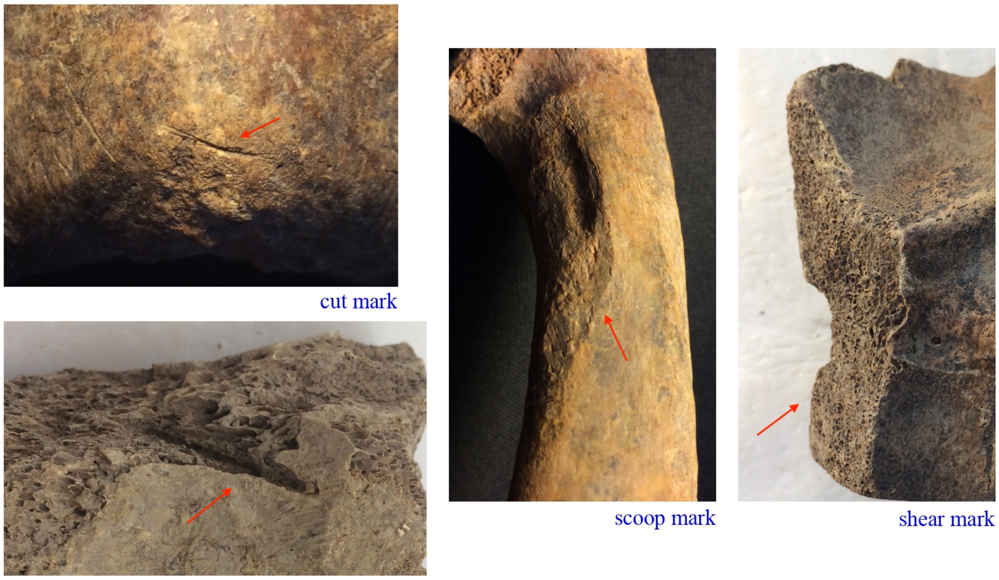

Figure 5.1 Examples of typical butchery marks

5.4.2 Bone Quantification

Three types of measurement are mainly used in this dissertation to represent the relative frequencies of animals and skeletal elements. They are mentioned in this dissertation for the evaluation of taphonomic, recovery and sampling biases, and the analysis of anthropogenic bone modification.

► The number of identified specimens (NISP)

This is primary data. To be considered identified, the specimen needed to be identified to element and at least mammal size category. This measure is widely used in all the analytical steps, and, especially, is the basis of bone fragmentation and butchery mark studies. At the same time, NISP can be greatly affected by various forms of taphonomic attrition (refer to Reitz and Wing 2008: 202-205 for a summary), for which reason the validity and limitation of a selected subset of animal remains will be discussed repeatedly in the following chapters.

► The minimum number of elements (MNE)

It is the basis for an estimate of the relative abundance of different body parts. I follow Lyman (1994b).

► Ratios of Observed to Expected Specimens

This is as a measure of the degree of skeletal completeness. The ratio of certain element represented is calculated against an expected number of this element. The calculation can be done in different ways (refer to Reitz and Wing 2008: 219-224 for a summary). In this dissertation, the expected value is based on anatomical relationships – that is, assuming the skeletons (based on MNI) were all complete, the totally expected number of certain element is calculated.

5.4.3 Measurement of *Li* Tripods

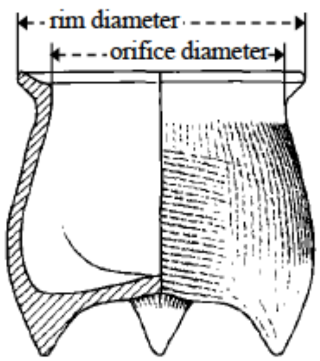

Figure 5.2 Drawing of a li tripod[76]

Both whole *li* and *li* sherds (which keep ≧1/3 of the whole rim and can be used to reconstruct the whole rim) are included. Rim and orifice diameters of *li* tripods are measured in a way as shown in Figure 5.2. The rim diameter of a *li* is usually close to the maximum width of the body (in the middle of a vessel) and the maximum height of the tripod and so indicates the capacity of the tripod, which refers to the maximum dimension of food for cooking; while the orifice diameter represents the actual openness of a tripod, which has impact on the efficiency of placing food into the pot (Reinhart 2011: 112). I have done most of the measurements used in the

[76] This is drawn based on a recovered *li* from Guandimiao, Li et al., 2008b, Fig 15:6.

dissertation while He Yulin in the Anyang Workstation of the Institute of Archaeology in the Chinese Academy of Social Sciences also kindly shared some unpublished data for my use.

CHAPTER 6: Guandimiao: Assemblage Composition and Taphonomic Study

This chapter is an extension of the published Guandimiao zooarchaeological report (Hou et al. 2019) on two topics – assemblage composition and taphonomy, and the discussion here focuses on a subset of bone remains from domestic contexts. Some information concerning size and overall composition of the domestic assemblage is introduced first as a supplement of the report, in preparation for analyses which will follow. Compared with the published report, more details on mammal taxa and skeletal elements are given in this chapter. After this, forms of taphonomic attrition are discussed. Taphonomic issues are emphasized at various points in this dissertation for different purposes. In this chapter, the discussion concentrates on bone destruction during taphonomic processes as a whole and after trash disposal in ancient times – that is, peri-depositional bone damage caused by diverse agents and bone attrition related to bone retrieval during and after field excavation. The frequencies of cattle, pig, and dog skeletal elements and portions are analyzed in the process and are continued to be mentioned in later chapters.

6.1 Size and Overall Composition of the Assemblage in Domestic Contexts

The whole Guandimiao archaeofaunal assemblage are composed of animal remains from three types of deposition: ritual, mortuary, and domestic remains (Hou et al. 2019). The animal assemblage of domestic use (Table 6.1) is from 432 units of diverse contexts, including 387 ash pits, 9 houses, 5 ditches, 15 wells, 8 kilns, and 8 layers. In most cases, there was only a small number of fragments in one unit, and the number of fragments from those non-pit contexts were even smaller. However, on account of the high level of $\delta^{15}N$ value (see Chapter 4 for details) and the intense animal attrition (mainly caused by dog gnawing, as discussed later in this chapter), it seems that archaeologically recovered animal remains may not reflect the scale of residents' meat consumption.

As has been discussed in the published report and in Chapter 4, the assemblage of domestic use is dominated by farm animals, especially cattle, pigs, and dogs (Table 6.1). In addition, there are wide discrepancies in NISP percentages between cattle and horses, and between pigs, sheep/goats and deer. For this reason, it can be assumed that almost all the bone remains identified only as large-sized mammals are of cattle bones and most fragments of medium-sized mammals should be pig bones. Based on available specimens, the age profiles of cattle and pigs in domestic contexts are close to those of the overall Guandimiao assemblage. As shown in the published report, based on teeth eruption and wear and epiphyseal fusion, cattle of different age stages were culled gradually but with two small peaks in 1.5-2 years (young) and after adult age (roughly after 4-6 years), while the distribution of pigs' age profile is more even from neonatal to old aged (8 years or older) categories. In the domestic subset, judged by size and texture of bones as well as epiphyseal fusion, there are only 26 bone fragments of very young cattle (infantile), 29 fragments of neonatal pigs and 73 fragments of very young pigs (infantile)[77]. The mortality profiles of dogs,

[77] Bone fragments of very young individuals are identified mainly based on bone size. These fragments are obviously smaller than the regular size of subadult and adult skeletons and with the markedly porous surface structure. For cattle, there are pelvis with unfused acetabulum, radius and first phalanx with their proximal epiphyses unfused, humerus and tibia with their distal epiphysis unfused. Judged by the stage of epiphyseal fusion, these fragments are from cattle of mostly less than one year old (based on a system for the construction of harvest profiles of cattle based on epiphyseal fusion raised by Silver 1969). For pigs, some fragments are very small which can be comparable to those of neonatal piglets seen in the modern bone collection of the Henan Institute of Cultural Relics and Archaeology, indicating these fragments are very likely from pigs of 0-1 months. Some bone fragments of pigs are larger than those of neonatal piglets, but smaller than those of sub-adult and adult individuals and with most main epiphyses unfused, which indicate these fragments may represent pigs of less than eight-months old (based on a system for the construction of harvest profiles of pigs based on epiphyseal fusion raised by Zeder et al. 2015). This is not a strict classification but is useful to help understand the rough amount of bone fragments of those very young (and small) individuals, which is meaningful for an estimation of the social scale of meat consumption (also see Halstead's model in Chapter 5 and a related discussion on Guandimiao in Chapter 8).

sheep/goats, and deer are not studied in detail, but the domestic assemblage includes only 14 fragments of young sheep/goats and 4 fragments of young dogs. However, we should be cautious that the age profiles could have been strongly biased towards older individuals or larger taxa (cattle, especially, and pigs when compared to dogs) (Lam et al. 2010). (This has been discussed in the report and more details are given in the following sections).

Table 6.1 Size and composition of the Guandimiao assemblage in domestic contexts

	NISP (NSP)			Weight			MNI		
	No.	N (%)a	N (%)b	W (g)	W (%)a	W (%)b	MNI	MNI (%)a	MNI (%)b
Cattle	886	65.53%	17.00%	85477	87.36%	52.61%	34	97.14%	15.04%
Horses	3	0.22%	0.06%	110	0.11%	0.07%	1	2.86%	0.44%
Large sized	463	34.25%	8.88%	12261	12.53%	7.55%	-	-	-
Total large sized	**1352**	**100.00%**	**25.94%**	**97848**	**100.00%**	**60.23%**	**35**	**100.00%**	**15.49%**
Pigs	1269	58.00%	24.35%	46422	76.05%	28.57%	118	62.43%	52.21%
Dogs	299	13.67%	5.74%	5030	8.24%	3.10%	51	26.98%	22.57%
Sheep/goat	103	4.71%	1.98%	2327	3.81%	1.43%	9	4.76%	3.98%
deer	95	4.34%	1.82%	4408	7.22%	2.71%	11	5.82%	4.87%
Medium sized 1	70	3.20%	1.34%	232	0.38%	0.14%	-	-	-
Medium sized 2	163	7.45%	3.13%	1417	2.32%	0.87%	-	-	-
Medium sized _Unidentified*	189	8.64%	3.63%	1205	1.97%	0.74%	-	-	-
Total medium sized	**2188**	**100.00%**	**41.98%**	**61040**	**100.00%**	**37.57%**	**189**	**100.00%**	**83.63%**
Rabbits	4	-	-	0	-	-	1	-	-
Rats	1	-	-	0	-	-	1	-	-
Small sized	2	-	-	6	-	-	-	-	-
Total small sized	**7**	**-**	**0.13%**	**6**	**-**	**0.00%**	**2**	**-**	**0.88%**
Medium-Large _Unidentified*	195	-	3.74%	2262	-	1.39%	-	-	-
Unidentified debris**	1470	-	28.20%	1311	-	0.81%	-	-	-
TOTAL	**5212**	**-**	**100.00%**	**162467**	**-**	**100.00%**	**226**	**-**	**100.00%**

Key: NSP = Number of specimens, NISP = Number of identified specimens;
(%)a = (the number of specimens) / (the number of certain sub-size group) × 100%;
(%)b = (the number of specimens) / (the number of the total assemblage) × 100%.
* Medium sized _Unidentified = specimens can only be identified to the medium-size category; Medium-Large _Unidentified = specimens which hold a possibility to be from either medium or large mammals, but cannot be decided.

** Unidentified debris are mainly those extremely tiny bone fragments. The calculation of the debris is not as serious as other specimens but offers a general idea.
Notice: Cattle's MNI=34, not 29 as has reported (Hou et al. 2019). The miscalculation is corrected here, but it does not affect any argument in the previous report.

Table 6.2 Taxon and Element distribution of the Guandimiao assemblage in domestic contexts

	Cattle		Pigs		Dogs		Sheep/goats		Deer	
	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE
TEMP	-	-	64	64	13	13	2	2	2	2
MAX	20	18	109	104	24	24	1	1		
CRANI.FR	26	-	59	-	3	0	1	-		
MAN	74	34	327	231	92	85	16	15	11	11
ATLAS	11	11	31	31	7	7	1	-	1	1
AXIS	11	11	5	5	2	2				
CERV*	18	18	6	6	2	2				
THOR	3	3	19	19	1	1				
LUMB	2	2	26	26	1	1	2	2		
SACR	3	3	1	1	1	1				
VER.FR	7	-	5	-						
RIB.FR	27	-	45	-	1	-				
SCAP	17	-	52	42	5	4	2	2	4	4
INNO	25	12	49	42	7	6	2	1	1	1
HUMER	68	53	105	85	13	10	4	4	3	3
RAD	74	52	29	23	13	12	9	8	8	6
ULNA	35	26	37	34	17	16			3	3
FEMUR	65	31	45	29	14	13	5	5	1	1
TIBIA	48	30	74	52	17	15	16	14	5	4
MP3+4	76	41	23	23	13	13	17	12	22	16
CALC	30	30	14	14	2	2			3	3
TALUS	19	19	2	2						
PH1	42	42	2	2			1	1	1	1
PH2	23	23								
PH3	19	19	1	1						
Other	131	-	83	0	18	-	35	-	31	-
Total	886	478	1269	836	299	227	103	67	95	56
MNE/NISP	0.55		0.69		0.85		0.59		0.58	

Key:
Note: MNE of an element is represented by MNE of the most abundance portion of this element (the data of cattle, pigs and dogs also seen in Table 6.7, Table 6.8 and Table 6.9, under the field MNE1).
* CERV = 5 cervical vertebrae after atlas and axis.

Table 6.3 Anatomical units of the unidentified fragments in the Guandimiao assemblage of domestic contexts

	Medium 1	Medium 2	Medium _Unidentified	Large	Medium-Large _Unidentified
Cranial	3	21	33	70	48
Axial	42	56	15	89	28
Limb	24	79	125	285	62
Extremities			1	0	0
Unknown	1	7	15	19	57
TOTAL	70	163	189	463	195

Table 6.2 and Table 6.3 offer detailed presentation of body part distribution. In Table 6.2, the MNE value of an element equals to that of the most represented portion of this element (see Chapter 5). The ratio of MNE/NISP presents a very primitive measure of completeness of elements, because for a certain number of elements (with a stable MNE value) the value of NISP would become larger with a higher degree of fragmentation. This ratio is 0.55 for cattle, 0.69 for pigs, 0.85 for dogs, 0.59 for sheep/goats, and 0.58 for deer. The relatively high MNE/NISP ratio of dogs shows less specimens are discounted for dog than for other animals. This can be interpreted as dogs' elements are better preserved than others'. It also fits my observation that many dog' mandibles and some limb bones and cranial bones are wholly preserved (which can also be confirmed by detailed calculation of the frequencies of long bone portions in Table 6.9). However, the great discrepancy between NISP and MNE implies a high degree of bone fragmentation in general. Anatomical units shown in Table 6.3 are taken as a supplement of discussions on various issues related to cattle and pigs in this dissertation.

6.2 Destructive Taphonomic Processes (after human discard)

It is mentioned briefly in the Guandimiao report (Hou et al. 2019) that taphonomic processes may have caused severe impact on the animal assemblage, and, as a result, the accuracy of archaeofaunal remains in reflecting past human practices has been weakened significantly. In this section, I trace backwards various sources of taphonomic attritions after meat and grease were consumed and bones were discarded by humans. Analyses and discussions are made in the unit of domestic assemblage as a whole or based on comparisons of the three most common animals (cattle, pigs, and dogs, which are representatives of animals of different body sizes).

6.2.1 Recovery: Bone Collection and Curation

All the Guandimiao assemblage was hand collected in the field, washed in water, held in plastic bags, stored in large boxes, and recovered in the lab. The assemblage is relatively well stored and recovered (see Chapter 5) so that field excavation and bone collection process are expected to have introduced the most biases. Their effects are assessed by comparing the fragment dimensions, different preservations of adjacent large and small bones/portions, and variant conditions of broken surfaces.

6.2.1.1 Assessment of the Impact of Hand Collection

The pattern of specimen size distribution is examined by the range of maximum length (Table 6.4, Chart 6.1). 4463 fragments are included in total[78]. Almost all the specimens of <10 mm in length are unidentified debris, many of which appear to be from new breaks, suggesting they possibly fell off of some larger fragments recently (during or after excavation). Specimens in the range of 10-40 mm make up a relatively small portion. Among them, only one rodent limb bone is found along with a few suspected fragments -- this number is too small to be proportionate to the many rodent gnawed fragments and indicates the bias of hand collection.

[78] The length of teeth, horns/antlers, and worked-bone fragments (about 400 pieces) were not measured; specimens from 3 ash pits (about 50 pieces) were not measured; and another about 250 fragments with new breaks were not measured, most of which are sure to be longer than 40 mm.

Table 6.4 Specimen size (mm) distribution (calculated by NISP)

Maximum length (mm)	Identified (to taxon)		Unidentified		Total	
0-9	1	0.05%	1208	52.09%	1209	27.09%
10-39	156	7.28%	474	20.44%	630	14.12%
40-59	414	19.31%	184	7.93%	598	13.40%
60-79	476	22.20%	191	8.24%	667	14.95%
80-99	326	15.21%	121	5.22%	447	10.02%
100-119	261	12.17%	82	3.54%	343	7.69%
120-139	208	9.70%	31	1.34%	239	5.36%
140-159	115	5.36%	14	0.60%	129	2.89%
160-179	63	2.94%	10	0.43%	73	1.64%
180-199	36	1.68%	1	0.04%	37	0.83%
200-239	42	1.96%	2	0.09%	44	0.99%
240+	46	2.15%	1	0.04%	47	1.05%
SUM	2144	100.00%	2319	100.00%	4463	100.00%

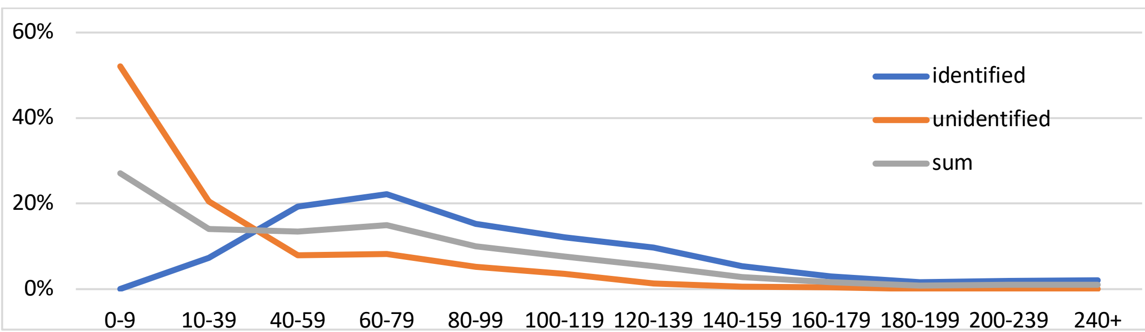

Chart 6.1 Specimen size (mm) distribution _ calculated by NISP

The frequencies of adjacent small compact bones and large limb bone (or portions) are shown in Table 6.5, with fragments of neonatal and very young individuals excluded (to avoid equifinality caused by differentiated bone destructions based on ages). For cattle, in each group, frequencies of large elements and portions are mostly even, while small compact bones are less represented. For pigs and dogs, large elements and portions are also better represented than small elements in general, and those small compact bones are even less seen. This cannot be owing to destruction process or body part transport only. Thus, it is not illogical to argue that many fragments of around and smaller than 40-50 mm (which is close to the length of a second or third phalanx of cattle or a metapodial of pig) are missing from excavation, which is consistent with the trend shown in Chart 6.1. It is obvious that the collection is not only incomplete but also biased, and that, compared to cattle bones, medium sized mammal fragments are more strongly underrepresented (Hou et al. 2019). This should have affected bone recovery and study in some way.

Table 6.5 Frequencies of adjacent large and small elements/portions

	Cattle		Pigs		Dogs	
Anatomical unit	MNE	Standardized	MNE	Standardized	MNE	Standardized
RAD-04	23	11.5	5	2.5	8	4
CARPL	15	2.5	0	-	0	-
MC	18	9	13	3.25	0	-
TIBIA-04	29	14.5	26	13	9	4.5
TALUS	21	10.5	2	1	2	1
CALC	32	16	11	5.5	2	1
MT	21	10.5	9	2.25	0	-
MP*	34	8.5	22	2.75	13	6.5
PH1	42	5.25	4	0.5	0	-
PH2	23	2.875	0	-	0	-
PH3	15	1.875	0	-	0	-

Key: CALC = calcaneum, CARPL = carpal, RAD = radius, MC = metacarpal 3+4 (proximal end, for cattle) or metacarpal 3/4 (for pigs) or metacarpal 2/3/4/5 (for dogs), MP = metacarpal/metatarsal 3+4 (distal end, for cattle) or metacarpal/metatarsal 3/4 (for pigs) or metacarpal/metatarsal 2/3/4/5 (for dogs), MT = metatarsal 3+4 (proximal end, for cattle) or metatarsal 3/4 (for pigs) or metacarpal 2/3/4/5 (for dogs), PH1 = phalanx 1, PH2 = phalanx 2, PH3 = phalanx 3, TALUS = talus, TIBIA-04 = tibia (distal end).
Note: The value of MNE is standardized by the anatomical number of elements/portions in a whole skeleton, so that, in each group, the expected ratio of any elements/portions compared is 1:1. A similar calculation can be found in Table 6.8, Table 6.9, Table 6.10. The values of MNEs happen to equal to those of NISPs for the selected elements/portions.

6.2.1.2 Assessment of the Impact of Bone Breakage During and After Excavation

For measured fragments (Table 6.4), the impact of bone breakage during and after excavation is represented by the percentage of recently damaged fragments (see Table 6.6). More than 65% of the total bones exhibit new break surfaces, and more than 28% are seriously broken with the original ends/break surface(s) destroyed. This calculation suggests that bone damage during and after excavation was rather extensive. Moreover, identified species are more intensively broken during this process than the unidentified fragments, which is reasonable since larger fragments on average are easier to identify than smaller pieces while they also hold a higher possibility than smaller fragments of being damaged during excavation and broken (see Table 6.4). This could also have inflicted significant negative impact on the studies below. Ideally, the completeness of elements is a marker of bone use. In addition, the highest probability of fining anthropogenic bone breaks (e.g., tool marks, characteristic bone morphology, special patterns of bone breakage) is in the location around the original bone ends or break surfaces. Modern damage could have had a large negative impact on these analyses.

Table 6.6 Fragments of modern damage (calculated by NISP)

	identified	unidentified	SUM
Modern damage	1527	610	2137
Serious modern damage	699	214	913
Total[1]	2144	1111	3255
Modern damage (%)[2]	71.22%	54.91%	65.65%
Serious modern damage (%)[3]	32.60%	19.26%	28.05%

[1] The dataset is the same as that mentioned in Table 6.4, with all the identified specimens (2144 pieces) and most part of the unidentified specimens (1111 pieces, excluding those debris of <10 mm) examined.
[2] Modern damage (%) = (fragments with modern damage) / (the total of identified or unidentified or both fragments) × 100%, with "fragments with modern damage" defined as fragments that have portions/all original surfaces erased because of modern damage.
[3] Serious modern damage (%) = (fragments with serious modern damage) / (the total of identified or unidentified or both group fragments) × 100%, with "fragments with serious modern damage" defined as fragments that have lost at least one original end/break surface because of modern human activities and the original length at the same time.

To summarize, the above analyses confirm that the process of field excavation and hand collection, as well as further curation steps, have generated obvious biases in the original archaeofaunal assemblage at Guandimiao. Compared to large elements and large fragments, many small elements and fragments, especially those in the unidentified subsets, are missing. This should have a greater impact on smaller species (mainly pigs and dogs) and younger individuals than larger species and individuals (mainly cattle). On the other hand, large bone specimens may also have suffered from intensive modern damage.

6.2.2 Frequencies of Skeletal Element/sPortions and Density-mediated Attrition

Table 6.7 Frequencies of cattle skeletal elements in Guandimiao domestic assemblage (excluding specimens of very young individuals)

Element	NISP	MNE-1	Percentage survival	Portion	MNE-2	Percentage survival
MAX	19	17	28.33%	MAX	17	28.33%
CRANI.FR	26	-	-	-	-	-
MAN	74	34	56.67%	MAN-01	34	56.67%
				MAN-02	18	30.00%
				MAN-03	27	45.00%
				MAN-04	25	41.67%
				MAN-05	18	30.00%
ATLAS	10	10	33.33%	ATLAS	10	33.33%
AXIS	11	11	36.67%	AXIS	11	36.67%
CERV	18	18	12.00%	CERV	15	7.14%
THOR	3	3	0.83%	THOR	3	0.83%
LUMB	2	2	1.33%	LUMB	2	1.33%
SACR	3	3	2.00%	SACR	4	2.67%
CAUD	0	0	0.00%	CAUD	0	0.00%
VER.FR	7	-	-	-	-	-
RIB.FR	27	-	-	-	-	-
SCAP	16	9	15.00%	SCAP-01	0	0.00%
				SCAP-02	9	15.00%
INNO	22	11	18.33%	INNO-01	1	1.67%
				INNO-02	3	5.00%
				INNO-03	11	18.33%
				INNO-04	3	5.00%
				INNO-05	6	10.00%
HUMER	63	48	80.00%	HUMER-01	9	15.00%
				HUMER-02	21	35.00%
				HUMER-03	48	80.00%
				HUMER-04	38	63.33%
RAD	70	48	80.00%	RAD-01	42	70.00%
				RAD-02	48	80.00%
				RAD-03	28	46.67%
				RAD-04	23	38.33%

ULNA	35	26	43.33%	ULNA-01	3	5.00%
				ULNA-02	24	40.00%
				ULNA-03	26	43.33%
				ULNA-04	-	-
FEMUR	64	30	50.00%	FEMUR-01	15	25.00%
				FEMUR-02	14	23.33%
				FEMUR-03	30	50.00%
				FEMUR-04	13	21.67%
TIBIA	47	29	48.33%	TIBIA-01	11	18.33%
				TIBIA-02	21	35.00%
				TIBIA-03	29	48.33%
				TIBIA-04	29	48.33%
MP3+4	75	40	33.33%	MP3+4-01	40	33.33%
				MP3+4-02	39	32.50%
				MP3+4-03	39	32.50%
				MP3+4-04	34	28.33%
CALC	30	30	50.00%	CALC	30	50.00%
TALUS	19	19	31.67%	TALUS	19	31.67%
PH1	41	41	17.08%	PH1	41	17.08%
PH2	23	23	9.58%	PH2	23	9.58%
PH3	15	15	6.25%	PH3	15	6.25%

Note: MNE-1 is for whole elements and MNE-2 is for elements divided into proportions as described in chapter 5.

Table 6.8 Frequencies of pig skeletal elements _Guandimiao domestic assemblage (excluding specimens of very young individuals)

Element	NISP	MNE-1	Percentage survival	Portion	MNE-2	Percentage survival
TEMP	58	60	28.85%	TEMP	60	28.85%
MAX	98	95	45.67%	MAX-01	95	45.67%
				MAX-02	6	2.88%
CRANI.FR	54	-	-	-	-	-
MAN	293	203	97.60%	MAN-01	46	22.12%
				MAN-02	115	55.29%
				MAN-03	203	97.60%
				MAN-04	123	59.13%
				MAN-05	112	53.85%
ATLAS	31	31	29.81%	ATLAS	31	29.81%
AXIS	4	4	3.85%	AXIS	4	3.85%
CERV	6	6	1.15%	CERV	6	1.15%

THOR	19	19	1.22%	THOR	19	1.22%
LUMB	26	26	3.57%	LUMB	26	3.57%
SACR	1	1	0.24%	SACR	1	0.24%
CAUD	0	0	0.00%	CAUD	0	0.00%
VER.FR	1	-	-	-	-	-
RIB.FR	45	-	-	-	-	-
SCAP	43	34	16.35%	SCAP-01	21	10.10%
				SCAP-02	34	16.35%
INNO	45	31	14.90%	INNO-01	6	2.88%
				INNO-02	16	7.69%
				INNO-03	31	14.90%
				INNO-04	21	10.10%
				INNO-05	3	1.44%
HUMER	92	79	37.98%	HUMER-01	6	2.88%
				HUMER-02	28	13.46%
				HUMER-03	79	37.98%
				HUMER-04	41	19.71%
RAD	27	21	10.10%	RAD-01	20	9.62%
				RAD-02	21	10.10%
				RAD-03	14	6.73%
				RAD-04	5	2.40%
ULNA	34	31	14.90%	ULNA-01	2	0.96%
				ULNA-02	26	12.50%
				ULNA-03	31	14.90%
				ULNA-04	0	0.00%
FEMUR	38	24	11.54%	FEMUR-01	4	1.92%
				FEMUR-02	14	6.73%
				FEMUR-03	24	11.54%
				FEMUR-04	12	5.77%
TIBIA	68	46	22.12%	TIBIA-01	10	4.81%
				TIBIA-02	44	21.15%
				TIBIA-03	46	22.12%
				TIBIA-04	26	12.50%
MP3/4	22	22	2.64%	MP3/4	0	0.00%
CALC	11	11	5.29%	CALC	11	5.29%
TALUS	2	2	0.96%	TALUS	2	0.96%
PH1	2	2	0.24%	PH1	2	0.24%
PH2	0	0	0.00%	PH2	0	0.00%
PH3	0	0	0.00%	PH3	0	0.00%

Note: MNE-1 is for whole elements and MNE-2 is for elements divided into proportions as described in chapter 5.

Table 6.9 Frequencies of dog skeletal elements _Guandimiao domestic assemblage (including all the specimens)

Element	NISP	MNE-1	Percentage survival	Portion	MNE-2	Percentage survival
TEMP	13	13	13.0%	TEMP	13	13.0%
MAX	24	24	24.0%	MAX	24	24.0%
CRANI.FR	3		-	-	-	-
MAN	92	85	85.0%	MAN-01	85	85.0%
				MAN-02	50	50.0%
				MAN-03	22	22.0%
ATLAS	7	7	14.0%	ATLAS	7	14.0%
AXIS	2	2	4.0%	AXIS	2	4.0%
CERV	2	2	0.8%	CERV	2	0.8%
THOR	1	1	0.2%	THOR	1	0.2%
LUMB	1	1	0.3%	LUMB	1	0.3%
SACR	1	1	2.0%	SACR	1	2.0%
CAUD	0	0	0.0%	CAUD	0	0.0%
VER.FR	0		-	-	-	-
RIB.FR	1		-	-	-	-
SCAP	5	4	4.0%	SCAP-01	4	4.0%
INNO	7	6	6.0%	INNO-03	6	6.0%
HUMER	13	10	10.0%	HUMER-01	6	6.0%
				HUMER-02	9	9.0%
				HUMER-03	10	10.0%
				HUMER-04	6	6.0%
RAD	13	12	12.0%	RAD-01	8	8.0%
				RAD-02	9	9.0%
				RAD-03	12	12.0%
				RAD-04	8	8.0%
ULNA	17	16	16.0%	ULNA-01	10	10.0%
				ULNA-02	16	16.0%
				ULNA-03	12	12.0%
				ULNA-04	2	2.0%
FEMUR	14	13	13.0%	FEMUR-01	6	6.0%
				FEMUR-02	10	10.0%
				FEMUR-03	13	13.0%
				FEMUR-04	8	8.0%

TIBIA	17	15	15.0%	TIBIA-01	5	5.0%
				TIBIA-02	11	11.0%
				TIBIA-03	15	15.0%
				TIBIA-04	9	9.0%
MP2/3/4/5	13	13	1.6%	MP2/3/4/5	13	1.6%
CALC	2	2	2.0%	CALC	2	2.0%
TALUS	0		-	-	-	-
PH1	0		-	-	-	-
PH2	0		-	-	-	-
PH3	0		-	-	-	-

Note: MNE-1 is for whole elements and MNE-2 is for elements divided into proportions as described in chapter 5.

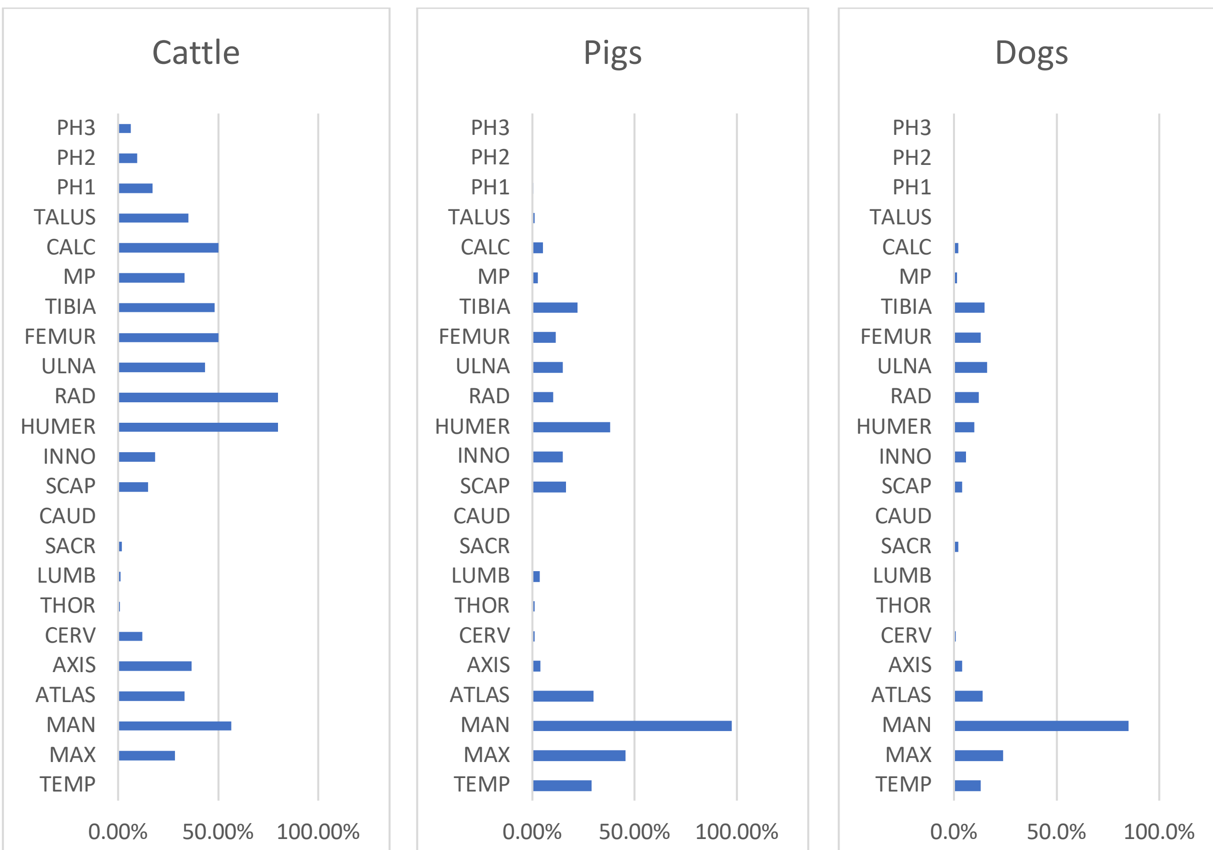

Chart 6.2 Frequencies of cattle, pig, and dog skeletal elements _Guandimiao domestic assemblage

The relative abundance of body parts for cattle, pigs, and dogs (Table 6.7, Table 6.8, Table 6.9, and Chart 6.2) can be an indicator of density-mediated attrition. Because of reasons mentioned in Chapter 5, detailed discussion on frequencies of skeletal elements in this section mainly refer to elements with relatively high density (cranial bones and limb bones) and large bone size which survived diverse forms of taphonomic damage. The degree to which elements of high density are better represented is remarkable (clearly shown in Chart 6.2). That is to say, the degree of bone destruction is strongly inversely correlated with element density. As has mentioned in the report (Hou et al. 2019), for cattle, the main elements are evenly distributed, which can be interpreted as meaning that cattle bones are the most robust in resisting various forms of attrition. The pattern of body part distribution of cattle matches the density mediated attrition model. For pigs and dogs, the abundance of mandibles is overwhelmingly higher than that of any postcranial element. Similar trends can roughly be found in sheep/goats and deer elements (see Table 6.2 for unstandardized data). Mandibles are among the densest elements and usually the most commonly preserved elements. Modern damage during and after field excavation may also have lowered the abundance of long bones. For these reasons and referring to the result of pig's age profile study (see Hou 2019 and discussed above), as regards smaller animals, even though the possibility of bone deletion or transport of certain individuals or body parts by other agents cannot be excluded, density-mediated attrition is still the primary factor for bone loss in the assemblage. In terms of the completeness of a skeleton, it is higher in cattle, and much lower in smaller animals.

At the same time, the degree of density mediated attrition on individual elements can be further studied by evaluating the intensity of long bone end attrition. The different frequencies of long bone ends and shafts are clearly shown in Table 6.7, Table 6.8, and Table 6.9. In addition, a more direct expression of density mediated attrition is the percentage of long bone end attrition. With four limb bones (humerus, radius, femur, tibia) together, the percentages of long bone end attrition are calculated as: 41.9% for cattle, 63.5% for pigs, and 44.0% for dogs. That is, taking limb bones as one unit, 41.9% of cattle, 63.5% of pig, and 44.0% of dog articular ends are missing. It seems the skeletal remains of all three animals are severely affected by attrition. Then, in the case of cattle, the larger size and greater robusticity of bones make it understandable that cattle bones are preserved relatively better than pigs and dogs. Long bones of dogs also seem more complete than those of pigs. This is partly due to factors explained above (in Section 6.1). Meanwhile, most of the element frequencies are higher for pigs than dogs (Table 6.8, Table 6.9, Chart 6.2). Thus, a more acceptable understanding is that dogs were also subject to severe attrition and that many fragmented dog bones are missing (because of density mediated attritions and/or modern damage) while relatively complete elements survived better[79]. It is clear based on the percentage of long bone end attrition that pigs' skeletal elements were most intensively modified by density mediated attrition. This also accords with the normal expectation that many greasy portions of pig bones are easily damaged by people and other agents, which is discussed later.

As for bone fragments of younger individuals, I refer mainly to those smaller than the regular size of subadult and adult skeletons (see discussions in Section 6.1). Table 6.10, Table 6.11 and Table 6.12 present the general situation of smaller specimens of cattle and pigs. Similar to the general trend of body part representation of the subadult-adult remains, most bone remains of younger individuals are from large elements and with high bone density. For long bones, it is very common that they were fragmented with one or both of the articular ends broken or fallen off, but the whole shaft preserved completely. Other elements, such as mandible and scapula, are also well preserved.

[79] In terms of density mediated attrition, the distribution of dog body parts of dogs may indicate the model of density mediated attrition does not fit well in dog's skeleton because of dog's different bone structure and density compared to cattle and pigs.

Table 6.10 Frequencies of young cattle skeletal elements _Guandimiao domestic assemblage

	NISP	MNE-1	Portion	MNE-2	Percentage survival
MAX	1	1	MAX	1	12.50%
ATLAS	1	1	ATLAS	1	25.00%
SCAP	1	1	SCAP-01	1	12.50%
INNO	3	1	INNO-01	1	12.50%
			INNO-03	1	12.50%
			INNO-04	1	12.50%
HUMER	5	5	HUMER-01	0	0.00%
			HUMER-02	4	50.00%
			HUMER-03	5	62.50%
			HUMER-04	0	0.00%
RAD	4	4	RAD-01	0	0.00%
			RAD-02	1	12.50%
			RAD-03	4	50.00%
			RAD-04	2	25.00%
FEMUR	1	1	FEMUR-01	0	0.00%
			FEMUR-02	1	12.50%
			FEMUR-03	1	12.50%
			FEMUR-04	0	0.00%
TIBIA	1	1	TIBIA-01	0	0.00%
			TIBIA-02	1	12.50%
			TIBIA-03	1	12.50%
			TIBIA-04	0	0.00%
MC3+4	1	1	MC3+4-01	1	12.50%
			MC3+4-02	1	12.50%
			MC3+4-03	1	12.50%
			MC3+4-04	0	0.00%
PH1	1	1	PH1	1	3.13%
PH3	4	4	PH3	4	12.50%

Note: MNE-1 is for whole elements and MNE-2 is for elements divided into proportions as described in chapter 5.

Table 6.11 Frequencies of young pig skeletal elements _Guandimiao domestic assemblage

	NISP	MNE-1	Portion	MNE-2	Percentage survival
TEMP	2	2	TEMP	2	7.69%
MAX	7	5	MAX	5	19.23%
CRANI.FR	4	-	-	-	-

MAN	27	21	MAN-01	4	15.38%
			MAN-02	9	34.62%
			MAN-03	21	80.77%
			MAN-04	20	76.92%
			MAN-05	14	53.85%
SCAP	6	5	SCAP-01	2	7.69%
			SCAP-02	-	-
INNO	4	3	INNO-01	3	11.54%
			INNO-02	2	7.69%
			INNO-03	2	7.69%
			INNO-04	1	3.85%
HUMER	5	5	HUMER-01	0	0.00%
			HUMER-02	4	15.38%
			HUMER-03	5	19.23%
			HUMER-04	1	3.85%
RAD	1	1	RAD-01	1	3.85%
			RAD-02	1	3.85%
			RAD-03	0	0.00%
			RAD-04	0	0.00%
ULNA	2	2	ULNA-01	0	0.00%
			ULNA-02	2	7.69%
			ULNA-03	1	3.85%
			ULNA-04	0	0.00%
FEMUR	6	5	FEMUR-01	2	7.69%
			FEMUR-02	4	15.38%
			FEMUR-03	5	19.23%
			FEMUR-04	1	3.85%
TIBIA	6	6	TIBIA-01	0	0.00%
			TIBIA-02	5	19.23%
			TIBIA-03	6	23.08%
			TIBIA-04	1	3.85%
MT4	1	1	MT4	1	3.85%
CALC	3	3	CALC	3	11.54%
PH3	1	1	PH3	1	0.96%

Note: MNE-1 is for whole elements and MNE-2 is for elements divided into proportions as described in chapter 5.

Table 6.12 Frequencies of infantile pig skeletal elements _Guandimiao domestic assemblage

	NISP	MNE1	Portion	MNE2	Percentage survival

TEMP	2	2	TEMP	2	25.00%
MAX	4	4	MAX	4	50.00%
CRANI.FR	1	-	-	-	-
MAN	7	7	MAN-01	3	37.50%
			MAN-02	5	62.50%
			MAN-03	7	87.50%
			MAN-04	7	87.50%
			MAN-05	5	62.50%
AXIS	1	1	AXIS	1	25.00%
VER.FR	4	-	-	-	-
SCAP	3	3	SCAP-01	3	37.50%
			SCAP-02	3	37.50%
HUMER	8	8	HUMER-01	0	0.00%
			HUMER-02	8	100.00%
			HUMER-03	8	100.00%
			HUMER-04	0	0.00%
RAD	1	1	RAD-01	0	0.00%
			RAD-02	1	12.50%
			RAD-03	1	12.50%
			RAD-04	0	0.00%
ULNA	1	1	ULNA-01	0	0.00%
			ULNA-02	1	12.50%
			ULNA-03	1	12.50%
			ULNA-04	0	0.00%
FEMUR	1	1	FEMUR-01	0	0.00%
			FEMUR-02	1	12.50%
			FEMUR-03	1	12.50%
			FEMUR-04	0	0.00%

Note: MNE-1 is for whole elements and MNE-2 is for elements divided into proportions as described in chapter 5.

In summary, for the Guandimiao animal assemblage as a whole, patterns of body part distribution generally correspond to a density-mediated attrition model (even though serious modern biases exist). Following this logic, animal carcasses and skeletal elements should have mostly been modified *in situ* once animals were slaughtered in Guandimiao, with little evidence of other types of body part transport and deletion[80]. However, the completeness of a skeleton is species/body size dependent such that, compared with smaller animals (mainly pigs and dogs), larger animals (i.e., cattle) have a higher percentage of and more diverse elements preserved. In addition, the degree of completeness of available individual elements (especially long bones) is highest in cattle and lowest in pigs with dogs in the middle. This pattern can partly be explained by different bone densities and related attritions between cattle and pigs (see below). In the case of dog, however, it is likely that many bones were completely destroyed (which also fits the idea of a density mediated attrition) and, or, the fragmented pieces were small and missed by hand collection. Judging by the preserved fragments, it is also possible that many dog bones were wholly preserved during consumption and then dumped. This explanation of dog bones can also be applied to interpret the formation of a few specimens of younger cattle and pigs which also present a high degree of element completeness

6.2.3 Peri-Depositional Factors (dog gnawing, specifically)

Density-mediated attrition is commonly linked to carnivore consumption, and the high-survival element model is also based mainly on carnivore damage to bones (though human meat consumption based on bone utility can also generate a similar pattern). During the peri-depositional process, there are some other activities which can also impact the pattern of element distribution, especially sub-aerial weathering and burning. The assemblage shows little evidence of weathering and burning damage, indicating bone remains were preserved in good condition after being discarded (Hou et al. 2019). Though a small portion (8.22%) of fragments were gnawed by rodents, the gnawing marks are usually shallow and sparsely covering a small surface. These

[80] However, the study of body part representation here still cannot resolve the problem of whether some live pigs or whole pig carcasses were delivered outside of Guandimiao, which has been suggested in the published report (Hou et al. 2019).

activities may have impacted fragmentation and bone surface modification, but their effect should have been very limited. This leaves dog mediated attrition and human food practices as the major factors in shaping the pattern of skeletal element distribution.

Dog's teeth marks occur on around 19% of all specimens identified to mammal size (19% = 717/(5212-1470)), with elements of medium sized mammals bearing a higher percentage than those of large sized mammals (21.5% vs. 17.7%). The frequency differs very significantly among the three most common taxa (Table 6.13): cattle (21.5%), pigs (28.7%) and dogs (12.3%). The fact that the lowest frequency of gnawing marks was on dog bones rather than on cattle and pigs might be due to a tendency of dogs' complete consumption of bones of smaller animals (though collection bias and post excavation attrition of small elements also plays a role). Comparatively, pig bones are larger in size than dogs, but less dense than cattle bones, and more easily damaged, so that both gnawed and ungnawed pig fragments can be better represented in the assemblage than dog bones (even though the low abundance of most high survival elements also suggests intense bone destruction) but with higher percentage of gnawing marks than cattle. Accordingly, the relative skeletal completeness of dogs should be much lower and that of cattle should be higher, while that of pigs might be somewhere between. This result corresponds to the previous argument based on the body part profile study.

Table 6.13 Frequencies of dog gnawing on cattle, pigs, and dogs (calculated by NISP)

	Cattle		Pigs		Dogs	
gnawed	188	21.51%	344	28.74%	32	12.26%
ungnawed	686	78.49%	853	71.26%	229	87.74%
χ^2 test	$\chi^2 = 37.186$, p = 0.000					

In addition, distributions of dog gnawing marks in the three taxa vary between anatomical units. Frequencies of gnawed specimens in cranial elements (including mandibles), vertebrae and limb bones (humerus, radius, ulna, femur, and tibia) are compared, showing significant differences

(Table 6.14). The pattern is the same among cattle, pigs, and dogs: limb bones bear the highest incidence of dog gnawing (which partly confirms the study of the intensity of long bone end attrition), and are followed by vertebrae, while cranial bones seem the very least preferred by dogs. This order of anatomical unit gnawing is mentioned in many studies on strategies of carcass consumption for carnivores (e.g., Brain 1981; Halstead 2011; Ioannidou 2003; Marean and Spencer 1991; Saladié et al. 2014). It also roughly matches the pattern of body part abundance and explains the great difference between cranial and limb bone frequencies in smaller taxa (mainly pigs and dogs).

Table 6.14 Frequencies of dog gnawing on anatomical units of cattle, pigs, and dogs (calculated by NISP)

	gnawed	ungnawed	gnawed %	gnawed	ungnawed	gnawed %	gnawed	ungnawed	gnawed %
Cranial	21	192	9.86%	162	447	26.60%	13	129	9.15%
Vertebra	25	62	28.74%	83	105	44.15%	2	23	8.00%
Limb	100	190	34.48%	168	122	57.93%	16	58	21.62%
Total	146	444	24.75%	413	674	37.99%	31	210	12.86%
χ^2 test	χ^2 = 40.856, p = 0.000			χ^2 = 85.506, p = 0.000			χ^2 = 403.889, p = 0.000		

6.2.4 Summary

To summarize, modern damage during and after excavation and dog destruction after bone discard are likely the biggest factors in intensively modifying the Guandimiao animal remains in domestic contexts. Modern damage results in, on the one hand, underrepresentation of some small elements and bone fragments, and, on the other hand, breakage of some large fragments. The dog mediated attrition is also selective, so that bones of low density and small in size have been subjected to more severe attrition. As a result, the skeletal completeness in the domestic contexts of Guandimiao should be low, and the information offered by body part frequencies should be seriously biased. Compared to large animals (mainly cattle), the modification to smaller taxa (pigs and dogs) is even more intense. Although the sample is not large enough for a detailed discussion of younger individuals, it can still be expected that the amount of bone fragments from such individuals is seriously underrepresented. In addition, based on body part representations and related discussion, there is no clear evidence of body part deletion due to transport[81]. Because the assemblage has been significantly disturbed, both qualitative and quantitative methods are used in the following discussion on animal butchery and food processing. At last, the above studies show that some smaller taxa (especially dogs) and younger individuals are inclined to be wholly processed with less bone fragmentation than others.

[81] However, as discussed in the Guandimiao report (Hou et al. 2019), based on a study of death profile and gender, it is still possible some whole pigs and even cattle were exported from Guandimiao.

CHAPTER 7: Guandimiao: Reconstruction of Cattle and Pig Butchery Patterns

Insofar as subsequent attritional processes can be controlled for, the pattern of bone breakage and degree of fragmentation can be a source of information concerning carcass processing and serve as a measure of the intensity of such activities, while visible butchery marks can be a direct evidence of food preparation. Based on previous analyses in Chapter 6, both the pattern of bone breakage and that of fragmentation and butchery marks will be analyzed in this and subsequent chapters in order to discuss meat food processing and consumption. This chapter will mainly describe patterns of bone breakage and butchery mark distribution in order to show as many carcass processing details as possible.

In view of the limitation of the sample size, when cattle and pig bone are discussed, remains of large and medium-sized 2[82] mammals (which are mostly unidentifiable fragments of cattle and pigs) are also mentioned sometimes as a reference. Almost all the analyses are done based on remains of relatively older and larger individuals, while the situation of very young animals (see Chapter 6 for definition and description) are discussed when possible.

7.1 Bone Breakage and Fragmentation

In order to study animal butchery and culinary process, analyses in this section focus on bone fragments without serious modern damage, which, accordingly, retain all or most of the

[82] Parts of the medium-sized 2 mammal remains are identifiable as medium herbivores (sheep, goats, or deer). When remains of "medium-sized 2 mammals" are mentioned in this chapter without special notice, it always refers to the non-herbivorous samples in this category.

ancient fracture surfaces and are measurable for maximum length (refer to Appendix II for the measurements of bone dimensions). In addition, shear marks are taken as a reliable evidence of anthropogenic bone breakage. Biases of taphonomic attrition, especially damage caused by dogs, are frequently mentioned in this section so as to better understand possible human choices.

7.1.1 Long Bones

A calculation of different types of long bone fragments (Table 7.1) supports the conclusion of the taphonomic analyses in Chapter 6. The assemblage has been greatly disturbed during the process of modern excavation and curation. Shaft_cylinders are typical remains of carnivore scavenging while longbone fragments with articular ends, end-shafts, and end_splinters are more likely leftovers of human consumption[83]. In the long bone group of pigs, shaft_cylinders are relatively close in numbers to fragments with ends, end_shafts and end_splinters, while in the cattle group, fragments with ends overwhelmingly dominated, impling that pig bones have been subjected to much heavier dog attrition than cattle bones (this matches the result of bone density discussion in Chapter 6). We can imagine that, in most cases, even though cattle bones were obtained by dogs, it would not be easy to chew up all the spongy portions. Thus, it can be roughly assumed that the Guandimiao cattle long bone fragmentation was mostly the result of human activities[84]. Therefore, an analysis of anthropogenic fragmentation of cattle long bones can be done by studying a subset of whole long bones, long bone ends, end-shafts, end_splinters, and shaft_cylinders. However, it seems very difficult to trace human behaviors on pigs by any rigorous

[83] In addition, shaft splinters may be found in bone remains of either dog gnawing or human activities. They may appear rather randomly in the assemblage and may be severely underrepresented. However, they have little impact on my analysis.

[84] This is also the case as is shown in Ioannidou's experiment (2003) on dog scavenging specifically. It turns out in the end of this experiment that the human raised dogs caused little serious damage to the cattle bones (including long bones) while they inflicted very heavy attrition on the pig and sheep bones.

quantitative calculation of long bone fragments. Accordingly, a descriptive method is employed instead to avoid the intense intervention of dog gnawing on pig bones.

Table 7.1 Types of long bone fragments (calculated by NISP, excluding loose epiphyses or specimens of very young individuals)

		Cattle	Pig	Large mammal	Medium-sized 2 mammal*
Whole		22	3	-	-
Old break	End	14	1	-	-
	End-shaft	111	81	-	-
	End_splinter	10	0	1	-
	Shaft_cylinder	20	59	-	-
	Shaft_splinter	64	13	60	34
Whole%**		14.0%	3.5%	-	-
New break***		76	71	3	21

* Specimens of medium-sized 2 mammal = specimens can only be identified as non-herbivorous medium-sized 2 mammals.
** Whole% = Whole ÷ (Whole + End + End-shaft + End_splinter) × 100%[85].
*** New break = specimens with serious modern damage (see Chapter 6).
Note: For cattle, long bone fragments = fragments of humerus, radius, femur, tibia, metapodials; for pigs, long bone fragments = fragments of humerus, radius, femur, tibia.

► Cattle

The high incidence of completely preserved long bones (and there are at least eight possibly whole specimens, by which I mean, have one end seriously damaged during excavation) in Table 7.1 indicates that many long bones were processed and consumed without breakage; in other words, there were a number of long bones discarded without marrow extraction. Also, compared to end-shaft fragments, there is only a small number of articular ends/end_splinters and shaft_cylinders, which may suggest it was not common to strike off the two ends of a long bone and take the bone marrow out.

The maximum dimension of long bone fragments can also help to interpret the approach of bone breakage. When compared with the length of a relatively whole long bone, the

[85] Ideally, one whole element can be broken to at least two end-shaft fragments. So, this result is not standardized.

completeness of a fragment can be estimated. That is, the location of the bone cut on the original whole limb bone can be inferred, which should be a reflection of human choice. Since most gnawed fragments completely or partly retain their articular ends, the dimension of long bones or fragments (with old breaks) should be very close to the original length after consumption, thus it is acceptable to treat gnawed and ungnawed fragments together.

In general, comparisons of the maximum length of bone fragments with those of whole long bones show that most end-shafts have kept a length of 1/3-2/3 of a whole bone, among which a large number of fragments are about half the length of a whole bone. In addition, the limited number of long bone ends and shaft_cylinders are mostly smaller (1/4-1/2 of a whole bone in length). Accordingly, it can be argued that, in Guandimiao, most long bones were chopped into two halves from the shaft (though not necessarily exactly in the middle of the shaft) while a few especially long bones (e.g., some femurs) were probably chopped to three parts. Most shaft_splinters (including those only identified to "large mammal" category) are smaller than end_shafts or shaft_cylinders (even though some smaller shaft fragments may have been lost during excavation) which is consistent with the common observation that shaft splinters are by-products of human or dog generated bone breakage, not purposely produced for bone working. Moreover, even though femur and tibia are a little longer than humerus and radius (as well as metapodials), their treatments are quite similar (except that the femur sometimes shows a higher degree of fragmentation in the shaft). Long bone breakage is directly related to marrow exploitation (especially the breakage of metapodials). It is very time-consuming to dig marrow out from the end-shaft fragments, which may need to be boiled in a vessel (to make broth). Therefore, the way of long bone breakage suggests boiling was likely an important approach for bone cooking, and there should be some large cooking pots in order to boil these large bone parcels, which are further discussed in the next chapter (Chapter 8). Finally, except marrow in the long bone cavity, grease in articular ends is also an important bone fat resource. However, there are only a few pieces of old broken epiphysis splinters in both the categories of cattle and large mammals, the small number of which cannot be simply owing to taphonomic attritions (there are hundreds of fragments of <40 mm). So, it is reasonable to think that people in Guandimiao didn't intensively extract bone grease from long bone ends.

Even though the collection may have been heavily modified by diverse taphonomic damage, some statements on pigs' long bones are still possible. Firstly, although there are only a few wholly preserved long bones, there are at least ten possibly whole specimens with one end serious damaged during excavation, not to mention those gnawed by dogs. Thus, it would be proper to say that a portion of long bones were wholly cooked and consumed. Although it is difficult to prove, it is likely that chopping off the ends of a pig long bone wasn't a frequent practice. Long bone ends or end_splinters are rare in the subset of pigs or medium-sized 2 mammals. In addition, the structure of pig long bones is slightly different from that of bovids and cervids – pig long bones have the trabecular bone extending more proximally and distally in the bone cavity (which can extend the grease-rich area preferred by dogs and may lead to even more serious damage). Because of this, in order to take marrow out, it is not as efficient to chop the articular ends off as with bovids and cervids (e.g., Binford (1981: 148-166)). Instead, for pigs, it is more efficient to break long bones from the midshaft[86].

For elements other than long bones, a descriptive approach is mainly used to present as many details as possible.

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[86] Some long bone fragments show (near) transverse fracture across the mid-shaft which are possibly also an indicator of bone breakage by human (referring to a summary and discussion by Gifford-González (2018: 212-221)).

7.1.2 Cranium

Compared to other elements (including mandible fragments), there are only a relatively small number of cranium fragments in the domestic assemblage (see Table 6.2 and Table 6.3).

► Cattle

There are no whole skulls preserved, and the small amount of cranium fragments is rather disproportionate to the degree of bone fragmentation. Based on the existence of many maxillae and mandibles, it is unlikely that cattle carcasses with no head were transported into Guandimiao or that cattle skulls were moved out of the settlement. Cranial bones should be less attractive to dogs than other fat-rich elements. Thus, the lack of cattle cranial fragments may be mainly owing to the hand retrieval method bias against the recovery of small fragments. If this is the case, the dimension of cranial specimens in the collection (relatively large pieces) should represent the acceptable size of bone parcels for cooking and consumption. In terms of the dimension of bone fragments, except for a few specimens, most fragments are not longer than 140 mm in any dimension.

► Pigs

Many cranial fragments of pigs have been damaged during modern excavation and curation (about half of the subset) and some of them were gnawed by dogs (about 1/5 of the subset). The available specimens with old broken fracture surfaces (NISP = 95 $_{\text{[pigs]}}$ + 2 $_{\text{[medium-sized 2 mammals]}}$) show that most fragments are smaller than 160 mm.

Some specimens are whole or part of the posterior half of a pig cranium. In terms of the posterior half of a pig cranium, based on these fragments, it refers to a portion of a pig's cranial bone including the posterior half of the frontal bone (sometimes), parietal, occipital, temporal, and part of the connected zygomatic bone. There are nine specimens have this portion wholly preserved

(Figure XI-1), and there are also fragments with half of this portion intact (left/right side) or some even smaller pieces of this portion (Figure XI-2). Some of these specimens show obvious chop marks and sheared surfaces indicating purposeful chopping activities. In modern times, pig brains are often removed by hacking through the cranium transversely so as to open the cranial cavity in the posterior half of the cranium[87]. Bone evidence from Guandimiao proves that Shang people also used a similar method to extract pig brains, and they could further separate the cranial bone into smaller pieces. (Similar fragments are also found in the subset of sheep/goats.)

Evidence shows that the anterior parts of pig craniums (including mainly facial bones, premaxilla and maxilla) were also fragmented to small pieces. For example, one frontal specimen presents clear chop marks and very regular break surfaces (Figure XI-3c)

and several specimens show that the right and left maxillae were separated, and one maxilla may be split up into even smaller pieces (Figures XI-3a, XI-3b). Therefore, it is quite possible that, after the brain had been removed, some pig craniums were further chopped into small pieces. It can be further hypothesized that small cranial pieces were probably stewed rather than roasted for consumption.

7.1.3 Mandible

Mandibles are among the most well represented elements. Based on my observation, although dog ravaging may have caused some damage on some portions of mandibles, such as the edge of the ascending ramus and mandibular angle, nevertheless most of the old-broken fragments are generally well preserved. Therefore, the pattern of mandible fragmentation can be described and summarized.

[87] A modern case of pig head butchery, which includes a similar way of brain removal can be found in YouTube: Butchering a Pig Head - How to Debone a Pig Head. https://www.youtube.com/watch?v=yyAyx32jkAw.

► Cattle

Various types of mandible specimens are seen. Firstly, there are several pieces of relatively complete specimens, composed of a large part of the horizontal body and most of the ascending ramus. In some cases, a breakage happens at the mandibular diastema (in the space between I3 and P2) (Figures XI-4c, XI-4d). Fragments of ascending ramus are common, with either a horizontal fracture to make the upper portions (coronoid process and condyle process) split off (Figure XI-4a) or a fracture close to the mandibular body (after the third molar) to separate both the mandibular angle and connected ramus portions from the horizontal body. In addition, a few fragments indicate mandibular bodies could also be divided to small pieces at a place around M1 (Figure XI-4c).

In terms of the maximum dimension, except a few larger specimens (with main parts of the mandibular body and ramus kept), most of the mandible fragments are in the range of 40-200 mm. More specifically, most specimens smaller than 120 mm are fragments of ascending ramus or small chips of mandibular body (especially for mandible fragments identified as “large mammal”), while specimens with whole/part of a horizontal body are usually larger. Dog related attrition of cattle mandibles seems to be minor. Thus, the fragmentation pattern should reflect human behavior.

► Pigs

A huge number of pigs’ mandibles were collected. Among them, there are a few examples of wholly preserved dental arch and one side (left or right) of a whole mandible. In addition, although various types of (either large or small) fragments were observed, the breakage occurs in mainly three locations. A mandibular arch is usually split into two halves from the diastema (between canine and the second premolar) (Figuress XI-5a, XI-5b) and, in some cases, a mandible is chopped through from the midline of the symphysis. In many cases, a mandibular body is cut apart around the first molar (between P4 and M1, or M1 and M2) so as to separate the dentary into smaller fragments (Figures XI-5c, XI-5d, XI-5e). The upper part of a ramus (coronoid process and condyle process) is often chopped off, sometimes together with (a part of) the angle of the mandible (Figures XI-5c, XI-5d).

Although dog gnawing marks are seen in some fragments with vertical ramus preserved, mandibles are elements with high density and many mandible specimens are in relatively good condition visibly. Except a few whole mandibles and some small pieces, most fragments are in the range of 60-180 mm.

► Summary

The subsets of cattle and pig mandible samples are similar in many ways. Both have a small amount of whole and many fragmented specimens. The breakage patterns of cattle and pig mandibles are also very similar. Removal of coronoid process and condyle process on ramus is frequent, which possibly relates to mandible disarticulation or cheek filleting. The anterior portion of the mandibular body was often chopped off from the diastema while the portions of premolar and molar were frequently separated as well (although the latter pattern seems to be more common for pigs), which might aim to break the mandibular body into smaller fragments for marrow and/or further cooking as in other sites worldwide, (e.g., Landon 1996, Nijssen 2017, Rixson 1989).

7.1.4 Vertebrae

► Cattle

Cervical vertebrae, especially atlas and axis, are relatively better represented than thoracic and lumbar vertebrae. It is seen in the collection of both whole and fragmented cattle atlases and axes, while only whole or mostly whole cervical vertebra specimens (retaining the structure of vertebral centrum and arch) are represented in the collection. An examination of the fragments shows that the breakage of an axis was usually done by transversely dividing through the centrum (Figure XI-6). In the thoracic and lumbar vertebra specimens, the spinous process of thoracic vertebrae and transverse processes of lumbar vertebrae were usually fractured.

► Pigs

Atlases dominate the collection, while lumbar vertebrae are better represented than cervical or thoracic vertebrae, and most vertebrae are wholly preserved, suggesting that smaller fragments were likely missed in hand collection.

In addition, among the cattle and pig subsets (as well as those of large and medium-sized 2 mammals), vertebral fragments are mostly whole vertebral bodies and broken vertebral processes (the latter of which may or may not be purposely cut off due to structural weakness). Therefore, even though the assemblage has suffered serious taphonomic attrition, it can still be inferred that the approach of longitudinally cutting through the center of the vertebral column while dismembering a cattle or pig carcass was rare in Guandimiao.

7.1.5 Ribs

Rib remains have been intensively modified by taphonomic processes. Thus, in order to record a pattern of fragmentation, only frequently appearing types are mentioned here.

Other than many small sections of ribs (Figure XI-7a), there are a few wholly preserved pig or cattle rib specimens. For some cattle specimens that can be identified, the rib heads are missing and one of them displays a flat sheared fracture surface (Figure XI-7c), which may be evidence of separating rib slabs from the vertebral column (e.g., Binford 1981:113; see more discussion in Section 2.2.4 of this chapter). By comparing with the modern pig collection in the Henan Institute of Cultural Relics and Archaeology, some well-preserved rib sections in Guandimiao assemblage of pig are about 1/3 to 1/2 of a whole rib. Some specimens of pig ribs from the same excavation unit seem to around the same length (Figure XI-7b) and may be remains of a single event.

7.1.6 Scapula

Cattle scapulae are not discussed here because nearly all of them were collected for divination use or bone working (Hou et al. 2018).

Both whole and fragmented specimens of pig scapulae appear in the collection. It is very common to see fragments with only the glenoid and neck (and a portion of the blade), and at least one specimen shows chopping marks on the fracture surface indicating human activities of scapula division.

7.1.7 Pelvis

There are no whole innominates of cattle and pigs preserved in the collection. The fragments of cattle and pigs share many similarities and can be grouped to several types. The portion of the acetabulum is best represented, sometimes with parts (shafts) of the ilium, ischium, and/or pubis (Figures XI-8a, XI-8b). For cattle, fragments are also with only a section (shaft) of the ilium or ischium or pubis and the connected portion of the acetabulum (that is, only 1/3-1/2 of the articular surface presented). In addition, there are also some ilium fragments with the wing and a small section of the arm of the ilium and some ischium fragments (Figure XI-8c). Even though some fragments suffered severe taphonomic damage, considering together the frequently shown fragment types and some sheared fracture surfaces and/or chop marks around fracture surfaces, the method of pelvis division is clear. The left and right sides of a pelvis were usually separated, and each innominate was further broken into smaller sections with the acetabulum, ilium, ischium and pubis usually separated. In some cases, the cattle acetabulum were further chopped to smaller fragments.

7.1.8 Small Compact Bones

For cattle bones, except those gnawed by dogs, most of the recovered small bones were whole. Specifically, almost all the tali and most of the calcanei were wholly preserved, which may be related to the approach of disarticulation.

For pigs, there are only a few small bones (i.e., carpals, tarsals, and phalanges) in the assemblage, and almost all of them are intact.

7.1.9 Notes

Generally, for both cattle and pigs, the whole and fragmented specimens analyzed were relatively large elements (except cattle cranium), and there are some common patterns, which can give information on cattle and pig butchery. A summary of patterns of bone fragmentation and butchery is discussed at the end of this chapter. Moreover, for younger individuals, it is possible that limited breakage was done before cooking (more discussion has been given in Chapter 6).

7.2 Butchery Marks

7.2.1 Distribution of Butchery Marks by Taxa/Animal Sizes

All the non-bone-working related specimens which had a relatively well-preserved bone surface are included in this discussion. The distribution of butchery marks by taxa/animal sizes can be found in Appendix III.

On consideration of the serious damage due to taphonomic processes, three points should be mentioned before any explanation is made. Firstly, specimens with butchery marks are less common in bone categories defined by mammal size than those defined by taxa, but this has little effect on the final discussion of butchery practice. Since the influence of post-depositional damage on Guandimiao assemblage is weak and marks on bone surfaces are generally well preserved, this might be explained as follows: a) bone fragments identified only to mammal size are usually small and so less likely to bear butchery marks, and b) many of them are fragments of long bone shafts, rib blades, and cranial bones (see Table 6.3 in Chapter 6) which are less likely to have dense butchery marks (refer to Grody 2016a: 186). Based on this logic and with a little further deduction, it can be argued that even though many bone fragments have likely been missed during excavation, there is probably limited impact on the study of butchery marks. Generally, most of the omitted fragments should be relatively small pieces and elements (see a discussion in Chapter 6) which are less likely to have many butchery marks. Studies on butchery patterns of cattle and pig are the main focus of this dissertation, and they are much less affected on account of the relatively large sample sizes of cattle and pig remains. Nevertheless, the situation of sheep/goats, deer, and dogs is possibly affected to some extent due to their small sample sizes and the poor preservation of many small elements (especially for dogs). Finally, the main bias should come from under-represented elements and element portions caused by taphonomic attrition. For example, the destruction of long bone ends as well as vertebra and rib fragments by dogs may impede the study of disarticulation, and evidence of bone breakage (such as sheared fracture surface and chop marks) can be destroyed by both dog gnawing and modern damage. In this case, pig bones should be more severely affected than cattle bones.

Based on Appendix III: Table 1, most specimens with butchery marks are found in cattle and pig bone assemblages, while there is only a very small portion of such type of bone fragments for dog, sheep/goat, and deer altogether. As discussed above, ratios of butchery-mark-bearing bones of dog, sheep/goats and deer may not be reliable for butchery study, and a comprehensive reconstruction of butchery and consumption practices is not possible. On the other hand, some information about butchery and consumption can still be collected. Firstly, butchery marks are found on many bone elements of dogs (e.g., cranial bones, atlases, mandibles and limb bones), which matches with the assumption that some of them were cooked for meat (see Chapter 4). There are also some clues showing variations of animal butchery between large and medium herbivores. For sheep/goats and deer, no butchery marks on metapodials or mandibles were found but they are quite common in cattle remains. Since butchery marks on metapodials are often related to skinning, disarticulation and tendon removal, the absence of butchery marks on sheep/goat and deer metapodials may indicate a different approach of skinning or extremity disarticulation (which may be realized by cutting through the wrist and ankle joints). The same might be true for mandible treatment.

In addition, butchery marks are also found on eleven fragments of infant pigs and very young pigs and cattle. This type of specimen is almost certainly underestimated by survival and retrieval biases. However, these specimens still confirm that very young animals were also consumed.

In the remaining part of this section, distribution patterns of butchery marks for cattle and pigs are discussed in detail.

7.2.2 Distribution of Butchery Marks by Element_ Cattle and Pigs

This section is a description of the distribution of butchery marks on bones, aiming to connect butchery marks to certain butchery tasks and to summarize the butchery patterns of cattle and pigs.

Distribution of different types of butchery marks for cattle and pigs by element are listed in Tables III-2 and III-3. The following description and analyses are mainly based on specimens included in the two tables. However, more detailed analyses of the distribution of butchery marks and the possible human activities related, as well as drawings and images of cut, chop, scoop, and shear marks on diverse elements are presented in Appendix IV.

7.2.2.1 Cranium

► Cattle

There are very few butchery marks identified on cattle cranial fragments to reconstruct the butchery process. However, one fragment with clear chop marks and sheared surfaces indicates at least some cranial bones were chopped to chunks.

► Pigs

Because there is a very small number of skull fragments with butchery marks in the assemblage, information about cranium butchery is very limited. Shear and chop marks are mostly related to the activities of cranium dismemberment, and a cluster of butchery marks around the facial bones are very likely a result of cutting the cheek muscles off and disarticulating the mandible. In addition, butchery marks on/around the occipital condyles are probably caused in the process of separating the skull and the vertebral column.

7.2.2.2 Mandible

► Cattle

Butchery marks are concentrated on the medial and lateral sides, as well as the bottom of the dentary bone. Judging by locations of butchery marks on mandibles, cheek muscles and tongues were removed from mandible and the mandible was usually cut free from the cranium as a whole. In addition, some chop marks may be related to activities of bone fragmentation as discussed in Sec 1.3 of this chapter.

► Pigs

Butchery marks can be categorized to several groups based on their locations, which are very similar to the situation of cattle mandibles.

7.2.2.3 Vertebrae

► Cattle

Butchery marks are mainly seen on specimens of atlas and axis.

Atlas A small number of butchery marks are all seen on three whole-preserved specimens, which may be generated in the process of severing the atlas from the head.

Axis Two types of specimens with butchery marks are seen in the collection, which may represent two ways of vertebra dismemberment and/or filleting.

Other vertebrae Butchery marks on other vertebrae are quite limited. They can be either the lateral, or the dorsal sides, or on transverse processes. These marks may have been inflicted during steps of dismemberment or filleting. However, there are few butchery marks on the vertebral centrum which are usually intact.

► Pigs

Atlas Almost half of the specimens have cut marks, most of which are regularly distributed on both the dorsal and ventral surfaces. They were quite likely engendered by activities of head severing.

Other vertebrae Because of sample size, lumbar vertebrae with butchery marks are relatively well represented. Most chop and shear marks, as well as a few cut marks, are perpendicular to the vertebral column, which should be for the purpose of vertebra dismemberment. Cut marks, specifically, at the base of the transverse processes may be related to muscle removal and/or tearing the rib slabs off the vertebral column.

7.2.2.4 Ribs

► Cattle

Most butchery marks concentrate on the portion close to the proximal rib head and are seen on all four (cranial, caudal, medial, and lateral) sides, especially on the medial and lateral surfaces. Butchery marks related to muscle removal are possibly those transverse marks along the dorsal surface and close to the proximal rib end. Butchery marks on the medial side and on/close to proximal rib heads might be generated by rib slab dismemberment. In addition, scoop marks seen on two specimens may indicate intensively cutting off scraps of meat on ribs. At last, there are sheared fracture surfaces on the body of several rib sections, which are direct evidence of rib fragmentation for the purpose of meat cooking.

► Pigs

There are only a few rib specimens with butchery marks, the pattern of which is roughly similar to those of cattle.

7.2.2.5 Scapula

Cattle scapula is not discussed here.

► Pigs

Most butchery marks are concentrated on three locations. Butchery marks around the distal portion (below the glenoid cavity and around the neck) of scapulae are very likely related to ligament cutting and bone disarticulation. Butchery marks along the edge of the spine on the lateral side and those along the superior and lateral borders on the medial surface should be generated by muscle removal. It seems there is no intensive filleting on scapulae.

7.2.2.6 Pelvis

For both cattle and pig pelvises, most of the butchery marks are around the acetabulum. These marks, corresponding to some butchery marks on the proximal end of femurs, are quite possibly generated in the process of cutting off the hind limb from the body. Some other butchery marks on the rim of the acetabulum and on the ilium/ischium/pubis shafts may indicate activities of bone fragmentation.

7.2.2.7 Humerus, Radius-Ulna, Femur, and Tibia

Distributions of butchery marks on the main four limb bones of cattle and pigs share many similarities. In terms of specimens with butchery marks, humeri are much better represented than radius-ulnae, femurs, or tibiae. Patterns of butchery mark distribution on these four limb bones follow the same logic. Butchery marks around the proximal and distal articulator ends (including both portions of epiphysis and metaphysis) are related to activities of bone disarticulation and meat removal, while butchery marks on shafts are more possibly related to filleting. Cut marks are much more common than chop marks in general, and scoop marks are rarer. Therefore, it seems that the usual technique of limb bone disarticulation was to cut off ligaments around the joints so as to separate the two articulated bones, while it is quite rare to have a joint that was directly chopped through. However, even though many long bones were broken in the midshaft, it is uncommon to see very clean and flat sheared surface.

7.2.2.8 Metapodial

► Pig

Pig metapodials are not discussed because of sample size.

► Cattle

Metapodials are well represented, and many fragments have butchery marks. Butchery marks, mostly cut marks, are around the bone shaft (especially the anterior surface) and the two distal trochoid joints, which should be related to activities such as skinning, filleting, tendon removal, disarticulation, and bone fragmentation.

7.2.2.9 Tarsals: Talus, Calcaneum, and Central-4th Tarsal

Pig tarsals are not discussed because of sample size.

Many tali and calcaneus have butchery marks. Most butchery marks are located around the middle portions of tali and calcanei which avoid the attached surfaces of the two elements. However, it is rare to see butchery marks on the central-4th tarsal, and there are only a few butchery marks on the proximal ends of metapodials. Therefore, it strongly suggests that disarticulation and/or skinning were usually done by cutting around the talus and calcaneum.

7.2.2.10 Phalanges

A few cattle phalanges have butchery marks which suggest these bones were also processed possibly not for skinning but for cooking. Pig tarsals are not discussed because of sample size.

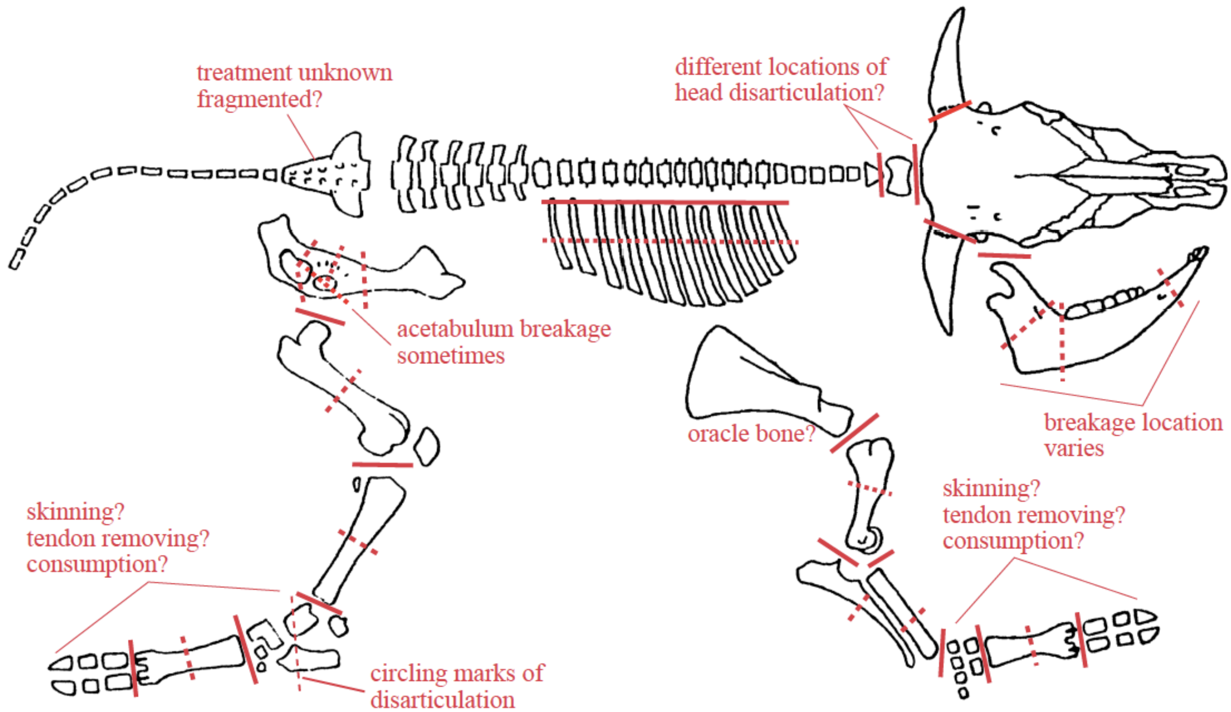
7.3 Reconstruction of Cattle and Pig Butchery Patterns

Butchery marks are the most direct evidence of carcass butchery, while the pattern of fragmentation and the types of elements also provide additional information concerning butchering behaviors (Reitz and Wing 2000: 126-127). Thus, results of the above two sections are summarized and the general patterns of cattle and pig carcass processing are shown in Table 7.2, Figure 7.1, and Figure 7.2.

Table 7.2 A summary of butchery methods to elements _ cattle and pigs

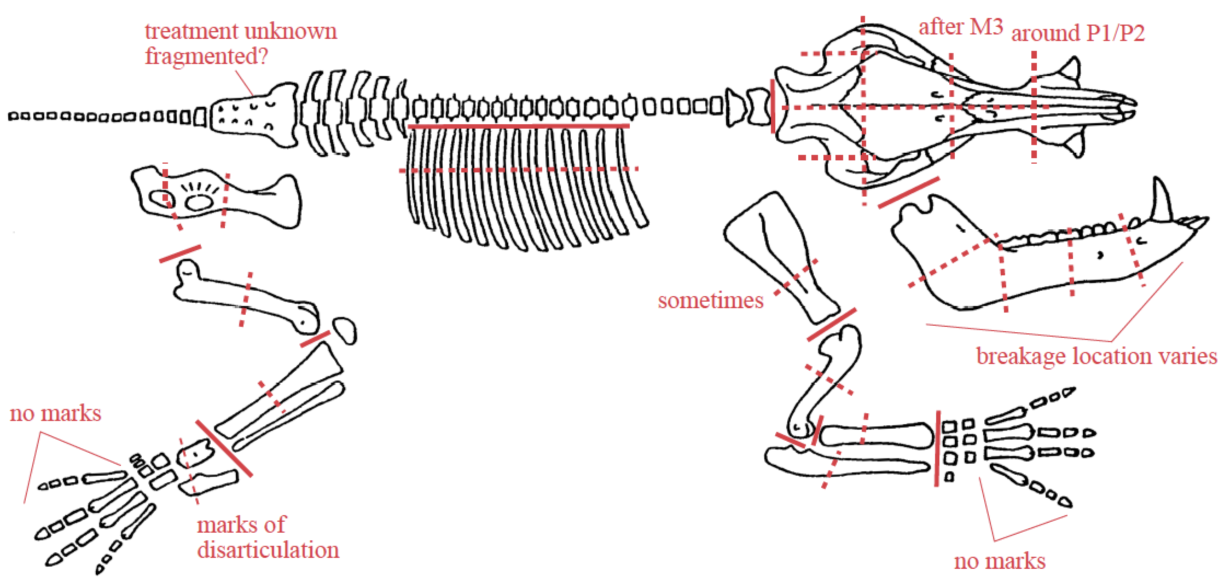
	Cattle	Pigs	Similarities	Edible resources
Cranium	-	Brain extraction	Chopped to small segments (stewed?)	Brain; meat
Mandible	-	-	tongue removal, defleshed (e.g., cheek muscle), disarticulation, whole or broken to small segments (stewed?)	Meat; marrow (sometimes)
Atlas and axis	Some axis vertebrae are separated to two parts (cranial vs. caudal)	-	Mostly whole; head disarticulation (?) or further disarticulation by cutting off ligaments (?)	Meat; marrow

Other vertebrae	-	Sometimes chopped transversely to separate connected vertebrae; muscle removal (e.g., tenderloin)	Wholly preserved (except sacrums); mostly ligaments cut off for disarticulation	Meat; marrow; (grease?)
Ribs	Muscle removal (dorsal and ventral) and bones scraped		Rib slabs separated from the vertebral column; whole/chopped to segments	Meat
Scapula	Unknown (few specimens)	Whole/broken to segments; defleshed	-	Meat
Pelvis	-	-	Ligaments cut off to free the femur; chopped to several segments	Meat
Limb bones	A few wholly preserved; mostly two or three segments	Some wholly preserved; mostly two segments (?)	whole/broken to segments; cutting off ligaments around epiphyses for disarticulation; defleshed	Meat; marrow (grease?)
Carpals and tarsals	Ligaments cut off for disarticulation (and skinning)	Unknown (no specimen)		
Metapodials	Whole or broken to segments; skinning (?); ligaments cut off for separation from phalanges; processed for food	Cooked whole		Meat; tendon; marrow
Phalanges	skinning (?)		Cooked whole	Tendon



Note: the base template is modified from Landon (1991: 301, Figure 6.55). The red solid lines show locations of disarticulation, which are evidenced by butchery marks; the red dotted lines show locations of bone breakage (in secondary and tertiary butchery), most of which are deduced from the pattern of bone fragmentation.
Long bones (humerus, femur, radius, tibia) were broken to two or three portions.

Figure 7.1 Cattle: patterning of carcass butchery



Note: the base template is modified from Landon (1991: 302, Figure 6.56). The red solid lines show locations of disarticulation, which are proved by butchery marks; the red dotted lines show locations of bone breakage (in secondary and tertiary butchery), most of which are deduced from the patterns of bone fragmentation, while the pattern of cranium and rib dismemberment are deduced from both patterns of bone fragmentation and butchery mark distribution.

Figure 7.2 Pig: patterning of carcass butchery

On the whole, cattle and pig carcasses were processed in quite a similar way. The morphologies of vertebrae (vertebral centrums are mostly wholly preserved while the transverse processes are often broken) and ribs (the heads are often missing or with chop/shear marks) indicate rib slabs of both sides were usually split off from the vertebral column. This should have happened in the stage of secondary butchery. Related to this, it can be inferred that in the first stage of butchery, a cattle/pig carcass was opened at the belly and eviscerated, which roughly matches the order recorded in the *Liji* 礼记[88] and is a traditional and simple way of gross carcass dismemberment (in contrast to splitting a carcass through the center of the vertebral column into two sides, see Audoin-Rouzeau 1987). Head and extremities may have been severed from the carcass in the first stage of butchery. Then, main muscles around the back were likely removed (at least from cattle carcasses) and rib slabs of both sides should have been chopped off during secondary butchery to leave the vertebral column as a whole, and both the fore and hind limbs were clearly taken off from the scapula and pelvis. Although there are chop marks around some bone joints, cut marks are the dominant pattern, which, together with the many wholly preserved articular ends, suggests that disarticulation was usually realized by cutting off ligaments around the joints. Different body parts were further processed separately. There is a relatively complete chain of evidence for pig head processing -- the brain, meat, and tongue were taken out and even the skull and mandibles were chopped for cooking (quite possibly stewing), and it is quite possible

[88] See the comment of Ling Tingkan 凌廷堪, a Qing scholar, on *Liji* 禮記 (Ling 2002: 273-276).

cattle heads were treated in the same way. Vertebrae were filleted and separated from each other, and some ribs were further chopped into short segments. Based on butchery marks on long bone shafts, we know that long bones should have been defleshed more or less and some of them were then chopped into parcels (while others were kept whole). Moreover, butchery marks on cattle metapodials and extremities indicate this part was also cooked for food. If this was the case, stewing would be the best choice to cook these elements which are full of ligaments and tendons. Since there are no butchery marks found on pig metapodials, some pig feet may have been cooked whole (and the cooked pig feet could have been separated into small segments then). It can be seen based on ratios of chop and shear marks that in the final stage of butchery, heavy tools were sometimes used, mainly for bone fragmentation (e.g., cranium, mandibles, ribs, scapula, pelvis, and long bones).

To sum up, based on a detailed study of the Guandimiao animal assemblage, it is possible to reconstruct the butchery patterns of cattle and pigs, which have only minor differences. These patterns are very helpful to understand the processes of carcass butchery. On the other hand, generalized patterns should be treated cautiously (Landon 1996). As Landon argues, there are a great number of variations of bone treatment that may not all be reflected in a pattern. In addition, the butchery patterns of some elements are too vague to be reconstructed for a variety of possible reasons. Such patterns, especially the patterns of butchery marks are the final aggregations of information from all stages of carcass processing, so that they are not necessarily caused by the activities of tertiary butchery or food consumption, and most of them can impact analysis of methods and procedures of final cooking and consumption. Moreover, as with the cattle and pig bone assemblages in Guandimiao, sample sizes of different elements greatly differ, which can also affect the representativeness of a butchery pattern. The interpretation of butchery patterns of cattle and pigs should not be directly extrapolated to other species (e.g., dogs, sheep/goats), while the butchery of very small individuals may also be different (as some pieces of evidence have suggested). Despite these qualifications, the patterned description of cattle and pig butchery offers a preliminary answer to the question of how people in Guandimiao butchered animals and prepared the carcass for cooking.

In the next chapter, based on the information/data of bone fragmentation and butchery marks, some special topics are discussed in order to further describe the pathway of food consumption and to study the social scale of meat consumption in Guandimiao.

CHAPTER 8: Guandimiao: Discussion on Patterning and Interpreting Carcass Processing and Food Preparation

Two main sections are included in this chapter: (1) analysis on the intensity of animal butchery and body part processing, and (2) a discussion and summary of the nature and social scale of (cattle and pig) carcass processing and meat consumption in Guandimiao. As for the intensity of butchery, I concentrate on analyses of the degree of fragmentation and the frequency of butchery marks. The two indexes are correlated with each other, and both of them may also depend on many factors, such as carcass size, butcher's skills, purpose of butchery, butchery traditions and approaches, butchery tools, preparation and cooking conditions (e.g., Domínguez-Rodrigo and Yravedra 2009; Lyman 1987; Seetah 2006: 98, 2008). Comparing cattle and pig subsets, the main purpose of this butchery-intensity study is to identify some of the active factors mentioned above. In another words, this is an extension of Chapter 7 by making a quantified study of carcass butchery. Then, based on Halstead's model of carcass processing and meat consumption, and integrating the results of Chapter 6, 7 and the first section of this chapter, a summary is given, so that a relatively clear and complete view of food practice in Guandimiao can be obtained.

8.1 Evaluation of the Intensity of Carcass Processing

8.1.1 Bone Breakage and Fragmentation

Butchering and consumption caused bone breakage and fragmentation is closely related to activities of bone nutrient (mainly marrow and grease) extraction, and they can be affected by other factors, such as butchery tools, cooking vessels, and cooking techniques. In this section, two main factors -- the degree of bone completeness and the maximum bone dimension -- are examined to study the pattern of anthropogenic bone breakage and the degree of fragmentation. The degree of completeness of elements and element portions is necessary for evaluation of the approach and degree of bone fat exploitation. The maximum bone dimension is inferred through analysis of dimensions of cooking pots (*li* 鬲 tripods), so as to further understand the purpose of bone breakage and fragmentation.

8.1.1.1 The Degree of Bone Completeness and Bone Fat Exploitation

Both marrow and grease are sources of fat in bones. Marrow is primarily in the large medullary cavities of limb bones and mandibles, which are among elements of highest density. For this reason, in order to get marrow out, some heavy tools are needed to break the relatively thick layer of cortical bone. However, since bone marrow is a nutrient dense food and getting animal fat from marrow is a relatively simple process, marrow extraction has been a widespread human practice since earliest times. Grease is another source of fat, found within the cancellous bone. Compared to marrow extraction, much more work is needed in order to obtain grease. The cancellous bone must first be broken and then the bone fragments boiled in pots for some time (usually hours). For this reason, marrow extraction is more cost effective than grease processing (Munro and Bar-Oz 2005), and the degree of bone fat removal can be taken as a measurement of intensity of animal resource utilization (e.g., Munro and Bar-Oz 2005; Outram 2001; Peres 2018).

Long bones of cattle and pigs are most suitable for such a discussion. The completeness of limb bones can be reflected by proportions of wholly preserved long bones, long bone ends, end-shafts, end-splinters (Table 7.1 in Chapter 7). Based on the analysis done in Chapter 7, for both cattle and pigs, there was a portion of long bones that were processed and cooked whole, while many were broken from the midshaft, and it was quite rare to further fragment an articular end.

That is, roughly speaking, the intensity of bone fat exploitation was low. It seems that marrow removal was a frequent occurrence but did not always take place, while bone grease in spongy bones was of little importance compared to meat extraction and was not often purposely extracted. In another words, the Guandimiao residents were not starving for animal fat[89] (although the efficiency of tools is also a minor factor as is discussed later in Section 8.1.2 of this Chapter). Considering the evidence of bone breakage, it is very likely that boiling was the main way to remove bone marrow (and grease), and some bones were broken in order to fit cooking pots (which is further discussed in the following Section 8.1.1.2), which also indicates marrow and grease extraction may have been a outcome of general cooking preferences.

8.1.1.2 Maximum Bone Dimension, Cooking Pots, and Pot-sizing

If boiling was a main technique for animal food cooking, the dimension of cooking pots can have a very direct influence on body part dismemberment during food preparation. Bones have to be reduced to the degree that they can fit into a pot (Oliver 1993:210). Such cooking-related bone breakage is called pot-sizing (Marciniak 2005:150). The dimension of resulting bone chunks can vary according to carcass sizes and element types. In most cases, pot-sizing is necessary especially for large carcasses and big elements (Halstead 2007; Marciniak 2005). In order to interpret the intensity of butchery, as well as to understand the relationship between carcass processing and cooking (figuring out the importance of boiling for meat cooking), a relatively

[89] Although cultural preferences may have played a role in the avoidance of some cooking techniques and resource exploitation, minimally it can be said that the villagers of Guandimiao did not fully utilize bone grease resources.

simple comparison of the dimension of bone specimens and the size of cooking pots (*li* triopods 鬲) are considered in this section[90].

8.1.1.2.1 *Li* Tripods – the Dimension of Cooking Vessels

200 specimens of *li* tripod from 138 pits in the residential area of Guandimiao were randomly selected and measured. The value of the rim diameter and that of the orifice diameter are highly correlated (p = 0.000). All the samples were grouped into three clusters by taking a K-means cluster analysis (Chart 8.1). As shown in the chart, many specimens (153 pieces, 76.5% of the total specimens) from 120 pits represent small and medium *li* tripods, with a rim diameter of 120-240 mm and an orifice diameter of 85-180 mm. 47 specimens (23.5% of the total specimens) from 46 units represent larger pots[91], with a rim diameter of 225-300 mm and an orifice diameter of 170-260 mm. The rim diameter is usually close to the maximum width of the body (in the middle of a vessel) and the maximum height of the tripod and so indicates the capacity of the tripod, which refers to the maximum dimension of food for cooking. The orifice diameter represents the actual openness of a tripod, which has impact on the efficiency of placing food into the pot (Reinhart 2011: 112). The three groups can roughly match modern experience of daily life. Usually, a cooking pot of around 180 mm in width can be used by one or two people to cook noodles, porridges or soups, a pot smaller than this size (usually 140-160 mm) can only meet the need of a single person[92], pots of around 240-260 mm are suitable for 3-5 people, and other larger pots can

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[90] *Li* tripods dominate in the Guandimiao ceramic collections and there were only a few *guan* 罐 and *yan* 甗 which were also possible to be used for cooking, while a small portion of other types of ceramics. Therefore, *li* tripods were the most possible candidate of cooking wares (as has discussed in Section 4.3)

[91] Large ceramic vessels less likely to be preserved or identified than smaller ones since they are easier to be broken to tiny pieces which makes the recovery of even the whole orifice a tough job. Thus, the proportion of large *li* tripods is possibly more or less underrepresented, and there may be a few even larger tripods that haven't been included.

[92] For ancient people, who may have consumed more staple food than people today, a pot smaller than 180 mm in rim diameter may not be big enough for cooking.

be used to serve more people[93]. Besides, some very small *li* tripods (such as those smaller than 140 mm in rim diameter) are unlikely for cooking meals and may have served some other purpose. If my modern estimates are analogous to ancient times[94], a large part of the *li* tripods should be for groups of 2-4 people (or 1-5 people at most), which may indicate the regular capacity of local households (also be discussed later in this chapter), while cooking for a large group by using large *li* might not be that common.

[93] Information is collected based on my own experience and various instructions shown on Jingdong (https://www.jd.com, one of the largest e-commerce websiteas in China).

[94] The large deviation inside each cluster of the Guandimiao data may reflect the hand making process in ancient times and/or biases caused by imprecise recovery based on pot sherds.

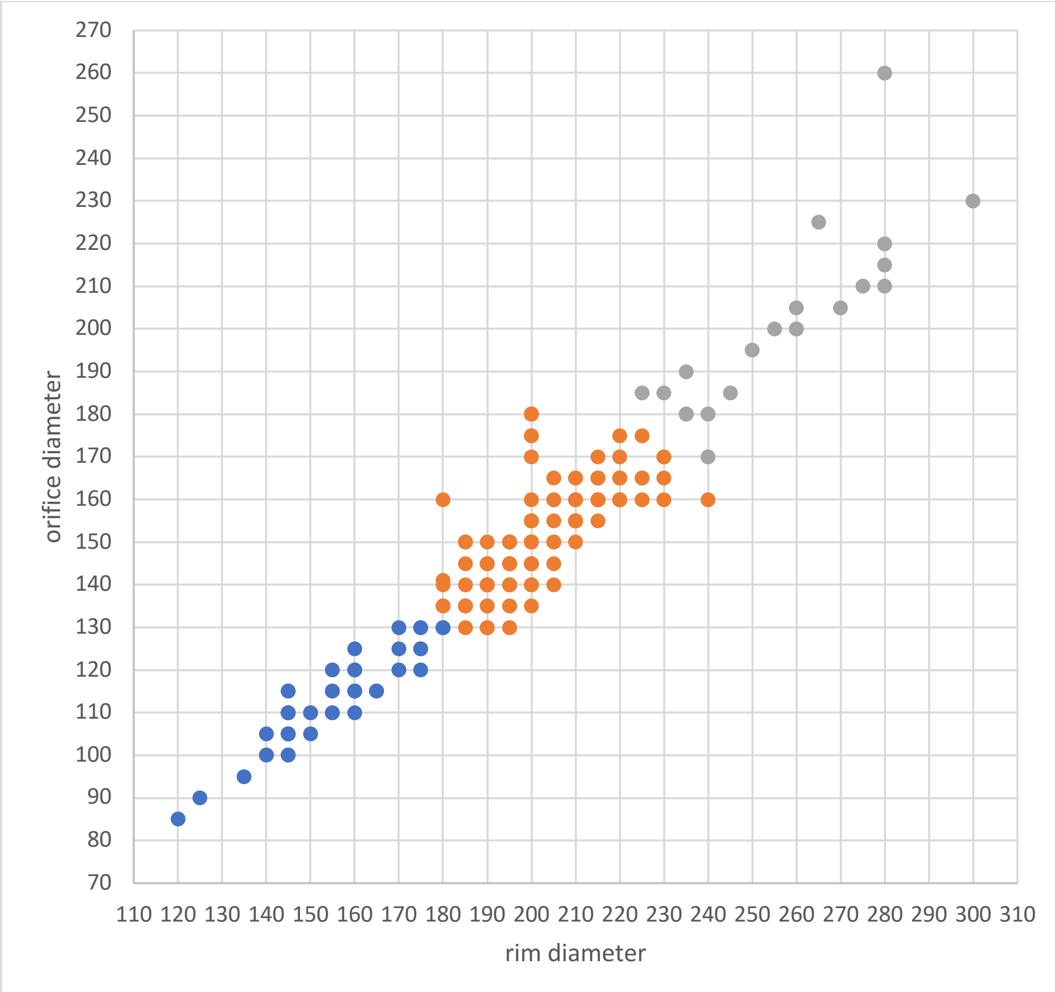

Chart 8.1 Guandimiao li tripods: rim diameter vs. orifice diameter[95] *(mm)*

8.1.1.2.2 Cattle

Based on results of the taphonomic study and related analysis in Chapters 6-7 and Section 1.1 of this chapter, bone fragments with old breaks can roughly represent bone chunks which were processed and cooked. It is quite possible that boiling was the main technique of meat (and bone) cooking (refer to discussions in Chapter 4, 6, 7, and in the following Section 1.2 in this chapter). Therefore, specimens with old breaks are selected in this section to study pot-sizing.

► Limb bones (humerus, radius, femur, tibia)

[95] Some specimens of the same size were shown as one overlapped dot in the chart.

Limb bones are some of the longest and meatiest bones. They are crucial evidence for studying the relationship between bone fragmentation and cooking vessels. As mentioned in Chapter 7, specimens of whole long bones, long bone ends, end-shafts, end_splinters, and shaft_cylinders are included in this study.

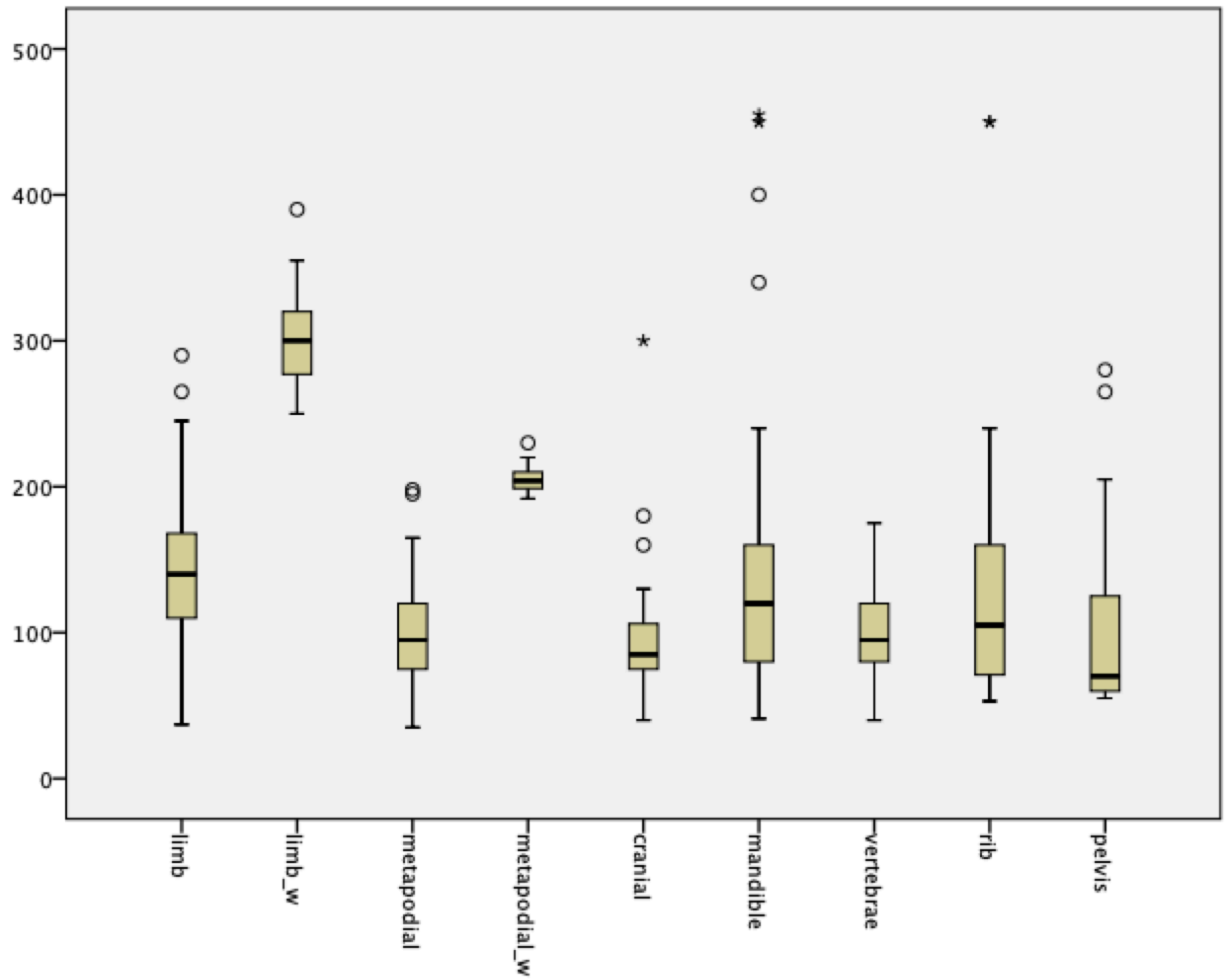

Chart 8.2 Guandimiao: dimensions (mm) of old-broken specimens of cattle[96]

[96] Limb = fragmented limb bones, limb_w = wholly preserved limb bones, metapodial = fragmented metapodials, metapodial_w = whole metapodials.

Distributions of the maximum length of long bone specimens are shown in Chart 8.2 (also refer to Appendix II for more details). The separation of whole long bones and long bone fragments in length is clear. The wholly preserved long bones (13 specimens) are 240-400 mm long. Except six specimens, all the other fragments (103 specimens) have a length <220 mm, and most of them are in the 80-180 mm range ($p = 0.703$) which is about 1/3-1/2 the length of a whole bone. As I have argued in Chapter 7, most of the limb bones may have been broken in the middle shaft to create two halves.

In order to study pot-sizing by the dimension of bone fragments, several factors should be taken into account. In the stage of cooking preparation when these bone segments were fresh, the bone-in meat joints would have been larger (with articular cartilage covering the end of the epiphysis and quite possibly some meat scraps attached on the bone even if most meat had been filleted). Also, it is usually required that some space be left in the tripod when it is filled with bone chunks. Therefore, if 100 mm (based on my cooking experience) is left as a buffer zone, a cooking *li* tripod with a maximum body diameter (roughly represented by the rim diameter of the same pot) larger than 180 mm could have been used to cook some of the single long bone meat joints while a tripod of 280-300 mm width in its rim and body should be large enough to cook most of the individual fragments. However, if the efficiency of cooking is considered at the same time, the orifice diameter of a tripod should also be taken into account since the open is a little bit narrowed compared to the body. In order to easily put a meat joint into a *li* tripod and take it out again, the orifice diameter should also have to be close to 180 mm or larger while the rim diameter of the same tripod should be around 200-230 mm or larger (the calculation is made considering the width of most *li* rims, referring to Chart 8.1). This is a very crude estimation, but it roughly corresponds with common sense cooking habits. Thus, some relatively large *li* were able to be used to cook cattle limb bones, and the large sized *li* were more likely to be picked when more than one piece of limb bone chunks was cooked. On the other hand, there was no tripod with a rim diameter larger than 300 mm recovered. Accordingly, the amount of meat joints cooked together in one large tripod should have been quite limited (perhaps a forelimb or a hindlimb or some similar volume of bones). In addition, the small number of whole long bones and a few of the largest fragments were too large to be cooked in any of the *li* tripods recovered. This suggests that at least some very large limb bone portions were cooked in other ways[97] (such as roasting, or even steaming[98]). In any case, it suggests that both the pattern of bone breakage and the degree of fragmentation are rather consistent for the four types of long bones. In sum, some logical connections can be developed based on the above analysis: a) if cattle limb bones were cooked in *li* tripods, they had to be broken into pieces in advance; b) long bones were only broken into large chunks to be cooked in some relatively large cooking pots and the intensity of bone fragmentation was not high (long bones were not purposely broken to small pieces for either grease extraction or fitting into small cooking pots); c) only a limited number of cattle limb bone chunks could be cooked whichever *li* was chosen[99].

► Other elements

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[97] Based on my rough comparison of ceramic *li* tripods from Zhengzhou Shangcheng 鄭州商城 (Henan 2001), Xiaoshuangqiao 小雙橋 (Henan 2012), and Anyang 安陽 (IACASS 1987, 2018), the largest *li* tripods are usually with a rim diameter around 300 mm and there are rarely any larger ones.

[98] Based on an observation of burning marks on the bone fragments (refer to Chapter 6), roasting couldn't be a popular cooking technique at Guandimiao.

I have observed some ceramic *zeng* 甑 steamer (as well as *yan* 甗) from Guandimiao site, the size and capacity of some steamers are larger than the largest *li* tripods of the same site. Therefore, there is a possibility that some large bones/portions were cooked by a steamer, though it may not be an efficient way compared to boiling.

[99] Even if cattle limb bones were cooked in other type of ceramic vessels (such as the *yan*, which may not be as common as *li* tripods in Guandimiao based on archaeological discoveries) or in other approaches, a similar argument can still be made.

As discussed in Chapter 7, cattle vertebrae were very likely cooked whole (keeping at least the general structure of the centrum and the vertebral arch). The maximum dimension is around 55-160 mm (24 fragments in a total of 29 measured specimens are 80-140 mm long). For metapodials, the pattern of breakage and fragmentation is comparable to that of the discussed limb bones, even though the metapodial specimens are much smaller on average. The situation of other large elements (mainly cranium, mandible, rib, and pelvis) is the same (Charts II-5, II-7, II-9; and Table 8.1). Most remains are fragmented element portions which are ≤180 mm, while a small number of specimens (e.g., mandibles, ribs) are nearly wholly preserved bones. There is no evidence showing a concentration of very large/small fragments in particular features while it is common to see a few fragments of diverse elements (long bones, vertebrae, ribs, cranial bones and mandibles, girdle bones) mixed together in the same unit (refer to a discussion in Chapter 6). Thus, it is very likely that fragmented cattle bones, including long bones and other elements, were cooked in the same way -- mostly boiled in large *li* tripods, while, considering also the small portion of large *li* presented, cattle bone cooking and eating couldn't be a very frequent occurance in the daily life of small groups. In other words, we need to further consider the possibility that beef was cooked, consumed and/or distributed in a relatively large group in some special events, which is discussed in the next section of this chapter.)

Table 8.1 Dimensions (mm) of old-broken specimens of cattle

	NISP	Mean	Median	Std. Dev	Minimum	Maximum
H-F-R-T	96	138.67	39.628	140	245	40
Cranium	25	105.3	90	50.63	45	300
Mandible	44	133.1	125.5	58.43	50	340
Vertebrae	29	101.5	95	24.77	55	155
Rib	20	143.3	105	115.72	53	450
Pelvis	11	107	70	72.53	55	280
Metapodial_fragment	52	98.6	95	32.5	50	198
Metapodial_whole	9	206.1	204	12.22	192	230

Note: specimens with old breaks and a maximum length of ≥40 mm are included.
Cranium: 23 specimens are 40-180 mm long, and 16 specimens are 80-180 mm.
Mandible: 36 specimens are 40-180 mm long, and 25 specimens are 80-180 mm.
Vertebra: all measured specimens are 40-160 mm long, and 25 specimens are 80-160 mm long.
Rib: 16 specimens are 40-180 mm long, and 10 specimens are 80-180 mm long.
Pelvis: 9 specimens are 55-125 mm long, and the other two are longer than 200 mm.
Metapodial_fragment: all measured specimens are 40-180 mm long, and 37 specimens are 80-180 mm.

8.1.1.2.3 Pig

Because of the severity of canine caused attrition, a general estimation is made here instead of a discussion of the specific dimensions of specimens.

As discussed in Chapter 7, pig limb bones are usually either wholly preserved or broken into two halves. Several whole limb bones in the Guandimiao assemblage[100] are measured, and the maximum lengths range around 130-220 mm. Half of a limb bone should thus be around 65-110 mm long. When the capacity of a cooking pot is considered, most of the medium-to-large sized *li* tripods were suitable for bone-in pork cooking, while some larger limb bone chunks may have been either boiled in some large *li* tripods or cooked by using other techniques. The other elements were possibly cooked in similar ways considering the maximum length of various fragments[101] although it is unclear if different body parts were cooked together or separately to make different cuisine.

In other words, for both cattle and pigs, the patterns of bone breakage and fragmentation in pre-consumption butchery are quite similar (as discussed in Chapter 7). There seems to be a

[100] In Guandimiao, there are no whole pig limb bones recovered from domestic contexts, while all the whole specimens are from the ritual contexts where some sacrificial pig skeletons were found.

[101] Among old-broken specimens of pig (as well as some non-herbivorous medium sized 2 mammals) which bear no clear dog's gnawing marks, 83 of the total 95 cranial fragments are 40-120 mm long (Chart II-8); except several whole mandibles, 162 of the total 166 mandible fragments are 40-180 mm long (Chart II-10); 44 of the total 48 vertebra fragments are 40-100 mm long; and 23 of the total 27 pelvis fragments are 60-140 mm long. The maximum dimensions of these specimens roughly overlap with that of limb bones. This is not a rigorous calculation of the original size of meat joints before cooking but can more or less reflect the distribution of dimensions of bone fragments.

tendency toward the minimum modification of body parts (especially limb bones and vertebrae) in the process of food preparation, so that most bone chunks are relatively large. Thus, in terms of cooking preparation, the intensity of butchery appears to be low. For this reason, only some *li* tripods were suitable for bone-in meat cooking. A comparison of the maximum bone dimension to the (rim and orifice) diameters of *li* tripods raises the possibility that cattle bones were cooked singly in some medium sized *li* or (sometimes?) several pieces were prepared in large *li* tripods, while it is quite possible that more medium-to-large sized tripods were used for pig bone cooking (although it is unknown if specific-sized pots were preferred in practice). In either case, only a few bone chunks can be cooked together at one time in a *li* tripod. Moreover, given that there are some large/whole elements and portions, there must have been other methods of meat cooking (as discussed above), which may not have been adopted as frequently as boiling.

8.1.2 Butchery Marks

The relative proportions of the main types of butchery marks are roughly similar for cattle (Table III-2) and pigs[102] (Table III-3), and for all large and medium-sized mammals at Guandimiao (Table III-1). While cut marks are prevalent throughout the species and elements, chop marks (+ shear marks) and scoop marks are much less frequent. This roughly supports the conclusion in Chapter 7 that cattle and pigs were butchered in a broadly similar manner. At the same time, there are some key differences in the type and location of the butchery marks on cattle and pig skeletons (as a whole) as well as on separate elements and portions. In this section, these differences are discussed in detail in order to trace the possible butchery tools, techniques, and traditions, as well as related cooking and eating preferences.

[102] When chop and shear marks are calculated together as butchery marks caused by heavy chopping tools, there is no difference between cattle and pig bones in terms of the distribution of butchery marks (χ^2 = 104.540, p = 0.000).

8.1.2.1 Differential Occurrence of Butchery Marks by Species

The incidence of specimens with butchery marks is higher in cattle than in pigs. To be specific, when the incidence of certain butchery marks is calculated as the proportion of specimens with a certain type of butchery mark among the total number of specimens, incidences of all four types of butchery marks are higher for cattle than for pigs (see values in the row "Incidence of butchery marks" in Tables III-2 and III-3), and so is the percentage of specimens with butchery marks within the total number of the species, and, for most elements (except some vertebrae), the percentage of specimens with butchery marks among the total number of elements (see values in the column "Butchered bone (%)" in Tables III-2 and III-3). At the same time, cattle bones have butchery marks relatively equally distributed on various elements (including both large and small elements), which differs from pigs where most of the butchery marks occur on large elements only (see values in the column "Butchered bone (%)" in Tables III-2 and III-3)[103]. The frequency of butchery marks can be roughly an indicator of workload (since there is no obvious difference in terms of butchery tools and techniques) and more work was needed to butcher a cow than a pig, a fact likely explained by their different body sizes. Furthermore, it can be inferred that most cattle elements were filleted and disarticulated, while some articulated elements (such as the fore and hind feet with metapodials and phalanges) of pigs may be treated as one unit during butchery.

8.1.2.2 Differential Occurrence of Butchery Marks by Elements and Portions

In this section, the type and location of butchery marks on individual elements is analyzed separately based on Tables III-2 and III-3 (for a calculation of butchery marks on elements), while the treatment of some element portions is discussed based on Tables III-4 and III-5 (for a

[103] There is very serious taphonomic damage to pig bones and many small compact elements are missing. However, at least pig metapodials and calcaneum are available for study of butchery marks considering their sample sizes.

calculation of butchery marks on some element portions), and the general pattern is summarized then. Even though taphonomic attrition is always a source of bias, especially for pig bones, this discussion is still meaningful since, for most elements, more than 10 specimens are available for observation.

The distribution of four types of butchery marks are as follows:

(1) *Cranium* For both cattle and pigs, there are only a small portion of cranial fragments (compared to other elements) with butchery marks which are composed of more chops and shears than cut marks. These are very typical remains of cranium fragmentation. Even those specimens without butchery marks were also very likely broken by humans considering the density of cattle cranial bones.

(2) *Vertebrae* For cattle atlas and axis and pig atlas, the incidence of butchery-mark-bearing specimens is rather high, and the marks are regularly distributed. These marks indicate certain patterned butchering processes, quite possibly the activity of severing the head from the body, while some filleting may have been done at the same time. However, while pig atlases show only cut marks, cattle specimens show both cut and chop marks. In addition, butchery marks on the lumbar vertebrae of pigs are clustered on the ventral side of transverse processes, as discussed in Chapter 7, probably for muscle removal.

(3) *Ribs* Because the different degrees of identification, most rib specimens of cattle and pigs are those with/close to rib heads and the connected square rib bodies, where a cluster of butchery marks are concentrated. As discussed in Chapter 7, some of these marks indicate a method of shearing off the rib slabs from the vertebral column, some are related to the activity of chopping a whole rib into small sections, and a few other marks may be produced by filleting and

eviscerating. Based on the frequency of butchery marks, less work was probably done on pig ribs than those of cattle.

(4) *Pelvis* Most cut marks are distributed around the acetabulum, which should represent leg disarticulation. It is obvious that more strokes were given to cattle pelvis than pig pelvis in order to cut off the ligaments around the hip joint. On the other hand, filleting may not have left many clear marks on other parts of a pelvis.

(5) *Long bones* Cut marks also dominate on the four main limb bones (humerus, radius, femur, and tibia). When such marks on the two ends could be caused by either disarticulation or filleting, other marks on the shaft should be related to meat removal. Given that. cattle limbs are much larger than those of pigs, it is reasonable to see that, on average, there is a larger portion of specimens with cut marks in the subset of cattle bones. On the other hand, comparing frequencies of cut marks on articular ends and those on shafts, there is no clear difference on cattle bones, while there is a trend on pig bones where articular ends tend to hold a higher frequency of cut marks (especially based on a calculation of humerus, although without a serious statistic test). One explanation is that more filletings were done on long bone shafts of cattle than those of pigs considering the bone size and also that some pig bones could have been wholly cooked.

(6) *Tarsals and metapodials of cattle* As mentioned in Chapter 7, high incidences of butchery marks (especially cut marks) on calcanea, tali, and metapodials indicate the fore- and hind-limbs of cattle were usually separated from legs, and tendons skins were very likely removed.

The above detailed analyses show that types and incidences of butchery marks were closely related to body parts and anatomical locations. The distribution of four types of butchery marks can offer rich information on several aspects of carcass butchery.

(A) Skeleton portions with the highest incidence of butchery marks are mainly joints, such as atlas and axis (head-neck joint), ankle (and wrist) joints, and joints of vertebral column and ribs (around rib heads), as well as joints of limbs. These marks are mainly remains of disarticulation during the primary and secondary butchery stages, and they can indicate the most prevalent butchery approaches and/or the major labor investment, which were more or less standardized activities. Moreover, the relatively low incidence of butchery marks on some elements can also reflect some usual butchery methods, such as the fragmentation of cranium for food preparation and pig's wholly preserved metapodials and phalanges.

(B) Since the anatomical location of butchery marks and the purpose of butchery activities are highly related (Bunn 2001), the function of location-related butchery marks can be discussed, and frequencies of four types of butchery marks can further suggest the possible types of related butchery tools being used. Cut marks appear widely and constantly on various elements and locations for purposes of disarticulation (by cutting off the ligament around joints), filleting (also including tongue removing and eviscerating, by cutting on limb bone shafts, around vertebrae and rib blades, and along the mandibular body), and skinning (on extremities). A few chop and shear marks (both heavier butchery marks) are mainly seen on certain portions of cranium, mandible, ribs, pelvis (shafts), and limb bones, which suggest that these marks are most likely the remains of element dismemberment (and sometimes filleting) in the secondary and/or final butchery stages. For cattle, there are even fewer chop marks on limb bone ends which may be related to the disarticulation of limb bones. Thus, some inference concerning butchery tools can be made -- Guandimiao butchery tools were composed of mainly cutting tools, while heavy tools were used relatively rarely.

(C) The analysis suggests that filleting activities, represented by some cut marks and scoop marks, were only done when necessary. On both cattle and pig bones, scoop marks are the most direct evidence of filleting, and the incidence of scoop marks is extremely low[104]. For cattle, the incidence of butchery marks on vertebrae (represented by cervical vertebrae) is close to that of limb bone shafts. Considering the more complex structure and uneven bone surface of vertebrae compared to limb bones, this result indicates that filleting on cattle vertebrae was not as intensive as that on limb bones (refer to Grody 2016). Similar situations can be observed on cervical and thoracic vertebrae of pigs. For pig lumbar vertebrae, butchery marks are highly concentrated on the ventral side and may be related to the removal of the main muscle nearby. Filleting marks on cattle and pig pelvis are also rare. In a word, the intensity of filleting is low, which indicates many bone chunks were cooked with a layer of flesh covered on the surface. To go further, this distribution pattern of butchery marks support that most of these marks were generated in the stage of carcass butchery and food preparation rather than consumption[105].

8.1.3 Summary

Butchery patterns of cattle and pigs in Guandimiao have been compared in several ways and can be discussed with a considering of cooking and eating activities. According to detailed analyses in Chapter 7, the final products of cattle and pig carcass butchery are quite similar in terms of the pattern of bone breakage and the degree of fragmentation. Based on a comprehensive study of the morphology, length and completeness of long bone specimens mainly and other bones, and a comparison of dimensions of specimens and capacities of *li* tripods, it can be inferred that

[104] Crader (1990) and Landon (1996) also have mentioned scrape marks as remains of filleting. According to my observation, such marks are even less frequent than scoop marks in Guandimiao assemblage.

[105] Also, it is argued by some scholars that cooked muscles and joints are rather soft and easy to be disarticulated and filleted, so that few marks can be left on bones (Binford 1981; Isaakidou 2007), and most marks should be generated in the butchering process.

the intensity of cattle and pig carcass butchery was low. It seems that animal meat, rather than bone fat, was the primary concern during body part processing, cooking and consumption (however, the existence of many whole limb bones (refer to Chapter 7) indicates that marrow was not always extracted and used), while bone grease in spongy bones was usually ignored. Meanwhile, for both cattle and pig carcasses, only necessary butchery and breakage was made, and the aim of butchery was not always to fit meat joints into various cooking pots. This is the case especially for cattle butchering that only some especially large *li* tripods (which take a small portion in the total *li* tripods) were usable for bone cooking and the size of bone fragments cannot be adjusted flexibly, while there was possibly more freedom to choose medium or large *li* tripods for pig bone cooking. Animal butchery may be limited by available butchery tools, or local habits and preferences, which is further discussed in Chapter 11. Considering the situation of bone modification, bone-in meat stewing is likely the most common cooking method, while some other cooking techniques should also have been adopted at least for cooking some very large meat parcels or even body parts/carcass (which indicate the appearance of varied recipes).

The distribution of butchery marks on cattle and pig skeletons further supports a similar treatment on both cattle and pig carcasses. On the one hand, the type, location, incidence, and possible function of butchery marks on both cattle and pig bones are quite similar, which indicates similar procedures and techniques of carcass disarticulation, filleting, and bone fragmentation. On the other hand, for most elements (especially long bones), the higher incidence of butchery marks on cattle bones than on pig bones can be explained by body size – in order to separate the connected elements or cut meat off from a particular element, more work is needed for cattle than pig bones. Accordingly, it can be argued that there may have been a roughly standard butchery procedure and a stable set of butchery tools for both cattle and pig butchery, in which cutting tools played a main role and heavy chopping tools were limited in use. Furthermore, the rather regularized distribution of diverse butchery marks probably indicates the appearance of some experienced (but not necessarily specialized) butchers.

8.2 The Nature and Social Scale of Cattle and Pig Carcass Butchery and Consumption

In Chapter 7 and the first section of this chapter, most work has been done to give a description and analysis of the technique details of carcass butchery and meat cooking. This section is a summary and extension of the previous results based on Halstead's model (2007), which mainly aims to make a systematic discussion on questions related to meat distribution and consumption.

► A general discussion of the composition of species

As has been frequently mentioned, three domestic animals -- cattle, pigs, and dogs – were the main source of meat in Guandimiao. Some small individuals, such as dogs and some neonatal or very young pigs (and maybe also infant cattle) were consumed freshly by a small group of people (e.g., a single household). Considering the carcass size, these individuals were small enough to be consumed over a short period of time. It was very common at Guandimiao that several bone fragments of neonatal or very young pigs were recovered together in one pit, indicating the possible deposition of a whole skeleton in one pit (because of various forms of taphonomic attrition, it is rare to discover a whole skeleton). Judging by the observed butchery marks, at least some of these individuals were discarded after consumption[106]. A similar situation is also seen in a few pits with some dog fragments of some young and adult individuals. Even though the ratio of such bone

[106] It is possible that many very young individuals were not purposely culled by people but died after birth or because of animal disease. However, the appearance of butchery marks on some specimens proves that at least some of them were processed and consumed.

fragments in the assemblage is small, considering the possible taphonomic biases, such meat consumption may not have been rare in Guandimiao. Based on an analysis of patterns of bone breakage and butchery mark distribution (refer to Chapter 6 and 7 for related information), small carcasses tend to be less modified than large individuals, and most elements of small animals were possibly wholly preserved for cooking. These individuals were small enough that they were able to be cooked in some medium to large *li* tripods (without special restriction to cooking pots). In the following, the possible contexts of subadult and adult cattle and pig consumption are discussed.

► The possibility of wasteful consumption of fresh carcasses

Most cattle and pig specimens are subadult or adult remains. Based on my observation, it is unlikely that any large yearling or older cattle or pig carcass was wastefully consumed in a household in a short period of time. Firstly, there is no evidence of the concentration of bone fragments from the same individual or large body parts in one unit. Around 3800 bone specimens in total (with a maximum dimension of 10+ mm, referring to Table 6.1 in Chapter 6) were collected from 430 units (including 9 houses and 384 pits). That is, in most cases, there were only a very small number of bone fragments in a unit, which usually contained a mixture of various cattle and pig elements. There are only a few cases where several pieces of connected elements (such as several connected vertebrae, a distal tibia and several connected tarsal bones) were from the same unit. As discussed in Chapter 6, these patterns cannot all be attributed to taphonomic attrition. Considering the archaeological contexts – houses and ashpits scattered on the site without evidence of special concentration - the remains of these units were possibly daily waste from houses nearby. Thus, if for a certain period, food waste from a household was discarded in a fixed place, the *in situ* distribution of animal remains doesn't support wasteful carcass consumption. Secondly, there was no selective consumption of meat-rich portions or some other special parts. Based on my study, for both cattle and pigs, all types of elements and various forms of animal nutrients (such as muscles and tendons, marrow, brains) were processed and consumed. Thirdly, although the intensity of bone grease exploitation was low and there are some wholly preserved elements (especially long bones), they have no necessary connection with wasteful carcass consumption. In addition, the discovered daily cooking pots and possible number of consumers (refer to the analysis in the first section) does not match a wasteful consumption model.

► The possibility of meat preservation for domestic consumption over an extended period

There may have been some body parts or filleted meat preserved for domestic consumption over a prolonged period. Some approaches to meat curing, which may have been popular in the Chinese Bronze Age, have been recorded (refer to a summary in Chapter 4). The cold winter in Central Plains is also helpful for meat preservation if an animal was butchered during the winter months[107]. However, it was unlikely that cattle or pig carcasses as a whole were preserved and then consumed by a single household. This can be understood based on a consideration of archaeological contexts (as listed in the above section).

► The possibility of fresh carcass consumption in an extended group

The most common way of cattle and pig meat allocation and consumption was likely that a carcass was dismembered, and meat was shared in an extended group with several households. This is supported by an analysis of the archaeological context of bone preservation (see the beginning of this section) and a discussion of the maximum bone dimension, cooking pots, and

[107] It is problematic to study butchery season based on animal age profiles. However, if pigs in Guandimiao were born in spring and only one litter was produced per year, the slightly higher mortality in 8-12 months than in 6-8 months or 12-18 months (Hou et al. 2019) may support the idea that many pigs were slaughtered in winter even though pig slaughter was a year-round activity.

pot-sizing (refer to the first section of this chapter). Nevertheless, the social contexts/meaning of meat sharing and consumption were likely complicated.

Specifically, in daily life, the basic unit of meat cooking and consumption should be in small groups, and there was little difference between households in the quality and quantity of meat resource acquired. Considering cooking pots were dominated by medium sized *li*, animal remains were scattered evenly around houses in the site, and most pits contained only a small number of bone fragments, it is clear that households had an equal chance to get cattle, pigs, and other species for food, while each household may have consumed only a small number of bone-in meat joins of various elements. Therefore, it can roughly be said that people living in small houses (households) should have consumed similar meat resources.

On the other hand, the comparison of cattle bones and *li* tripods above indicate that meat resources, especially beef, in households were possibly obtained via distribution among a large group/organization (e.g., the village as a unit) in some public events (e.g., sacrifice, feasting, festival), or by reciprocal exchange in a small group. As analyzed in the first section, cattle bones should have been cooked in some relatively large *li*. Two situations may have occurred. One possibility is that the most commonly seen medium sized *li* were taken to process many beef chunks (possibly one or two pieces each time) in a household. It also possible a large sized *li* was used to cook more bone chunks – considering the usual small number of cattle bones recovered from a pit and the small proportion of large sized *li* tripods, the cooking activity could have happened somewhere else while at least some of the cooked beef may have been taken back to be consumed domestically. In either case, some process of meat distribution was needed.

In Guandimiao, considering the limited capacity of meat resource production and consumption it is unlikely there was a meat market, while some kind of public events or reciprocal activities may have played such a role. This hypothesis is partly supported by discovered sacrificial remains in the southern part of the site (refer to Li et al. 2008a; Li et al. 2008b; Li and Zhu 2009; Li et al. 2018, and an introduction in Chapter 3). The assemblage from some ritual related pits includes wholly preserved cattle and pig carcasses (with butchery marks), as well as some dismembered body parts and bone fragments of both species (Hou et al. 2019). This indicates that feasting activities were sometimes taken place as a part of the sacrificial events, which was commonly seen in later times (Warring States and Han periods). According to later texts, it is possible that some sacrificial meat (either raw or cooked) may have also been given to participants and consumed in households. Thus, some cattle and pig bone remains found in domestic contexts may be leftovers received from sacrifice/feasting, or they may even be from some whole sacrificial carcasses which were directly shared by households after sacrifice. The shared meat resources could be either fresh or cooked. In addition, another reasonable speculation is that some livestock might have also been butchered in a household and fresh and/or cooked meat was then shared among relatives, friends, and other related people, or some meat might have been given as a gift to others in some special occasions, as it is done in many traditional societies. Although the case of cattle consumption is much clearer, after a series of analyses and comparisons, a similar situation should also be seen in the case of pig consumption. On the other hand, considering the dimension of meat joints and the capacity of medium sized *li* tripods, it is very likely that, compared with bone-in beef, bone-in pork was more frequently cooked in Guandimiao.

CHAPTER 9: Xiaomintun: Patterning Cattle and Pig Butcheries and Interpreting Food Preparation

This work was done in collaboration with Zhipeng Li and Yuling He from the Institute of Archaeology, Chinese Academy of Social Sciences (IACASS), Beijing.

The aim of this chapter is a study of the intensity of carcass butchery and bone-in meat cooking, which may be related to specialization and the independence of urban residents (of lower status) in Xiaomintun and may be affected by diverse factors. Based on a small group of selected specimens from Xiaomintun, the discussion here is concentrated on the degree of fragmentation and the frequency of butchery marks, which are comparable with Guandimiao and Zhougongmiao. In order to have a complete understanding of the Xiaomintun assemblage, a very brief study of forms of taphonomic attrition is given first. Then, the pattern of bone breakage and fragmentation and the distribution of butchery marks are described and discussed to get a general view of the processing and consumption of cattle and pigs. Finally, based on these analyses and with a consideration of ceramic cooking vessels (*li* tripods), the intensity of cattle and pig butchery and processing is discussed.

9.1 Size and Composition of the Assemblage

For the recovery and study of animal remains at Yinxu and, specifically, at Xiaomintun refer to Li (2009, 2011a, 2011b). In this study, the 904 pieces of cattle bones and 935 pieces of pig bones (Table 9.1) selected were all from twelve ash pits[108] in the Xiaomintun collection which are stored in the Anyang workstation. All the bone remains are from subadult and adult individuals based on the condition of the bones, which are comparable with the majority of the remains at Guandimiao[109]. All the remains were collected by hand. Because most of the maxillae and mandibles, the whole long bones, and some other wholly preserved elements were curated separately, they are not included in the selected samples in this chapter.

Table 9.1 Xiaomintun: Frequencies of skeletal elements

(a) Cattle

Element	NISP	Portion	NISP
MAX	2		
MAN[110]	118		
CRANI.FR	10		
ATLAS	28		
AXIS	15		
CERV	34		
THOR	36		
LUMB	42		
SACR	12		
CAUD	3		
VER.FR	57		
RIB.FR	167		
SCAP	0		
INNO	53	INNO-01	11
		INNO-02	13
		INNO-03	36
		INNO-04	8
		INNO-05	1
HUMER	19	HUMER-01	9

(b) Pigs

Element	NISP	Portion	NISP
MAX	6		
MAN	51		
CRANI.FR	125		
ATLAS	19		
AXIS	11		
CERV	12		
THOR	35		
LUMB	48		
SACR	5		
CAUD	0		
VER.FR	1		
RIB.FR	58		
SCAP	80	SCAP-01	50
		SCAP-02	64
INNO	92	INNO-01	26
		INNO-02	32
		INNO-03	55
		INNO-04	40
		INNO-05	13

[108] Many pits in Xiaomintun are very large, and the fill has been divided into several layers which can also be treated as separated features. Animal remains studied here are from either one or several layers of an ash pit or a whole ash pit, which can be treated equally.

[109] Based on Li's (2009) study and my own observation, bone remains of very young individuals are rare.

[110] Because almost all the teeth-holding mandible fragments are absent, the recorded specimens are mainly fragments of the ascending ramus.

		HUMER-02	8
		HUMER-03	9
		HUMER-04	10
RAD	35	RAD-01	14
		RAD-02	17
		RAD-03	13
		RAD-04	19
ULNA	16		
FEMUR	21	FEMUR-01	8
		FEMUR-02	12
		FEMUR-03	12
		FEMUR-04	6
TIBIA	22	TIBIA-01	9
		TIBIA-02	11
		TIBIA-03	10
		TIBIA-04	7
MP3+4	64	MP3+4-01	30
		MP3+4-02	36
		MP3+4-03	43
		MP3+4-04	31
CARPL	7		
TARSL	14		
CALC	28		
TALUS	16		
PH1	40		
PH2	19		
PH3	20		
Other	6		
SUM	904		

HUMER	85	HUMER-01	20
		HUMER-02	30
		HUMER-03	66
		HUMER-04	52
RAD	25	RAD-01	15
		RAD-02	15
		RAD-03	20
		RAD-04	13
ULNA	40		
FEMUR	82	FEMUR-01	18
		FEMUR-02	32
		FEMUR-03	53
		FEMUR-04	46
TIBIA	77	TIBIA-01	35
		TIBIA-02	49
		TIBIA-03	39
		TIBIA-04	33
MP3/4	26		
CARPL	1	CALC	
TARSL	10	TALUS	
CALC	16		
TALUS	8	T-C+4	
PH1	1	PH1	
PH2		PH2	
PH3		PH3	
Other	21		
SUM	935		

Note: an element means a whole element, and a portion is a part of an element as described in chapter 5.

9.2 Destructive Taphonomic Processes (after human discard)

On consideration of the approach to sample selection and the main purpose of this chapter, a simplified study of forms of taphonomic attrition is feasible and useful. Similar to the Guandimiao assemblage, bones are generally well preserved in the loess soils (refer to Li 2009: 34-35 to see the general discussion of bone preservation in Xiaomintun). Although there are a few pieces (25/1839) of burnt bones and a small number of specimens (122/1839) with traces of bronze corrosion staining (since some waste of bronze production was found in the middens), they have almost no influence on the preservation and observation of specimens. The main form of attrition caused by taphonomic progresses are missing bones and breakage during excavation and curation, as well as animal gnawing after bones were discarded as food waste.

The maximum lengths of all the specimens are measured. All the specimens are larger than 10 mm, and most of them are 40+ mm. In addition, the small compact bones (carpals and tarsals of both cattle and pigs, and pig phalanges) are rare in the assemblage. This pattern fits a common expectation concerning identified specimens and is similar to that seen in Guandimiao. Their effects are assessed by comparing the fragment dimensions, different preservations of adjacent large and small bones/portions, and variant conditions of broken surfaces.

Table 9.2 Xiaomintun: Fragments with modern breakage (calculated by NISP)

	cattle	pig	SUM
Modern damage	564	642	1206
Serious modern damage	262	320	582
Modern damage (%)[1]	62.39%	68.66%	65.58%
Serious modern damage (%)[2]	28.98%	34.22%	31.65%

[1] Modern damage (%) = (fragments with modern damage) / (the total fragments of cattle/pig) × 100%, with "fragments with modern damage" defined as fragments that have portions/all original surfaces erased because of modern damage.
[2] Serious modern damage (%) = (fragments with serious modern damage) / (the total fragments of cattle/pig) × 100%, with "fragments with serious modern damage" defined as fragments that have lost at least one original end/break surface because of modern human activities and the original length at the same time.

Bone breakage during and after excavation is rather extensive. For the selected specimens, around 65.6% of the total bones exhibit new break surfaces, and 31.7% of them are seriously broken with the original ends/break surface(s) totally destroyed (Table 9.2). Among the seriously damaged specimens, it needs to be noticed that 57 cattle bones and 90 pig bones (most of which are long bones) have loose or missing epiphyses, which can partly explain the situation that pig bones are more severely destroyed than cattle bones ($\chi^2 = 5.839$, $p = 0.016$). Though some bias may exist because of the absence of some wholly preserved elements, the high incidence of bone breakage at articular ends can largely be explained by the harvest profiles of cattle and pigs indicating that the majority of the cattle and pig populations were killed in a relatively young age (Li 2009, 2011b). The impact of modern bone breakage and epiphysis loosening are discussed in the following analyses.

The incidence of gnawing marks (Table 9.3) indicates that actions of carnivores (dogs) and rodents have been a source of taphonomic attrition after bone discard at Xiaomintun. At the same time, although the appearance of rodent gnawing marks seems to be more frequent than that of dogs, only 5 cattle bones and 27 pig bones are seen with the breakage surface seriously damaged by rodents and rodent's gnawing activities in general only slightly affect the work of bone surface observation. In addition, dog gnawing is less frequent in the Xiaomintun assemblage than in that of Guandimiao based on the calculation[111], and there is no significant difference between cattle and pigs in term of the ratio of dog gnawed specimens ($\chi^2 = 2.574$, $p = 0.109$) which also indicates the relatively good survival of the assemblage after dog ravaging. For these reasons, it is highly

[111] The intensity of long bone end attrition (as introduced in chapter 5 and discussed in chapter 6) is not a good measurement of carnivore ravaging here, since a basic assumption for the approach to study the intensity of long bone end attrition is that the whole long bones have been left in the same site and have a potential to be broken by carnivores, while what is discussed in this chapter are only some selected specimens from several ash pits in Xiaomintun.

Nevertheless, based on a study of long bones, it can be observed that the impact of dog's gnawing is not that significant. (a) Not only for cattle long bones but also for those of pigs, many specimens retain well preserved articular ends (at least the metaphysis portion if the epiphysis is missing), which can be supported by comparing the number of preserved ends and that of the adjacent portion of long bone shaft (Table 9.1). (b) Even though there is no rigorous calculation at present, it is clear that most dog teeth marks are on the articular ends and such marks are rarely seen on long bone shafts, while many fragments have very regular fracture outlines (mostly transverse or spiral in shape) in the mid-shaft, which are evidence of dynamic impact quite possibly caused by human blows. (A description and discussion of similar types of long bone fragments can be found in many published resources, e.g., Gifford-González 2018: 203-224 and Martínez 2007.)

likely that most cattle and pig bone fragmentation in Xiaomintun was caused primarily by humans, which is a basis for the discussion of bone breakage in the next section.

Table 9.3 Xiaomintun: frequencies of carnivore (dog) and rodent gnawing on cattle and pig bones

	Cattle		Pigs		Sum	
carnivore	67	7.30%	84	8.98%	151	8.21%
rodent	230	25.44%	269	28.77%	499	27.13%

9.3 Bone Breakage and Fragmentation

Because of the severe modern damage (including missing epiphyses), bone fragments without serious modern damage and those retaining all or most of the old-broken fracture surfaces were given the highest priority in the analysis, while other specimens were also included when necessary. In addition, shear marks are considered as the most reliable evidence of anthropogenic bone breakage.

9.3.1 Long Bones

Table 9.4 Xiaomintun: Types of long bone fragments (calculated by NISP, excluding loose epiphyses)

		Cattle	Pig
Whole		8	11
Old break	End	6	1
	End-shaft	92	178
	End_splinter	4	0
	Shaft_cylinder	13	36
	Shaft_splinter	12	4
New break		9	19

Note: (a) For cattle, long bone fragments = fragments of humerus, radius, femur, tibia, metapodials; for pigs, long bone fragments = fragments of humerus, radius, femur, tibia. (b) Some specimens with epiphyses that fell off naturally during/after excavation are included[112].

In Table 9.4, the end-shaft specimens dominate in both cattle and pig long bones, suggesting many long bones were broken in the shaft. Meanwhile, the existence of some whole

[112] For cattle, there are only three completely whole metapodials. For pigs, there is one radius and one tibia which are fully intact. All the other "whole" specimens are all those with at least one epiphysis missing during/after excavation.

specimens shows a different pattern of long bone treatment (although the relative frequency is unknown due to the selection bias of the current data). Accordingly, the maximum length of long bone specimens can be an indicator of the degree of long bone fragmentation.

► Cattle

The maximum lengths of all of the 98 measurable long bone fragments are exhibited in Chart V-1. Most fragments are in the range of 60-160 mm. By comparing them with the length of some whole long bones in Xiaomintun[113], it can be argued that most fragments are about 1/3-2/3 the length of a whole bone. On considering of the distribution of types of fragments in Table 9.4, it is safe to say that most long bones were chopped into two or, sometimes, three parts, while metapodials were probably chopped into two halves. In fact, some specimens show chopping marks around the fracture surface on the long bone shaft, giving direct evidence of human breakage.

► Pig

The maximum lengths of all the measurable long bone specimens (137 fragments and one whole tibia) are grouped in Chart V-2. Most specimens (127 fragments) have a maximum length of 60-140 mm (mostly 70-120 mm), which is close to 1/3-2/3 the length of a whole bone when compared with the length of whole long bones recovered from Xiaomintun[114]. Thus, it appears that most long bones were broken in the shaft to divide each bone into two halves (e.g., Figure XI-9)[115].

[113] There were no completely whole humerus, radius, femur, or tibia in the selected specimens. Li (2009: 27-28) measured some whole long bones of cattle in Xiaomintun, seventeen radii range to 268-333 mm in length, and three tibiae are about 325-364 mm. So, it can be estimated roughly that a whole humerus can be around 290-365 mm and a whole femur can be around 345-395 mm. In addition, 94 metacarpals are 163-229 mm, and 39 metatarsals are 212-254 mm.

[114] Li (2009: 25-26) measured some whole long bones of pigs in Xiaomintun, three femur range to 224-250 mm, ten radii range to 130-159 mm in length, and twelve tibiae are about 180-216 mm (and the only whole tibia included in the selected sample group is 210 mm, as shown in Chart V-1). It can be estimated roughly that a whole humerus can be around 170-200 mm.

[115] As mentioned in Footnote 3, the fracture shape of the long bone shafts is also helpful for study of fragmentation – something which can be explored in further work.

9.3.2 Cranium

The cranial fragments of cattle are too rare to be analyzed.

► Pigs

Although there are about 70 specimens with modern fracture surfaces, the other cranial specimens are relatively well preserved with a few specimens retaining dog teeth marks. The maximum lengths of 56 measured specimens are in a range of 40-175 mm (Chart V-3).

Most specimens can be separated to three groups, and some of them bear clear sheared fracture surfaces, suggesting the approach of anthropogenic cranium fragmentation. As shown in Figure XI-10, it seems a pig cranium was divided to two halves roughly along the median plane, and each half was quite possibly split into three large parts – (a) an aboral part, including the posterior half of the frontal bone, the parietal, the occipital, the temporal, and (sometimes) part of the connected zygomatic bone (more than 20 specimens can be grouped to this subset, e.g., Figures XI-10a), (b) a medial part, including the anterior half of the frontal, the main portion of the zygomatic bone and the lacrimal bone, and sometimes related portions (at least 4 specimens are in this group, e.g., Figures XI-10b), (c) an oral part, including the premaxilla and the main portion of the maxilla (3 specimens). In addition, there are some specimens showing that part of the occipital (mainly the portion around the occipital condyle) was chopped off separately (at least 5 specimens, e.g., Figures XI-10c). Accordingly, although it is impossible to figure out the actual steps, the final pattern of pig cranial fragmentation is clear. With, however, the caveat that there is no specimen retaining the whole posterior half of a cranium as described for Guandimiao. Nevertheless, a logical deduction from this evidence is that the fragmented cranial bones were prepared for boiling.

9.3.3 Vertebrae

► Cattle

Many specimens are well preserved with few animal gnawing marks. The dimensions of the 123 vertebral specimens are shown in Chart V-4, which are highly concentrated into a range of 60-100 mm, while a few specimens are a little bit larger. In addition, based on bone dimensions, there is almost no distinction between different types of vertebrae in terms of the maximum length of a specimen, which may support a hypothesis of similar treatment during butchery and cooking.

Two types of atlas specimens are seen in the collection. Some atlases are relatively whole. Some other specimens retain only half of the bone, which are likely split by humans judging by the flat sheared fracture surface (Figure XI-11e). For axes, besides seven whole specimens, there are also four fragments showing transverse breakage of axis with sheared fracture surface (Figures XI-11c). For other cervical, thoracic and lumbar vertebrae, similar treatments appear on many specimens. They usually have the main structure of vertebral centrum and arch, while, quite often, the spinous process, the transverse processes (Figures XI-11a, 11b), and, in some cases, the cranial/caudal articular surface of the centrum are chopped off with clear sheared surfaces (Figures XI-11d), which quite likely represent efficient bone modification and disarticulation. In addition, some sacral vertebral fragments may indicate they were also chopped to chunks, while several specimens of caudal vertebral are all whole.

► Pigs

Except those suffering serious modern damage, most vertebral specimens (75 specimens) are in good condition, and the attrition caused by animal gnawing is rather weak. Generally, the pig vertebrae may have had the least anthropogenic breakage. Most of the vertebrae observed (atlas, axis, cervical, thoracic, and lumbar) are wholly preserved so that the dimensions of different types of vertebral fragments can be varied (Chart V5), and the spinous process and the transverse processes of some specimens were partly missing. Moreover, some specimens bear typical sheared surfaces on one (cranial/caudal) side of the bone (Figure XI-12), which should be direct evidence of vertebral column segmentation.

9.3.4 Rib

A large number of cattle and pig rib remains have been intensively modified by modern taphonomic processes, although animal ravaging seems not to be a major taphonomic agent in the sample.

For both cattle and pig rib specimens, it is common to find fractures with chopping marks (Figure XI-13) and definite sheared surfaces. Measurements of 106 cattle rib and 19 pig rib specimens in Chart V-6 show the dimensions of rib segments which were possibly preferred by the Xiaomintun residents. It turns out that there was no unique standard. Most cattle rib specimens are in the range of 60-160 mm, which is around 1/6-1/3 of a whole rib in length, while some specimens are much longer (the longest one is 460 mm, which is close to a whole rib). A similar situation is seen in pig rib remains such that many specimens are about 100-140 mm (about 1/3-1/2 the length of a whole rib) while other specimens are longer (the longest one is 230 mm, which is about 4/5 of a whole rib). Therefore, a possible interpretation is that ribs were butchered in various ways in order to cook different cuisines.

9.3.5 Scapula

Cattle scapula is not seen in my sample, which may be partly owing to the great demand for a production of oracle bones (Li 2009)

► Pigs

Only pig's scapula specimens appear in the selection, and most of them are well preserved.

Many specimens have quite a similar structure in that they usually retain a portion from the glenoid to a section of the blade, and some specimens have chop marks or chopped surface on the fracture edge (Figure XI-14). Accordingly, there appears to have been a regular way of chopping through the blade perpendicular to the scapular spine in order to prepare a scapula for cooking. Chart V-7 shows the maximum length of 43 specimens and most of them are in a range of 60-140 mm.

9.3.6 Pelvis

► Cattle

42 specimens are measured. Except a few relatively large (whole) specimens, several types of fragments are commonly seen. Beside four whole acetabulum, 32 fragments were found with only a section (shaft) of the ilium or ischium or pubis and the connected portion of the acetabulum (that is, only 1/3-1/2 of the articular surface presented; Figure XI-15). And several fragments of the connected portions also appear in the remains. Based on frequently seen chop marks and sheared fracture surfaces, it can be deduced that most of the fragments were remains of pelvis fragmentation by human, and that a pelvis of cattle was regularly divided into bone chunks as large as that of a pig pelvis although a few large specimens exist (Chart V-8).

► Pigs

60 specimens are measured (Chart V-8), including two main types of fragments (similar to what are seen in Guandimiao). Whole acetabulums were the most common and usually co-occurred with parts (shafts) of the ilium, ischium, and/or pubis. In addition, specimens of ilium and ischium portions not connected to the acetabulum were also frequently seen (Figure XI-16).

9.3.7 Small Compact Bones

For both cattle and pigs, almost all the selected small bones (i.e., carpals, tarsals, and phalanges) were kept intact.

9.3.8 Summary

Most of the selected specimens were relatively well preserved and many of them kept the original fracture surface(s) which enabled a description of the pattern of bone fragmentation and a discussion of reasons of bone breakage. For most elements of both cattle and pigs, the relative limited and stable morphologies of fragments as shown in this section imply that most of the breakage was quite possibly related to carcass butchery before consumption, since bone breakage during consumption tends to generate more variations in the morphologies of fragments. Therefore, by a study of the pattern of bone breakage and fragmentation, it is possible to distinguish the detailed treatment to some specific specimens, which are the direct evidence of butchery. Accordingly, summaries of fragmentation patterns of diverse body parts can also be a valuable reference of carcass dismemberment. For the breakage of cattle and pig body parts, there are traces of both similarities and distinctions. A comprehensive discussion is given in the following Section 9.5.

9.4 Butchery Mark Distribution by Element

Except mandibles, all the other specimens which have a relatively well-preserved bone surface are included for observation and calculation. The result is presented in Tables VI-1~Vi-4, based on which the following description and analysis are made. Except sheared marks/surfaces, most cut marks (in red line), chop marks (in blue line), and scoop marks (circled in purple) are depicted in figures (refer to figures in Appendix VII).

9.4.1 Cranium

► Cattle

Most of the specimens are too fragmented to reconstruct the butchery process. The existence of fragments with clear chop marks and sheared fracture surfaces indicates at least some cranial bones were chopped to chunks.

► Pigs

There are some specimens showing cut marks around the inferior of the zygomatic bone which are possibly related to cheek muscle removal and mandible disarticulation, as well as other specimens with cut marks on and around the occipital condyles which can be related to activities to free the head from the body. Besides, as mentioned in Section 9.3.2, many specimens with clear sheared fracture surfaces are the most direct evidence of cranium segmentation.

9.4.2 Vertebrae

► Cattle

Butchery marks are frequently seen on different types of vertebrae.

Atlas Butchery marks (mostly chop marks) mainly scatter on both the cranial and caudal edges of the bone, which may be related to head disarticulation. Some other marks indicate meat filleting.

Axis Only limited butchery marks are seen. Some butchery marks may be caused by filleting and/or dismemberment.

Other vertebrae For cervical, thoracic and lumbar specimens, incidences of specimens with butchery marks are all high and, in many cases, they may play similar roles in butchery in resulting from meat cut off the bone as judged by the locations of marks. At the same time, some chop marks and sheared surfaces may be evidence of bone fragmentation (as discussed in Section 9.3.3, e.g., Figures XI-11a, XI-11b, and XI-11d).

► Pigs

Atlas Many cut marks running across the cranial margin of the atlas are possibly related to the activity of severing the head from the body.

Other vertebrae There are a few cervical specimens with butchery marks, while butchered thoracic and lumbar vertebrae are relatively well represented.

In general, cut marks dominate on all the specimens, and they can be seen on both the dorsal and ventral surfaces. Cut marks on ventral sides of anterior and posterior articulator processes may be generated during the process of dividing the articulated vertebrae.

Such marks on the spinous process and the transverse processes are probably evidence of the major muscle groups being cut off.

9.4.3 Rib

For both cattle and pig rib specimens, many butchery marks on/close to proximal rib heads might be related to the activity of peeling off rib slabs from the vertebral column, while other marks in this location and marks on the body of a rib were likely inflicted by filleting or evisceration. Fragments with sheared fracture surfaces are evidence of rib breakage (as discussed in Section 9.3.4, and Figure XI-13).

9.4.4 Scapula

► Pigs

Cut marks are most seen and mainly located in three portions. Many of these marks are possibly the remains of filleting, while some marks around the glenoid cavity may be caused by cutting through the ligaments for the purpose of disarticulation and/or filleting. Chop marks, as well as sheared fracture surface, are mainly in the medial portion on the later side and transversely across the bone (e.g., Figure XI-14), which is definite evidence of scapula fragmentation.

9.4.5 Pelvis

► Cattle

Most cut marks are around the acetabulum and along margins of the ilium and ischium shafts, which are possibly related to activities of either femur disarticulation or filleting. Both chop and shear marks are seen on some ilium/ischium/pubis shafts and are closely related to activities of splitting the pelvis into smaller chunks which may happen in the stage of secondary or tertiary butchery.

► Pigs

Cut marks dominate on pig pelvises. Many butchery marks around the acetabulum and on the medial surface of the wing of ilium are very likely for disarticulation. Other cut marks may be remains of filleting. Chop marks probably indicate a purposeful breakage of the innominate into small segments (as discussed in Section 9.3.6).

9.4.6 Humerus, Radius-Ulna, Femur, and Tibia

In general, cut marks are the most common on the four limb bones, and chop and shear marks are also shown on some specimens, while only a few scoop marks are found on specimens (Tables VI-1 and VI-3). Similar to the situation of Guandimiao, the domination of cut marks on and around the articular surface and the wholly preserved articular end suggest that limb bone disarticulation was usually done by cutting off the ligament around the joints in order to separate the two articulated bones. It is so for both cattle and pigs. Some cut marks on the shafts were possibly generated by filleting.

Moreover, while a few chop marks around the articular ends may also be produced by activities of disarticulating and filleting, chop marks on the shafts of both cattle and pig specimens are directly related to long bone fragmentation relevant to the discussion of breakage pattern in Section 0.

9.4.7 Tarsals: Talus, Calcaneum, and Central-4th Tarsal

► Cattle

The distribution of butchery marks on bones around the ankle joint should be considered together and can indicate the approach of foot bone disarticulation. The prevalence of cut marks suggests the process of disarticulation was realized by cutting off the ligaments encircled the ankle joint.

► Pigs

The distribution of butchery marks on pig calcaneus and talus are roughly similar to that of cattle bones, which should also be related to disarticulation from the ankle joint.

9.4.8 Metapodials

For pig's metapodials, only one specimen is found with cut marks around the distal articular surface.

► Cattle

Butchery marks, mostly cut marks, are commonly seen around the bone shaft and on the two distal trochoid joints. Judged by location of butchery marks, these cut marks could represent activities of skinning or filleting (including tendon removing), and disarticulation. Chop marks are primarily on the midshaft and should be the remains of bone breakage, possibly for marrow exaction, which has been discussed in Section 9.3.1.

9.4.9 Phalanges

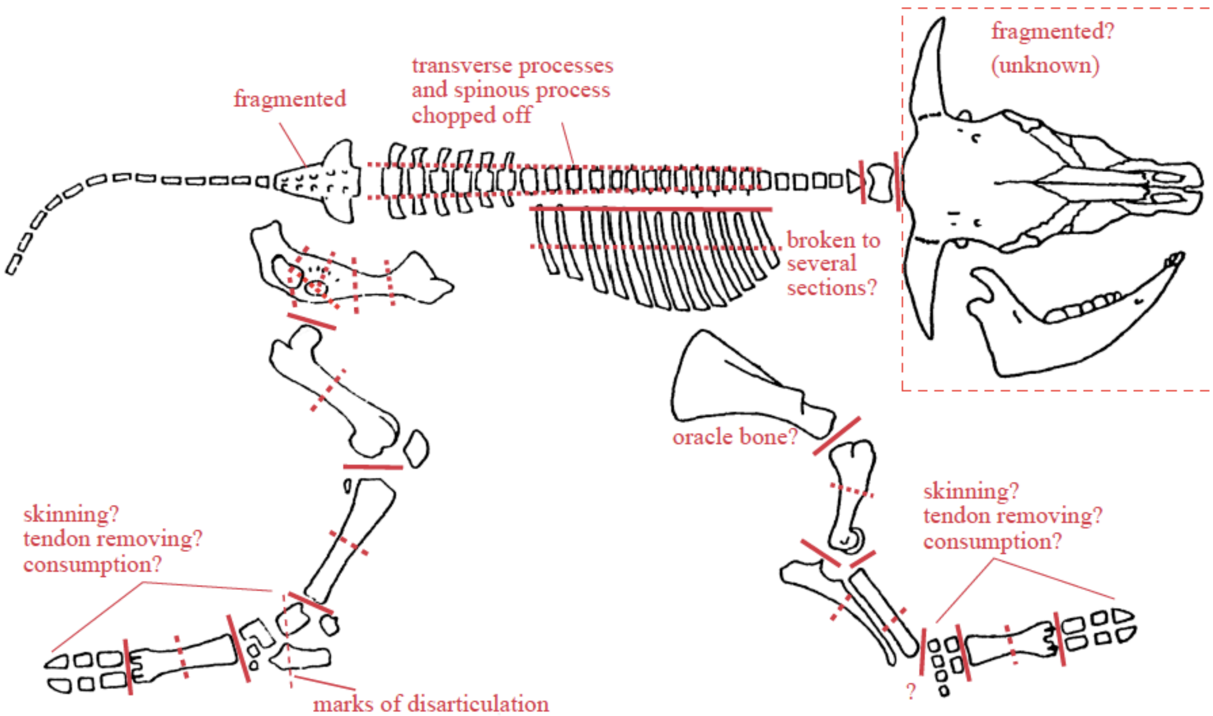
For pigs, only one specimen of the first phalanx is seen in the collection with no butchery marks.

► Cattle

It is common to find butchery marks on the first phalanges, and a few butchery marks on the second and third phalanx. It proves that the extremities of cattle were also processed and quite possibly cooked. Specifically, some cut marks around the proximal articular end of the first phalanges may correspond to butchery marks on the distal trochoid joints, both of which originated in the separation of extremities.

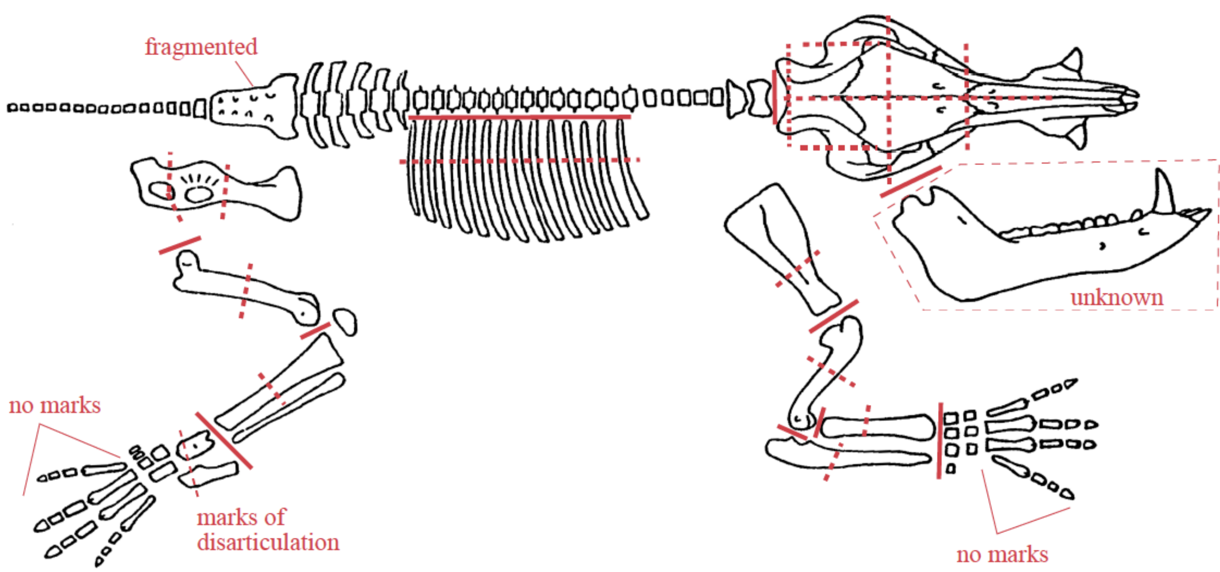
9.5 Reconstruction of Cattle and Pig Butchery Patterns

Based on the above analyses in Section 0 and Section 9.4, the pattern of cattle and pig butchery can be summarized. It should be noticed in advance that because our analyses are based on a group of selected specimens which have suffered from some destructive taphonomic processes, the pattern discussed here cannot be considered exhaustive and some details may be missing. However, a preliminary reconstruction of observed butchery patterns of cattle and pigs within the sample is still valuable for understanding animal processing at Xiaomintun and to enable a comparison of meat production and consumption between Xiaomintun and other sites.



Note: the base template is modified from Landon (1991: 301, Figure 6.55); the red solid lines show locations of disarticulation, which are proved by butchery marks; the red dotted lines show location of bone breakage (in secondary and tertiary butchery), most of which are deduced from patterns of butchery marks and bone fragmentation.
Long bones (humerus, femur, radius, tibia) were broken to two or three portions.

Figure 9.1 Xiaomintun: patterning of carcass butchery of cattle



Note: the base template is modified from Landon (1991: 302, Figure 6.56); the red solid lines show locations of disarticulation, which are proved by butchery marks; the red dotted lines show location of bone breakage (in secondary and tertiary butchery), most of which are supported by patterns of butchery marks and bone fragmentation.

Figure 9.2 Xiaomintun: patterning of carcass butchery of pigs

Considering the process of some main body parts, including the vertebral column and rib slabs, limb bones, and girdle bones, cattle and pig carcasses are processed in roughly a similar way (Figure 9.1, Figure 9.2), which is also comparable to the summarized patterns in Guandimiao (refer to the discussion and summary in Chapter 7). Generally, it is quite possible that the main muscles were taken off during butchery, and skeletal elements were mostly unhinged from the body in joints successively. The presence of butchery marks proves that all the elements should have been processed and consumed. It can roughly be shown that the cranium was regularly chopped into chunks (while the situation of mandibles is unknown), and so were the scapula and the pelvis (even though a cattle pelvis was possibly separated to more pieces, that is, more fragmented than a pig's pelvis). Rib slabs were torn off from the vertebral column and ribs were usually chopped into sections, although some relatively whole specimens show another way of rib butchery resulting in little fragmentation and possibly corresponding to a distinctive cooking method. Long bones (including the metapodials of cattle) were either entirely processed without breakage (Table 9.4) or split up into two or three portions. On consideration of butchery marks, extremities of cattle (including tendons) were disarticulated, and small bones were usually wholly consumed, while pig foot bones may not have been intensively disarticulated or filleted such that the bone surface of pig metapodials are mostly clean and without breakage or butchery marks.

However, the most apparent distinction between cattle and pig butcheries is the treatment of vertebrae. For pigs, it is common to find most specimens of vertebrae relatively wholly preserved. Except those bearing significant taphonomic attrition (including mainly modern damage, though dog ravaging also has played a role), most atlas and axis are whole, while most other cervical, thoracic and lumbar vertebrae also keep the structure of the centrum and vertebral arch and, frequently, part of the spinous process and transverse processes as well. In other words, it is not likely that a single pig vertebra in the sample was modified purposely by humans, although the cranial/caudal surface may have been sheared off during vertebra disarticulation or some edges of the various processes may have been broken (e.g., Figure XI-9). For cattle, vertebrae were butchered in varied ways as discussed in Section 9.4.2. The atlas and axis are either whole or chopped to small fragments, while most other cervical vertebrae are relatively whole (e.g., Figures XI-11c, XI-11d, XI-11e). Comparatively, many thoracic and lumbar vertebrae and even a few cervicals were more intensively butchered, so that, in many cases, the spinous and transverse processes have been completely (or, at least, mostly) split off, and the lateral and ventral surfaces of the centrum may also be pared off (e.g., Figures XI-11a, XI-11b). It seems that filleting was done in a rather efficient way, and that an extra step was made during cattle butchery so that the large and irregular-shaped vertebrae were further trimmed into smaller chunks (the dimensions of all types of vertebral specimens is direct evidence of this – most fragments are half or less than a full-sized vertebra in dimensions, and many of them are close to pig vertebrae in terms of maximum length, comparing Charts V-4 and V-5).

9.6 An Evaluation of the Intensity of Carcass Processing

9.6.1 Bone Breakage and Fragmentation

As mentioned in Chapter 8, the intensity of bone breakage and fragmentation can be affected by many factors, such as (a) the degree of animal resource utilization, which can be studied by the intensity of bone fat removal from cancellous structures and marrow extraction from medullary cavities, and (b) the approach of cooking, both of which can be explicated by a discussion of pot-sizing.

9.6.1.1 The Degree of Bone Completeness and Bone Fat Exploitation

This analysis is focused on long bones. There were some whole specimens in both the cattle and pig remains (even though some whole long bones had been removed from the assemblage), showing that bone fat exploitation was not always a necessity during animal resource exploitation. The amount of end splinters may indicate the possibility of cancellous bone fragmentation and purposeful grease production. As shown in Table 9.4, end splinters take a rather small portion in the limb bone remains of cattle and none of such a specimen is found in the collection of pigs. Thus, it was unlikely that bone fat gathering was a frequent practice. On the other hand, many long bone end-shaft fragments of about 1/3-1/2 of the length of a whole element demonstrate that most long bones were broken from the mid shaft and bone marrow should have been extracted probably by boiling. Therefore, the pattern of bone breakage in general supports a moderate extraction of bone fat at Xiaomintun[116].

9.6.1.2 Maximum Bone Dimension, Cooking Pots, and Pot-sizing

9.6.1.2.1 *Li* Tripods– the Dimension of Cooking Vessels

186 rim sherd specimens of *li* tripod from ash pits, houses, ditches, and strata of Xiaomintun were measured. The dimensions of the rim diameter and the orifice diameter are highly correlated ($p = 0.000$). As shown in Chart 9.1, these tripods can be grouped to three clusters based on dimensions by using a k-means cluster analysis, roughly similar to what is shown in Guandimiao[117], though the group of large sized *li* are conspicuously separate from smaller *li*.

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[116] However, it should be noticed that the analysis is based on a group of selected samples and, according to previous studies, a large quantity of cattle limb bones may have been collected and sent to the bone workshops of Anyang. It is unclear how the special use of cattle limb bones may have affected the process and consumption of limb bones.

[117] Some archaeologists also classified the Anyang *li* tripods to three size groups based on typological study (Niu et al., 2019) which is quite like what is found in my research, although they have argued most of the small li are made of untampered clay (not coarse sand tempered).

Though there are many small *li* (with a rim diameter of 105-180 mm), it is quite possible that *li* tripods of larger than 180 mm in rim diameter were used for cooking at Xiaomintun, while large tripods[118] (with a rim diameter of 280-330 mm) were not as common as those of medium-sized ones (with a rim diameter of 190-250 mm[119]). That is, based on a comparison with the situation in modern times, it is quite possible that most medium sized *li* tripods were for groups of 2-3 people (or 1-5 people at most) which may represent the basic unit of local households in daily life, and some large *li* were for more people (probably around 6-8 people).

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[118] Based on the rim and orifice diameters of *li* tripods, and it is obvious that *li* tripods in Xiaomintun are larger in general than those of Guandimiao. It may not be a consequence of recovery error even though most of the measured specimens are ceramic sherds without a whole rim. It may not be seriously affected by sampling error either since all the specimens are selected randomly and are from archaeological units scattered around the site. I am inclined to believe that the difference indicates different standards/techniques of *li* tripod production or different situations of. large *li* usage in Guandimiao and Xiaomintun.

[119] The definition of medium sized *li* in Xiaomintun is a little larger than those of Guandimiao, which may indicate some social meanings or could be a reflection of measurement error.

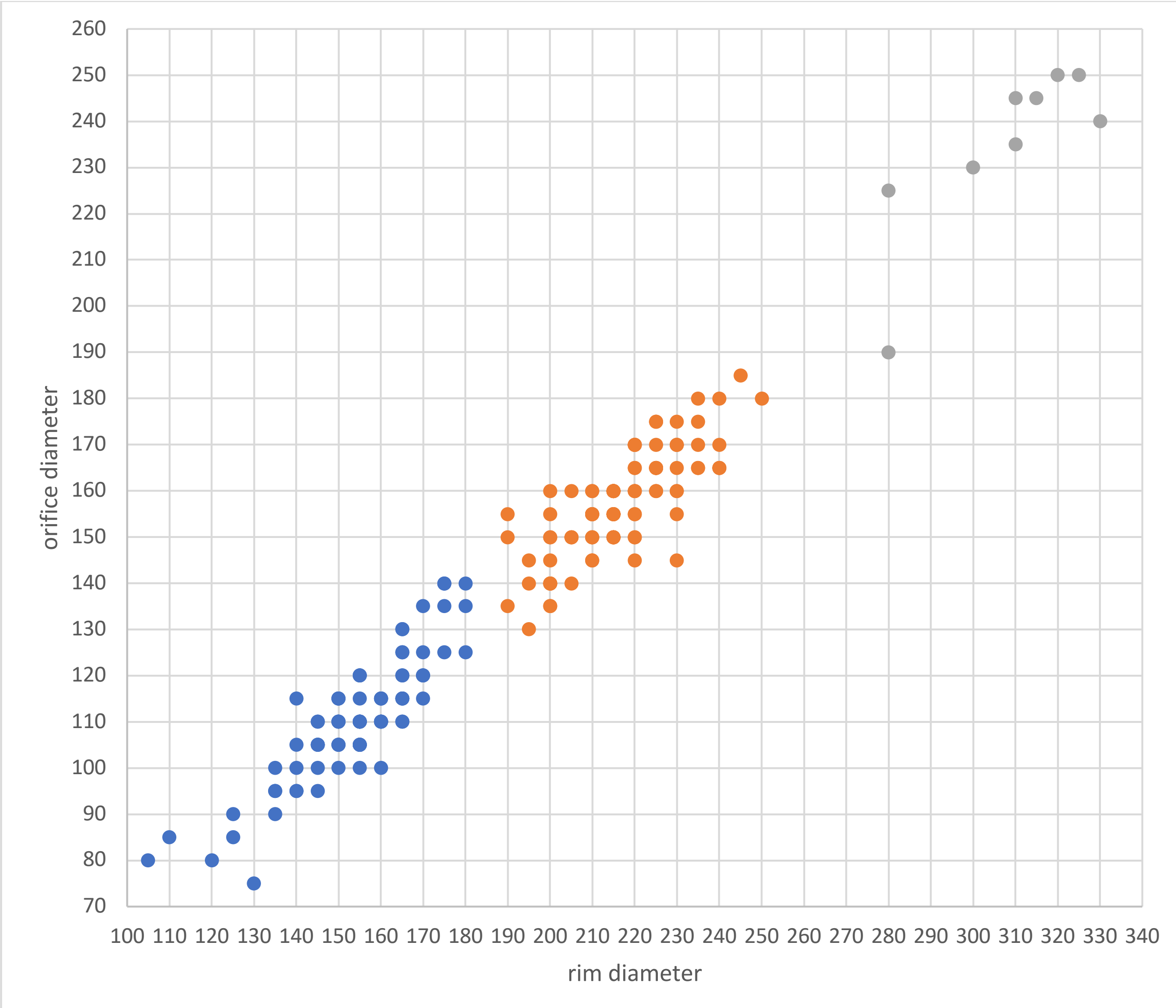

Chart 9.1 Xiaomintun: Dimension (mm) of li tripods_ rim diameter vs. orifice diameter

9.6.1.2.2 Cattle

Because the damage of premodern taphonomic attrition is relatively weak, cattle remains with old breaks can be treated as equal to food waste. Thus, specimens with old breaks were selected to study pot-sizing.

► Limb bones (humerus, radius, femur, tibia)

Of the 47 measured specimens, beside 9 larger specimens (170-265 mm), all the other fragments (38/47 = 80.7%) are 60-160 mm long (Chart 9.2, Chart V-1). Since most of the fresh meat joints should be larger than bare bone chunks and take 100 mm (as I assume) as a buffer zone in a cooking pot, a *li* tripod with the maximum diameter in the body (which can roughly be calculated by the rim diameter) around 160-260 mm (or larger) was able to cook most of the single long bone meat joints. On the other hand, in order to make it easy and efficient to put meat joints into a pot, the orifice diameter of such a *li* may also have to be around 160 mm or larger to allow bone chunks of 60-160 mm long to be put into a tripod efficiently, while the rim diameter (as a representative of the maximum diameter in the body) of the same tripod should be around 200 mm or larger correspondingly (refer to Chart 9.1). Therefore, this very rough calculation of the dimension of meat-cooking pots can be seen to largely match the result of *li* tripod grouping in Xiaomintun (as discussed in the above section, Chart 9.1). It is possible that at least a large part of the medium sized *li* tripods were used to cook several small bone-in beef joints or some of the single large chunks[120], while the largest *li* were large enough to hold all of the single bones and several pieces of long bone chunks at a time (suitable for a forelimb or a hindlimb or bones of similar volume). On the other hand, none of the reconstructed *li* tripods are large enough to cook a whole long bone, which, therefore, should have been cooked in other approaches that were uncommonly seen among the analyzed whole bones. That is, all cattle long bones cooked in a *li* must be fragmented. At last, if we believe that medium sized *li* were more commonly used in domestic cooking in Xiaomintun, the amount of cattle long bone consumed in daily life of small units is small, or, otherwise, long bone chunks were mostly cooked in large *li* during/at some special events/locations

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[120] To enable around half of the bone chunks (60-140 mm long, 27/47 = 57.4%) each to be cooked, a li tripod should have a rim diameter of at least 175-240 mm; to enable most of the bone chunks (60-160 mm long, 80.7%) to be cooked, a li tripod should have a rim diameter of around 200-250 mm (since no li tripod was found with the rim diameter of greater than 250 mm).

► Other elements

The distribution of maximum dimensions of other cattle elements have been analyzed in Section 0, and Appendix V and also summarized in Table 9.5 and Chart 9.2. Many vertebrae were intensively modified (e.g., with most of the spinous and transverse processes, as well as part of the centrum sometimes, chopped off), and most of them (118/123 = 95.9%) have a length of 60-140 mm (Chart V-4). Ribs were separated into segments. Most segments (92/106 = 86.8%) are smaller than 180 mm (40-180 mm), while 79.2% (= 84/106) of them are 60-160 mm long (Chart V-6). The pelvis was usually split to several parts. Most specimens (36/42 = 85.7%) are smaller than 180 mm, and many of them (29/42 = 69.0%) have a length of 60-160 mm (Chart V-8). Except three whole specimens, all the other metapodial fragments (49 pieces) are smaller than 200 mm, and most of them are smaller than 160 mm (46/49 = 93.9%) (Chart V-1). To sum up, besides a few large fragments, most specimens are smaller than 180 mm, and many of them are between 60-160 mm, a distribution of maximum dimensions which is comparable with that of the above four main long bones. Therefore, the same groups of medium and large sized *li* tripods were probably used to cook bone-in beef of various elements. It is possible that some relatively small *li* were used to cook several small meat joints or one or two pieces of large chunks, while more and/or larger bone fragments were cooked by large *li*[121].

Table 9.5 Xiaomintun: Dimensions (mm) of old-broken specimens of cattle

	NISP	Mean	Median	Std. Dev	Minimum	Maximum

[121] When a long bone fragment and intensively trimmed vertebral/rib/pelvis chunks have the same maximum length, the long bone fragment could be larger in practice considering the expanded spongy texture and the surrounded tendon of articular ends. Therefore, a vessel could hold more trimmed vertebrae or rib fragments than long bone chunks.

Compared with cattle vertebra remains from Guandimiao which usually show little modification, the trimmed cattle vertebra fragments in Xiaomintun are smaller in general. This means a medium sized *li* in Xiaomintun may have cooked more vertebra chunks than that of a similar size at Guandimiao. The situation of ribs and pelvises is unclear because only a few pieces were measurable at Guandimiao and a comparison between Guandimiao and Xiaomintun may not be representative.

H-F-R-T	46	137.2	135	40.6	70	265
Vertebrae	123	89.8	85	22.0	55	175
Ribs	106	124.4	105	66.2	50	460
Pelvis	42	131.1	110	71.4	50	380
Metapodial	49	109.4	110	26.2	55	185

Keys: H-F-R-T: a total of humerus, femur, radius and tibia fragments; metapodial: a total of all fragments of metapodials, and three whole specimens (of 205 mm, 210 mm, and 215 mm) are not included.

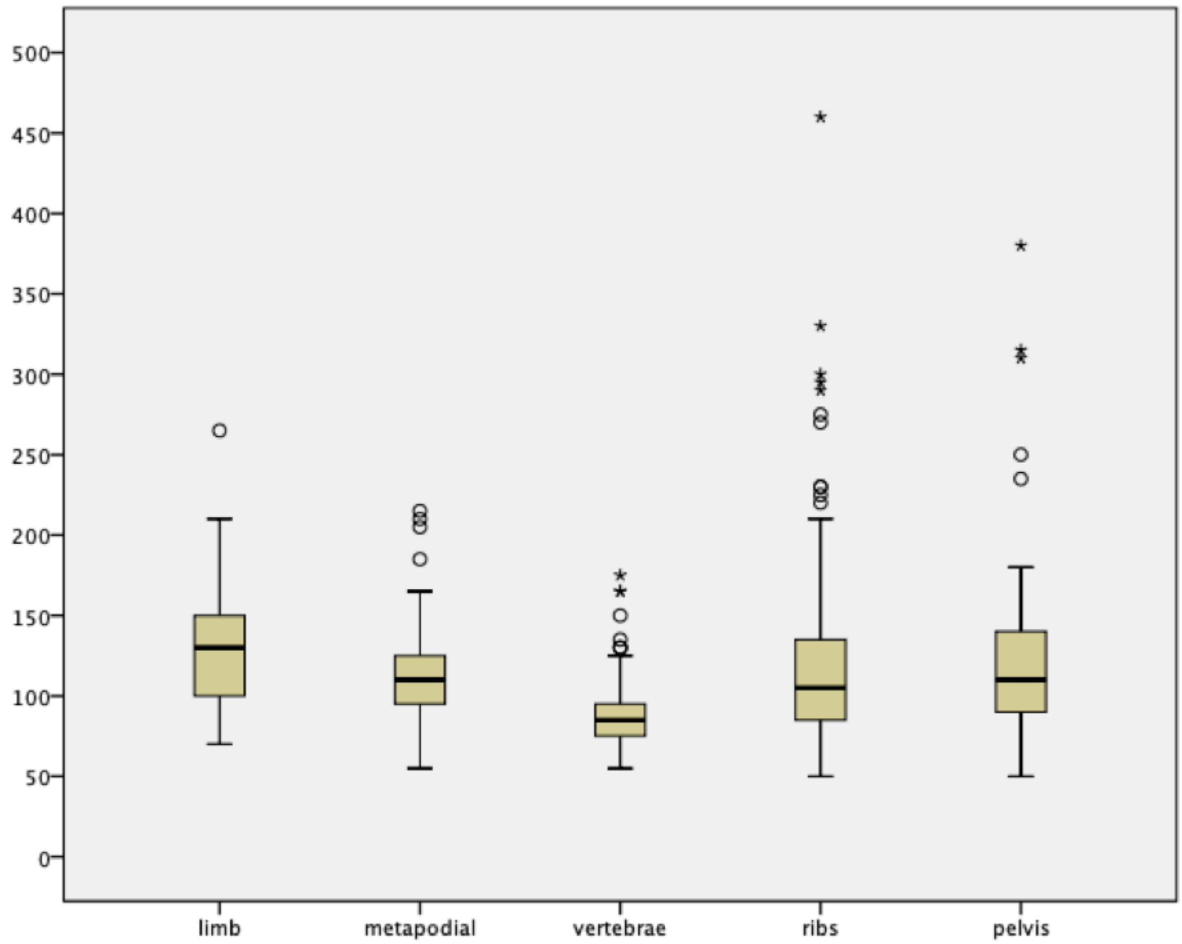

Chart 9.2 Xiaomintun: Dimensions (mm) of old-broken specimens of cattle

9.6.1.2.3 Pigs

According to the analysis in Section 0 and a summary in Table 9.6 and Chart 9.3, it is clear that most pig bone fragments had a maximum length of 60-140 mm. Specifically, 92.7% (= 127/137) of the long bone specimens are 60-140 mm, 91.1% (= 51/56) of the cranial fragments are

40-140 mm, 82.7% (= 62/75) of the vertebral fragments are 40-100 mm, 89.5% (= 17/19) of the cranial fragments are 60-180 mm, 88.4% (= 38/43) of the scapula fragments are 60-140 mm, 90.0% (= 54/60) of the pelvis fragments are 60-140 mm. Therefore, it can be said that various pig bone specimens are roughly similar in size (although are also a few whole specimens which can be assigned to another category).

Therefore, if dimension is the only variable in the selection of cooking pots, many medium-to-large sized *li* tripods were probably taken for bone-in pork cooking and the group of large sized *li* tripods should be capable of cooking almost all the pig bone chunks seen in the collection. Therefore, it is possible that pork joints were stewed in some *li* for daily consumption or feasting purposes, although a few very large bone fragments suggest the existence of other cooking methods. In addition, compared to cattle bones the pattern of pig remains may also indicate that bone-in pork was more frequently consumed in daily life compared to bone-in beef.

Table 9.6 Xiaomintun: Dimensions (mm) of old-broken specimens of pigs

	NISP	Mean	Median	Std. Dev	Minimum	Maximum
H-F-R-T	136	93.6	90	20.6	45	145
Cranium	56	91.9	80	31.6	40	175
Vertebrae	75	80.6	80	25.5	40	155
Ribs	19	125.3	110	41.7	65	230
Scapula	43	100.5	95	26.8	50	175
Pelvis	60	100.1	100	28.4	45	185

Keys: H-F-R-T: a total of humerus, femur, radius and tibia fragments, and the only whole tibia (of 210 mm) is not included.

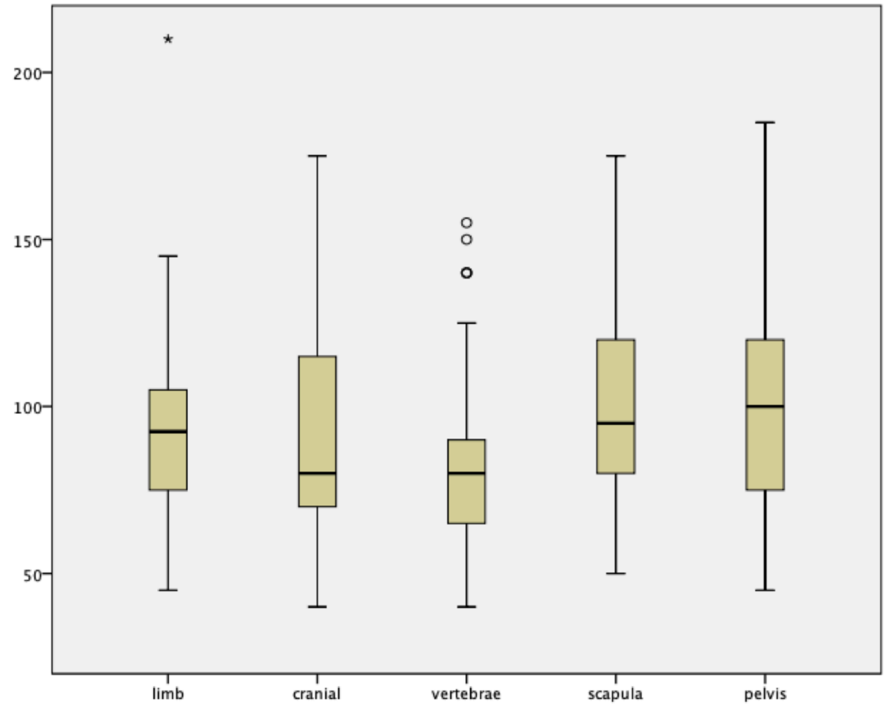

Chart 9.3 Xiaomintun: Dimensions (mm) of old-broken specimens of pigs

To summarize, a comparison between the size of *li* tripods and the maximum dimension of bone remains helps to identify the group of *li* tripods which were potentially taken for bone-in beef and pork cooking in Xiaomintun. Many medium to large sized *li* tripods were likely used in meat preparation. On the other hand, many skeletal elements (especially many cattle bones, refer to Section 0 of this chapter) have been reduced to a small size. This can partly demonstrate the effect of cooking pot sizes on bone breakage and fragmentation, which may indicate the frequency and amount of bone-in meat (especially beef) cooking. In daily life, it is likely that some small pieces of meat joints were cooked in the medium sized *li* tripods and consumed domestically. In some special occasions, more and larger pieces could be cooked in some large sized *li* tripods. Considering the dimension of cattle bones, a few bone-in beef chunks could be cooked in households sometimes while more beef were possibly cooked in large *li* tripods and consumed by large groups.

9.6.2 Butchery Marks

The similarities and differences in terms of carcass disarticulation and body part fragmentation of cattle and pigs have been roughly discussed in Section 9.5 and exhibited in Figure 9.1 and Figure 9.2. This section is a summary and further comparison of butchery mark distributions and butchery patterns based on detailed analyses, as well as data in Tables VI-1~VI-4, in previous sections. Since there are a relatively large number of both cattle and pig bones (for most elements, there are more than ten specimens) with butchery marks and the comparison can offer rich information on the different treatments of cattle and pig carcasses, which is valuable despite the selected nature of these specimens.

9.6.2.1 Differential Occurrence of Butchery Marks by Species

The relative proportions of specimens with cut, chop (+ shear), and scoop marks are quite different between cattle and pigs. For cattle, the occurrence of cut marks is very close to (though a little bit higher than) that of chop (+ shear) marks, among both specimens with butchery marks and all the cattle remains, while, for pigs, the former is much higher than the latter (compare the last two rows in Tables VI-1 and VI-3). This means specimens with chop and shear marks are more frequently shown on cattle bones than on pig bones. In other words, while cutting was important for both cattle and pig carcass butcheries, activities caused by heavy tools, including chopping and shearing, apparently happened more frequently on cattle than on pigs. Meanwhile, although whole cattle and pig remains each include almost equal portions of specimens with butchery marks (36.8% for cattle, and 37.9% for pigs), for each element specifically, the percentages of specimens with butchery marks varies between cattle and pig bones (compare the rightmost column in Tables VI-1 and VI-3). This indicates that diverse elements may be processed in different approaches, which is discussed in the following section.

9.6.2.2 Differential Occurrence of Butchery Marks by Elements and Portions

The types and locations of butchery marks on diverse elements are summarized separately in this section based on descriptions and analyses in Section 9.4 and related tables. Then, a general discussion of the functions of different types of butchery marks is made.

The distribution of types of butchery marks are as follows:

(1) *Cranium* The limited specimens with chop and shear marks show a regular processing that indicates that the cranium was usually divided to segments, and some scattered cut marks are possibly related to filleting and disarticulation.

(2) *Vertebrae* For both cattle and pigs, there are large portions of vertebra specimens with butchery marks. For cattle atlas and axis and pig atlas, incidences of specimens with butchery marks are higher than those of other vertebrae (and even higher than most other elements), and the marks are regularly distributed which is roughly similar to the situation in Guandimiao. These marks are quite possibly related to repeated activities of cutting off ligaments/muscles and severing the head from the carcass. However, the difference between cattle and pig specimens is also rather clear. As has been discussed in Section 9.5, on pig vertebrae, except for a few chop and shear marks related to the separation of connected vertebrae, it is almost all cut marks. On the contrary, specimens with chop (+ shear) marks on most cattle vertebrae take a larger part than those with cut marks, and they may have played various roles for disarticulation, fragmentation, and muscle removal.

(3) *Ribs* Butchery marks are largely seen on a portion close to the rib head. Some butchery marks, either cut, chop, or shear marks, around the rib head indicate shearing or cutting off rib slabs from the vertebral column, some chop or shear marks are related to separating a whole rib into small segments, and a few other marks, mostly cut marks, may be produced by filleting

and eviscerating. Therefore, the lower incidence of chop and shear marks on rib fragments of pigs than those on cattle ribs may be a reflection of the relative difficulty and efficiency of chopping off a rib, which is lower in pig ribs than in cattle ribs.

(4) *Pelvis* Butchery marks are mainly concerned with the hip and the sacroiliac disarticulations (represented by marks concentrated around the acetabulum and the wing of ilium), filleting, and bone fragmentation into small chunks. For both cattle and pig specimens, there seems to be differentiated uses of butchery marks based on locations of marks. Cut marks are largely related to disarticulation and filleting, while chop and shear marks indicate activities of fragmentation. This functional difference between cut marks and chop (+ shear) marks is possibly an explanation of the different incidences of chop (+ shear) marks on cattle and pig bones separately. Because the pelvis of cattle is much larger than that of pigs, more chopping activities are needed for the cattle pelvis in order to split it to small segments[122], and so, a higher portion of specimens with chop and shear marks should be found in cattle pelvis remains.

(5) *Long bones* On the four main limb bones (humerus, radius, femur, and tibia), butchery marks scatter on both (proximal and distal) articular ends and the shaft for disarticulation, fragmentation, and filleting. A slightly higher incidence of butchery marks on cattle than that on pigs may be due to the dimension of elements -- more butchery works may have been done on cattle bones than on pig bones. Judged by locations of butchery marks, it can be said that, for both cattle and pigs, cut marks are chiefly caused by disarticulation and filleting, and chop (+ shear)

[122] Based on Chart V-8, the dimensions of fragments of cattle pelvis are close to those of pig pelvis, which means both cattle and pig pelvises may have usually been chopped to chunks of similar sizes. If it was so, more chops and shears should be required to fragment a cattle pelvis than a pig pelvis. Moreover, it is also found that many pig pelvis specimens have a whole wing of ilium preserved, with cut marks on the medial surface which are possibly remains of disarticulation. However, it is more common to find some fragments of cattle ilium with few cut marks. This can help us understand the relatively lower incidence of cut marks on cattle pelvis compared to those on pig pelvis.

marks should be generated primarily by splitting a long bone to segments from the shaft (while a few of them may be related to filleting and/or disarticulation). In addition, it is significant for pig bones that most chop marks are shown on the midshaft and many of them are definitely related to bone fragmentation, suggesting a major purpose of chopping which is distinguished from that of cut marks. However, the separation of cut and chop marks may not be so clear on cattle bones.

(6) *Tarsals, metapodials, and phalanges of cattle* For cattle mainly, the high incidences of cut marks on tarsals, metapodials, and phalanges suggest regular activities of disarticulation, as well as possibly filleting (and tendon removing) and skinning. Many chop marks concentrated on the midshaft of metapodials indicate a breakage from the shaft.

Additionally, there are only a few scoop marks randomly scattered on several specimens which helps to confirm that intensive filleting is rarely seen, and so these marks are not discussed in detail.

As a summary of the above detailed analyses, the types and incidences of butchery marks vary based on body parts and anatomical locations in general and are also sometimes differentiated between cattle and pigs. These diverse patterns of butchery mark distribution are closely related to different butchery activities/stages and may also be associated with different treatments of cattle and pig elements and carcass. The connection between types of butchery marks and carcass butchery can be further summarized as follows.

(A) Though not as significant as what was seen in the Guandimiao assemblage, there is also a concentration with high incidences of butchery marks in the Xiaomintun assemblage on some elements and portions that construct the main joints, such as atlas and axis (head-neck joint), and joints of limbs generally. These represent repeated butchery activities and show some standardized butchery practices (such as head removing, and limb bone disarticulation).

(B) The correspondence between types/locations of butchery marks and the purposes of butchery activities can be summarized. Broadly speaking, for both cattle and pig, cut marks are chiefly produced during disarticulation and filleting, and chop (+ shear) marks are inflicted mostly by bone fragmentation. For pigs, the incidence of cut marks are higher than that of chop (+ shear) marks on all the main elements[123], and the functional separation between cut and chop (+ shear) marks is roughly clear. Chop and shear marks are mainly related to activities of disarticulation of connected vertebrae and fragmentation of some bone elements (e.g., cranium, ribs, pelvis, and limb bones). For cattle, although both cut marks and chop (+ shear) marks are commonly seen on bones, the incidence of chop and shear marks is higher than that on pig bones when referring to either the whole collection or most individual elements (compare Tables VI-1 and VI-3), and the functional distinction between cutting and chopping may not always be so strict. Several examples can be listed. Observation on pelvis specimens indicates that most chop and shear marks are produced by splitting the large element into small fragments. Chop and shear marks dominate on vertebrae, and they are possibly remains of different butchery activities (disarticulation, fragmentation, and even filleting). On limb bones (including metapodials), although most chop and shear marks are on long bone shafts that quite possibly originated from breakage of the bone into segments, some chop and shear marks around the articular ends may also be related to disarticulation and filleting.

(C) Accordingly, it is obvious that the choices of butchery tools in cattle and pig butchery are slightly different. Two types of butchery tools, cutting tools and heavy chopping tools which are almost for certainly made of bronze judging by the morphologies of many butchery marks as

[123] Cranium and mandibles are not included in the discussion.

well as considering the tool types recovered at Anyang[124], were used in Xiaomintun. Based on the above analyses, cutting tools quite possibly played a major role in pig butchery, especially in the stage of disarticulation and muscle removal, while chopping tools were used limitedly in shearing off the rib slabs and then in the last stage of bone breakage (after filleting). Comparatively, in cattle butchery, while cutting tools were still largely used for disarticulation and filleting, chopping tools were likely more frequently utilized for the disarticulation and filleting of vertebrae as well as even limb bones to some degree. Therefore, we can see that animal species, techniques and butchery tools are closely correlated. The differentiated processing of cattle and pigs is also a reflection of specialization in butchery.

(D) Based on the analyses of butchery marks, the intensity of filleting and bone process can be discussed. The general situation is that beside butchery marks for disarticulation and fragmentation, most of the filleting marks (represented by cut marks) seem to be related to removing the main muscles from the bone. The distribution of butchery marks on vertebrae can be taken as an example of this. As discussed above, for cattle vertebrae, large meat parcels together with some tiny bone splinters/dregs should have been chopped off, while the incidence of cut marks is lower than that on limb bones as a whole (Table VI-1). For pig vertebrae, similar to what is seen in Guandimiao, the incidence of cut marks is close to that of limb bones (Table VI-3). The low incidence of cut marks does not support intensive filleting. The distribution of butchery marks on both cattle and pig pelvis also indicates moderate filleting. Except butchery marks for

[124] The morphologies of chop marks and clean sheared fracture surface (as shown in several figures in this chapter) indicate there were sharp chopping tools. However, the Central Plains region lacks obsidian or chert resources to make sharp and durable stone tools, while shell tools couldn't be chopping tools (and, as I see, the morphology of cut marks also tells some difference when Guandimiao and Xiaomintun samples are compared). The Xiaomintun community was one of the main locations for bronze production. Therefore, there is almost no doubt that bronze butchery tools were used in Xiaomintun.

disarticulation (around articular surfaces) and bone fragmentation (with chop marks and/or sheared fracture surfaces), most other butchery marks (mainly cut marks) are around the obturator foramen (Figures VII-12 and VII-13) which is a main location of muscle and ligament attachment and needs much work to cut off the attached muscles. A similar pattern of butchery mark distribution can also be found on pig scapula. Moreover, the incidence of scoop marks is extremely low in both cattle and pig bones. All in all, this suggests only a moderate degree of filleting activities, which is likely largely related to cooking methods (rather than consumption activities). This is consistent with what can be inferred from the pattern of bone breakage and fragmentation -- both meat and bones should have been cooked in pots.

9.6.3 Summary

Based on the above analyses as a whole, it can be argued that the intensity of carcass processing during butchery and even cooking was low (the missing of some wholly preserved bones shouldn't affect this conclusion). This can be understood in several ways.

The study of the morphology and dimension of bone fragments, and the distribution of butchery marks as well, shows that both cattle and pig butchery were highly standardized. Though some detailed difference exists, they should have been butchered following roughly similar procedures which was very likely carried out by some experienced butchers using some stable sets of butchery tools (bronze cutting and chopping tools).

Although almost all the specimens are bone fragments, there is no clear evidence of intensive filleting or bone fragmentation (especially fragmentation of cancellous bone parts), which indicates bone chunks should have been cooked together with some meat attached while, nevertheless, bone fat wasn't an important concern for cooking preparation or during consumption. On the other hand, an analysis on a rough correspondence between the dimension of bone fragments and the capacities of some medium-to-large cooking pots implies that cooking vessel sizes were considered during butchery, and. it seems that only necessary bone modifications were made, by which I mean that it seems that a main aim for butchery was not to fit most fragments, especially those of cattle, into tripods of similar size, but to have multiple choices of tripods for cooking of various meat joints, so that some small bone fragments of both cattle and pigs could be cooked in relatively small *li* tripods in households, not to mention those processed in large cooking pots.

At last, a comparison on butchery marks shows that a main difference between cattle and pig butchery was in the ways of carcass disarticulation which were directly caused by the choice of different butchery tools. The disarticulation of pig carcasses was chiefly been realized by cutting tools, while both cutting and chopping tools were frequently used in cattle disarticulation. That is, different butchery techniques based on available tools had been developed. This implies that the intensity of butchery was moderate and efficient.

CHAPTER 10: Zhougongmiao: Patterning Cattle and Pig Butcheries and Interpreting Food Preparation

This chapter concentrates on a study of the intensity of animal butchery and bone-in meat cooking in Zhougongmiao, aiming to discuss the degree of specialization and independency of urban residents (of lower status) in this Zhou community. A small group of animal remains were selected from the Zhougongmiao assemblage. Similar to what was done for both the Guandimiao and Xiaomintun assemblages, the patterns of bone breakage and fragmentation and those of butchery mark distribution are the main foci in this chapter.

An introduction of specimens is made first, followed by an analysis on taphonomic attrition, and then, patterns of bone breakage and fragmentation as well as distributions of butchery marks are analyzed in detail, while a discussion on the intensity of butchery is given in the end of this chapter.

10.1 Size and Composition of the Assemblage

Animal remains from sixteen ash pits and five layers[125], which are mostly remains of low elites and commoners, are included. All these remains were collected by hand, which is similar to situations in both Guandimiao and Xiaomintun. Only the identifiable cattle and pig specimens from the selected features were used for detailed analysis, so that the studied animal assemblage

[125] All the ash pits and layers mentioned in this chapter are from five large residential areas which were quite possible occupied by lower elites and commoners (refer to Map 3 in Chapter 3 for the layout of Zhougongmiao). Except remains from one ash pit which had been included in the previous study (Zhang 2012) and are reexamined this time, all the other specimens have never been reported.

includes 781 cattle bone specimens and 212 pig bone specimens (Table 10.1) of subadult and adult individuals[126]. This is rather a small sample compared to those of Guandimiao and Xiaomintun. Therefore, I will include the main analyses, but make other steps simplified.

Table 10.1 Zhougongmiao: Frequencies of skeletal elements

(a) Cattle

Element	NISP	Portion	NISP
MAX	15		
MAN	23		
CRANI.FR	216		
ATLAS	3		
AXIS	0		
CERV	3		
THOR	5		
LUMB	4		
SACR	5		
CAUD	6		
VER.FR	69		
RIB.FR	80		
SCAP[127]	4		
INNO	24	INNO-01	4
		INNO-02	3
		INNO-03	9
		INNO-04	4
		INNO-05	1
HUMER	11	HUMER-01	0
		HUMER-02	2
		HUMER-03	5
		HUMER-04	8
RAD	19	RAD-01	11
		RAD-02	8
		RAD-03	5
		RAD-04	7
ULNA	12		

(b) Pigs

Element	NISP	Portion	NISP
MAX	13		
MAN	22		
CRANI.FR	10		
ATLAS	2		
AXIS	1		
CERV	0		
THOR	0		
LUMB	6		
SACR	2		
CAUD	0		
VER.FR	7		
RIB.FR	30		
SCAP	7		
INNO	12	INNO-01	2
		INNO-02	2
		INNO-03	1
		INNO-04	2
		INNO-05	1
HUMER	18	HUMER-01	1
		HUMER-02	7
		HUMER-03	17
		HUMER-04	8
RAD	10	RAD-01	5
		RAD-02	8
		RAD-03	7
		RAD-04	1
ULNA	8		

[126] It also includes in the assemblage 48 fragments of infantile and very young pigs and 5 fragments of very young cattle, which are not included in the following discussion in this chapter.

Since there are few horse fragments in the Zhougongmiao animal assemblage, all the vertebral and rib specimens are identified as fragments of cattle bones.

[127] It is believed that most cattle scapulae in Zhougongmiao were purposely collected for divinatroy use, so that few cattle scapulae are in the assemblage. Similar situations are also seen in Guandimiao and Xiaomintun.

FEMUR	14	FEMUR-01	3
		FEMUR-02	2
		FEMUR-03	9
		FEMUR-04	7
TIBIA	25	TIBIA-01	11
		TIBIA-02	7
		TIBIA-03	8
		TIBIA-04	14
MP3+4	43	MP3+4-01	22
		MP3+4-02	19
		MP3+4-03	21
		MP3+4-04	19
CARPL	24		
TARSL	17		
CALC	12		
TALUS	9		
PH1	20		
PH2	27		
PH3	22		
OTHER	69		
SUM	781		

FEMUR	10	FEMUR-01	1
		FEMUR-02	5
		FEMUR-03	5
		FEMUR-04	2
TIBIA	5	TIBIA-01	2
		TIBIA-02	2
		TIBIA-03	2
		TIBIA-04	2
MP3/4	11		
CARPL	1		
TARSL	0		
CALC	4		
TALUS	3		
PH1	3		
PH2			
PH3			
OTHER	27		
SUM	212		

Note: an element means a whole element, and a portion is a part of an element as described in chapter 5.

10.2 Destructive Taphonomic Processes (after human discard)

Bone remains in Zhougongmiao are very well preserved on the whole with little severe weathering and are suitable for bone surface observation. Except nineteen specimens with burning marks, five specimens with encrustation, and ten specimens with traces of bronze corrosion staining (which were found in the region of bronze workshop), all the other fragments are rather clean. The main taphonomic damage should be from bone missing and breakage during excavation and curation and animal gnawing after bones were discarded as food waste.

The situation of bone specimens missed during excavation is comparable to those of Guandimiao and Xiaomintun, such that fragile bone portions, small bone splinters and small compact bones should have been affected significantly. Modern bone breakage related to excavation and curation is also important source of taphonomic attrition (Table 10.2).

Table 10.2 Zhougongmiao: Fragments with modern breakage (calculated by NISP)

	cattle	pig	SUM
Modern damage	304	102	406
Serious modern damage	95	37	132
Modern damage (%)[1]	41.76%	53.68%	44.23%
Serious modern damage (%)[2]	13.05%	19.47%	14.38%

[1] Modern damage (%) = (fragments with modern damage) / (the total fragments of cattle/pig) × 100%, with "fragments with modern damage" defined as fragments that have portions/all original surfaces erased because of modern damage.
[2] Serious modern damage (%) = (fragments with serious modern damage) / (the total fragments of cattle/pig) × 100%, with "fragments with serious modern damage" defined as fragments that have lost at least one original end/break surface because of modern human activities and the original length at the same time.

Although the incidence of gnawing marks (Table 10.3) shows that carnivores (dogs) and rodents were taphonomic agents, ratios of disturbed specimens are relatively small (much smaller than that in Guandimiao, and smaller than in Xiaomintun) suggesting that bone waste was very likely buried rapidly after discard with little disturbance from animals. Therefore, it is roughly true that humans should be responsible for most cattle and pig bone fragmentation in Zhougongmiao.

In addition, judging by the percentage of specimens with serious modern damage and those with animal gnawing, the Zhougongmiao animal assemblage seems to be better preserved than those in Guandimiao and Xiaomintun. This might slightly affect the available specimens and related analyses, which will be mentioned when necessary in the following discussion.

Table 10.3 Zhougongmiao: frequencies of carnivore (dog) and rodent gnawing on cattle and pig bones

	Cattle		Pigs		Sum	
carnivore	51	6.53%	29	13.68%	80	4.35%
rodent	30	3.84%	10	4.72%	40	2.18%

10.3 Bone Breakage and Fragmentation

Limited by sample size, the description and discussion in this section focuses on cattle bones and the situation of pig bones is only summarized roughly in the end of this section.

10.3.1 Long Bones: cattle

A calculation of different types of long bone fragments in Table 10.4 shows that most cattle long bones were fragmented and whole elements were rarely seen. About half of the collection were end-shaft specimens (47 pieces), suggesting many long bones were broken in the shaft. It should be noticed that there was a group of specimens (13 pieces) with only a portion of the end-shaft preserved. This type of specimen is usually composed of a portion of an articular end and a section of the connected shaft splinter (e.g., Figure XI-17), which is unlikely to have been caused by natural force and is scarcely seen in Guandimiao or Xiaomintun. In addition, some articular ends and end splinters are seen in the collection.

Table 10.4 Zhougongmiao: Types of long bone fragments (calculated by NISP, excluding loose epiphyses)

		Cattle	Pig
Whole		3	1
Old break	End	11	-
	End-shaft	47+13	17
	End_splinter	7	-
	Shaft_cylinder	5	14
	Shaft_splinter	6	2
New break		13	4

Note:
(a) For cattle, long bone fragments = fragments of humerus, radius, femur, tibia, metapodials; for pigs, long bone fragments = fragments of humerus, radius, femur, tibia.
(b) It includes in the "End-shaft" category 13 specimens with only a portion of the end and connected shaft preserved.
(c) All the specimens with epiphysis missing are included.

The various types of long bone fragments indicate different ways of bone breakage, which can be discussed by referring to the maximum length of long bone specimens. The maximum lengths of all the 92 measured long bone fragments are exhibited in Charts VIII-1 and VIII-2. Most fragments are in the range of 60-180 mm. By comparing with the length of whole long bones in

Zhougongmiao[128], it can be inferred that most specimens, especially end-shaft fragments, are about 1/3-1/2 the length of a whole bone. Considering the many long bone end and end-shaft specimens in Table 10.4, it is likely that most long bones were chopped into two or three parts, while metapodials were probably chopped into two halves. In addition, fragmented articular ends (e.g., end_splinters, and incomplete end-shaft halves) present clear evidence that some long bone end and end-shaft portions were further broken into portions to uncover the spongy bone structure or completely open the marrow cavity, which could make it easily to remove bone fat.

10.3.2 Vertebrae: cattle

The maximum lengths of 59 vertebral specimens are shown in Chart VIII-3, most of which are in a range of 40-100 mm (some fragments are rather small).

Several types of cattle vertebral specimens are seen in Zhougongmiao. A group of fragments are mostly whole and retain the structure of the vertebral centrum and arch. Some other specimens show a clear breakage of the centrum (e.g., Figures VII-18b, VII-18c, with flat sheared surfaces). In addition, some small fragments (such as fragments of vertebral processes, e.g., Figure XI-18a) are also a result of vertebra fragmentation.

10.3.3 Ribs: cattle

Compared to specimens in Guandimiao and Xiaomintun, cattle rib specimens are well preserved. Of the total 80 cattle rib specimens, 59 fragments are in good condition showing no severe taphonomic attrition.

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[128] There is no completely whole humerus, radius, femur, or tibia of cattle in the selected specimens. The lengths of whole long bones can refer to my previous study on some Zhougongmiao bone remains., Li (2009: 27-28) measured some whole long bones of cattle in Xiaomintun, one radius is 326 mm in length, one femur is 390 mm in length, and two tibiae are 380 mm and 383 mm. So, it can be estimated roughly that a whole humerus can be around 290-365 mm and a whole femur can be around 345-395 mm. In addition, 94 metacarpals are 163-229 mm, and 39 metatarsals are 212-254 mm.

Rib fragments are usually rather small and most of them are in a range of 40-140 mm (Chart 10.2, Chart VIII-4). Since taphonomic attrition has proved to be a less important factor, many ribs were possibly chopped up by humans (e.g., Figure XI-19), and these small-size rib fragments could be directly relevant to the activity of pot-sizing.

10.3.4 Pelvis: cattle

A total of 23 specimens are observed and measured. These fragments can roughly be identified as two types of fragments: acetabulum fragments and other shaft fragments. There are both whole acetabulum and acetabulum fragments with (usually) a section (shaft) of the connected ilium or ischium or pubis (e.g., Figure XI-20a, XI-20c). Other parts are also seen as small fragments (e.g., Figure XI-20b). With a consideration of the dimensions of preserved fragments and especially that of fragments with butchery marks, (Chart VIII-5), it can be known that a large cattle pelvis was usually reduced into several small chunks.

10.3.5 Small Compact Bones: cattle

Except cattle calcanei, most identified small compact bones (i.e., carpals, tarsals, and phalanges) are wholly preserved. Five of the eleven calcanei are fragmented pieces. Since a cattle calcaneum is not a spongy bone but one with a high density, these are very likely anthropogenic fragments which were possibly generated during butchery.

10.3.6 Pig Bone Fragmentation and Breakage

Compared to cattle bones, there are only a small number of identifiable pig bone remains in the selected archaeological units with most elements included. In general, most elements are included in the collection and almost all elements are identified as fragmented bone portions. Long bones are usually broken in the shaft. Both cranium bones and mandibles are highly fragmented. Most vertebra specimens maintain the structure of vertebral centrum and arch, while the extending processes are chopped off. Other elements, such as ribs, scapulae, and pelves are all reduced to small sections.

10.3.7 Summary

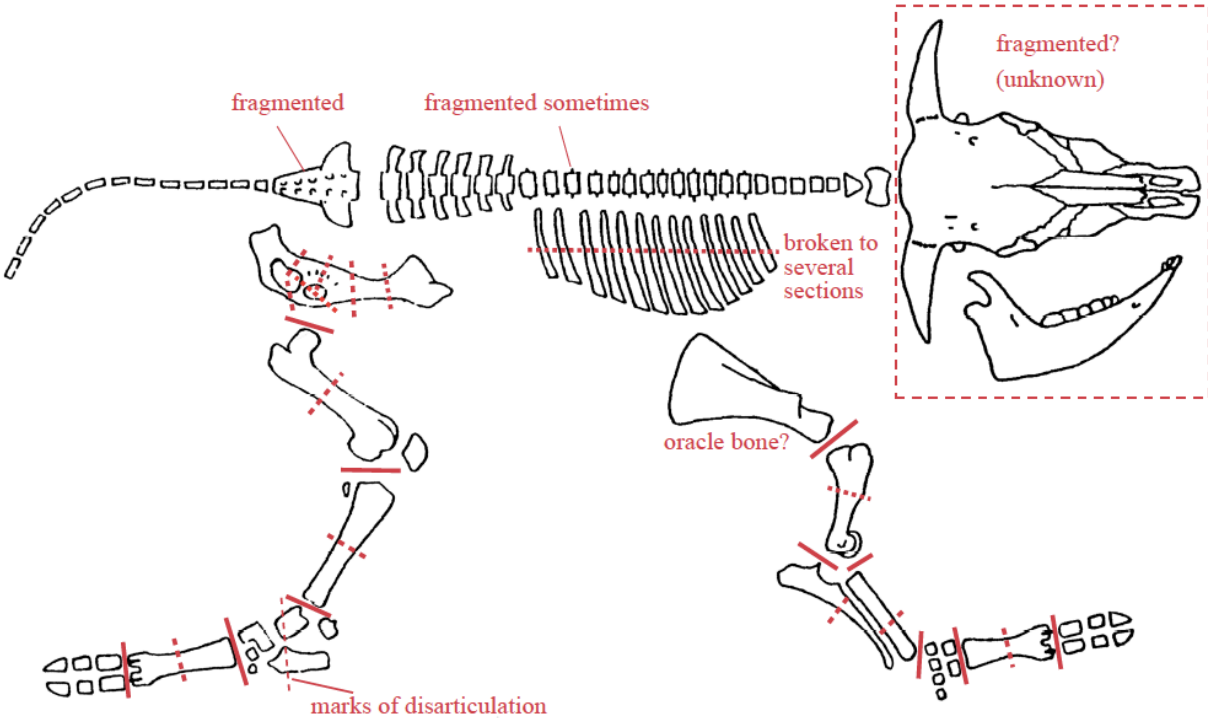
Most animal bone remains in Zhougongmiao have well survived various taphonomic processes, so that the pattern of bone breakage and fragmentation can enable a study of butchery activities. A summary of the butchery pattern is discussed latter in this chapter. For both cattle and pig remains, it is roughly the case that most elements are fragmented to rather small chunks and large bone fragments are rare. The detailed statistical analysis is given in the following Section 10.6 of this chapter.

10.4 Butchery Mark Distribution by Element

Except a few pieces, almost all the specimens are included for butchery mark observation and calculation. The result is presented in tables Appendix IX. Generally, the specimens with butchery marks are quite limited, especially among pig remains. Most butchery marks are caused by cutting and chopping. The detailed description and analysis are presented in Appendix X.

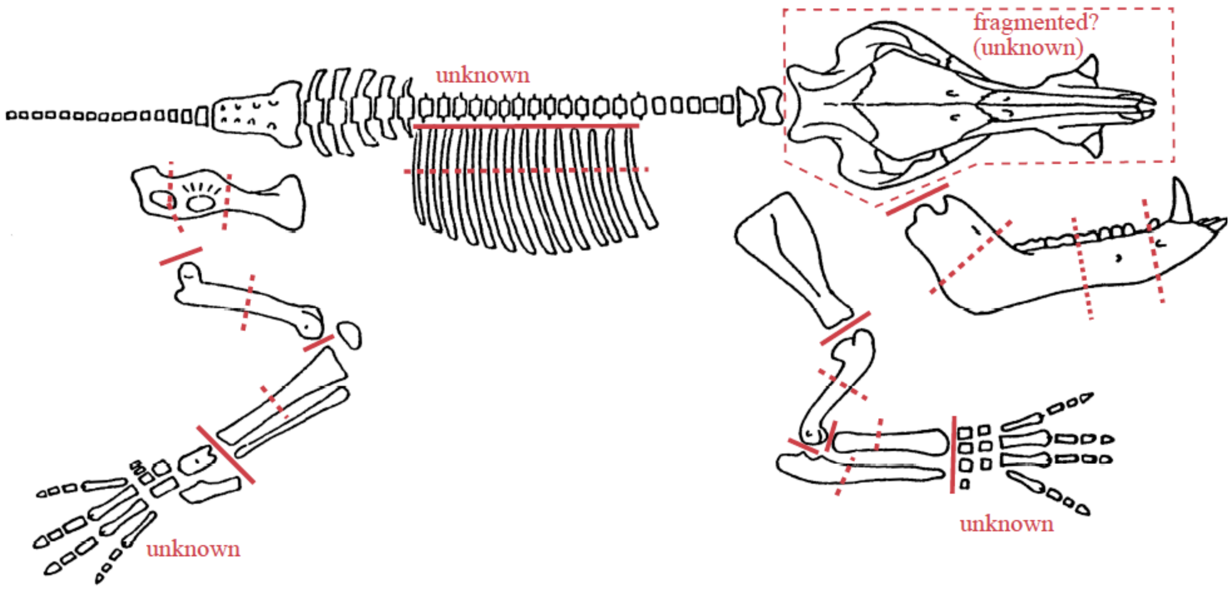
10.5 Reconstruction of Cattle and Pig Butchery Patterns

Based on the available specimens analyzed in Section 10.3 and Section 10.4, instead a full reconstruction of the Zhougonmgiao cattle and pig butchery patterns, some broad ideas are summarized below and also presented in Figure 10.1 and Figure 10.2.



Note:
The base template is modified from Landon (1991: 301, Figure 6.55).
The red solid lines show possible locations of disarticulation, which needs more butchery mark evidence; the red dotted lines show location of bone breakage, most of which are deduced from patterns of butchery marks and bone fragmentation.
Long bones (humerus, femur, radius, tibia) were possibly broken to two or three portions.

Figure 10.1 Zhougongmiao: patterning of carcass butchery of cattle



Note:
The base template is modified from Landon (1991: 302, Figure 6.56); the red solid lines show locations of disarticulation, which are proved by butchery marks; the red dotted lines show location of bone breakage (in secondary and tertiary butchery), most of which are supported by patterns of butchery marks and bone fragmentation.

Figure 10.2 Zhougongmiao: patterning of carcass butchery of pigs

Most cattle bones are well preserved but with only a few butchery marks. The small sample size might have introduced some bias into the statistical analysis of butchery marks. Nevertheless, it is still possible to gain a basic understanding of cattle butchery. Generally speaking, only very limited butchery marks have been generated in different stages of butchery (from skinning, eviscerating, dismembering, to large muscle removing). Some butchery marks on the vertebrae (e.g., cut marks on the transverse and spinous processes) are very likely caused by activities to take the main muscles off from the carcass back, which is also seen in Guandimiao and Xiaomintun. Meanwhile, judging by the mostly intact preserved articular ends and the location of butchery marks (e.g., Figures X1~X-6), most disarticulation, especially the separation of long bones, were realized by cutting off ligaments covering the joints, which generates only a few marks around the articular ends. Chopping may mostly be used to break bones, such as to split vertebrae, fragment ribs, cleave long bones longitudinally from the middle of the articular ends or transversely in the shafts, which sometimes left tool marks.

Moreover, rather than thorough filleting, the low occurrence of butchery marks and the pattern of bone fragmentation suggest that local residents in Zhougongmiao were more willing to make an effort to split large cattle bones up into small joints. There is almost no wholly preserved long bone in cattle remains (Table 10.4), and this is true for the other main elements as well (e.g., vertebrae, pelves, ribs, and even possibly cranial bones and mandibles).

Finally, based on the small collection, what can be known about pig butchery in Zhougongmiao is very limited. By comparing it with the pattern of cattle butchery, the situation of pigs can roughly be estimated. It is suggested by the intact articular ends, the low occurrence of butchery marks, as well as the type and location of these marks, that disarticulation was realized mainly by severing ligaments around joints. Large elements are usually reduced to small fragments. Therefore, it can be speculated that pigs were butchered following roughly the same rules as cattle butchery.

10.6 An Evaluation of the Intensity of Carcass Processing

As we have done in Guandimimao and Xiaomintun, this section aims to make a relatively quantitative evaluation of cattle and pig carcass processing in Zhougongmiao.

10.6.1 Bone Breakage and Fragmentation

10.6.1.1 The Degree of Bone Completeness and Bone Fat Exploitation

This section is a collection and discussion of some observations mentioned above. The degree of bone completeness can roughly be represented by the ratio of the number of whole specimens to that of all the long bone remains. For cattle remains, as shown in Table 10.4, of the 92 long bone specimens with old fractures, there are only three intact metapodials, the ratio of whole long bones is very low (0.03). That is, for long bone, marrow was usually extracted. Meanwhile, the existence of some long bone end splinters and divided end-shaft portions suggests that grease in the long bone epiphysis were also extracted sometimes via boiling. Similarly, the fragmentation of mandibles and even some vertebral body also indicates bone fat extraction from these elements. Therefore, it is obvious that both marrow and bone grease of cattle was extracted. The current samples suggest it should also be the case for pig bones cooking.

10.6.1.2 Maximum Bone Dimension, Cooking Pots, and Pot-sizing

10.6.1.2.1 *Li* Tripods– the Dimension of Cooking Vessels

122 rim sherd specimens of ceramic *li* tripods from ash pits, houses, ditches, and strata of Zhougongmiao are collected and measured. Dimensions of the rim diameter and the orifice diameter are highly correlated ($p = 0.000$). Based on a k-means cluster analysis, all the measures are divided to three groups which represent *li* tripods of three size categories (Chart 10.1). It includes mostly small and medium pots and a few large pots. Judging by capacity, it is very likely that the medium sized *li* were mostly used domestically and could supply 2-4 people with food. The larger *li* could be used in a larger group (around 6-8 people?).

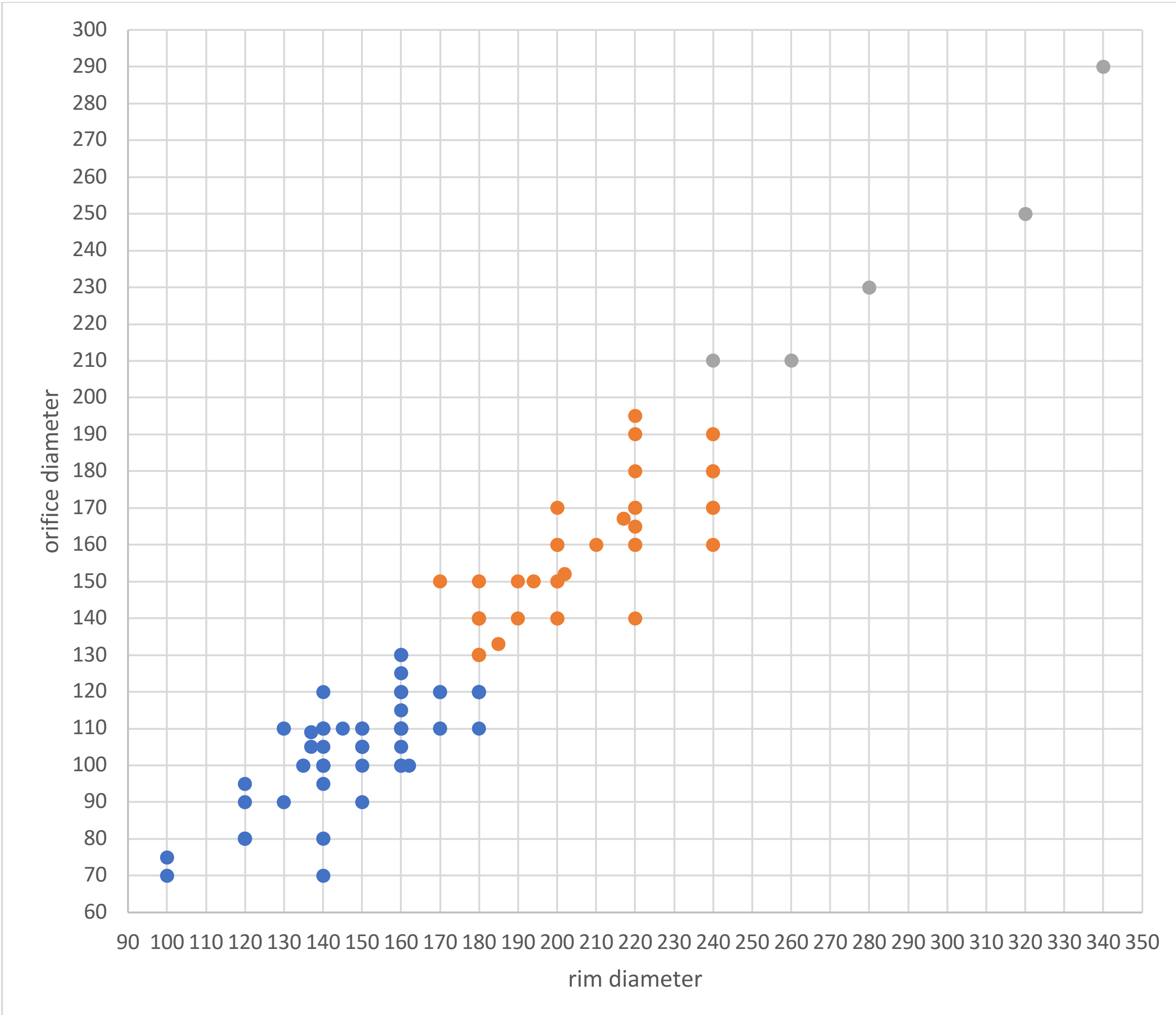


Chart 10.1 Zhougongmiao: dimension of the li tripod_ rim diameter vs. orifice diameter (mm)

10.6.1.2.2 Cattle

Because the damage of premodern sources of taphonomic attrition is relatively minor, cattle bone remains with old breaks can be directly treated as food waste, based on which, possible pot-sizing is studied.

Long bones (humerus, radius, femur, tibia) Most of the measured specimens (43/48 = 89.6%) are 60-180 mm long (Charts VIII-1 and VIII-2). When considering a buffer zone when bone-in meat is cooked in a pot, most *li* tripods with the maximum diameter (≈ the rim diameter) of larger than 160 mm are able to cook some single meat joints. If the efficiency of putting meat into a pot is also considered, it is better that the orifice diameter can be around 160 mm or larger, and the rim diameter should be around 200 mm or larger. In order to hold some single large bone chunks, the maximum diameter of a pot should at least be around 280 mm. That is, some relatively large (medium sized and large sized) *li* were more likely picked for meat cooking. Therefore, to make a rough estimation, the possible situation could be that some medium-sized *li* tripods were used domestically to cook several meat joints for a small group of people (2-4 people, in a household?), while, when a slightly large number of meat joints were cooked together or some large pieces were cooked, the large tripods were used. In any case, *li* tripods seem to be a proper vessel for meat cooking (especially considering some spongy bones were further fragmented), although some other methods may also have been used.

Other elements The distribution of maximum dimensions of other cattle elements have been analyzed in Section 3 and also summarized in Table 10.5 and Chart 10.2. Except several pieces, most fragments are smaller than 180 mm, and many specimens are longer than 60 mm. That is, if a *li* tripod was large enough cook long bone joints, it was able to cook the other meat joints. Therefore, the same groups of *li* tripods were probably used to cook various bone-in meat food.

Table 10.5 Zhougongmiao: dimensions (mm) of old-broken specimens of cattle

	NISP	Mean	Median	Std. Dev	Minimum	Maximum
H-F-R-T	48	116.3	108.5	38.7	30	185
Cranium	47	94.9	80	54.9	30	340
Vertebrae	103	66.2	60	25.7	20	165
Ribs	59	98.7	95	37.4	40	270
Pelvis	23	94.8	90	32.1	45	160
Metapodial	31	88.8	88	29.0	30	165

Keys: H-F-R-T: a total of humerus, femur, radius and tibia fragments; metapodial: a total of all fragments of metapodials, while three whole specimens (of 195 mm, 200 mm, 205 mm) are not included.

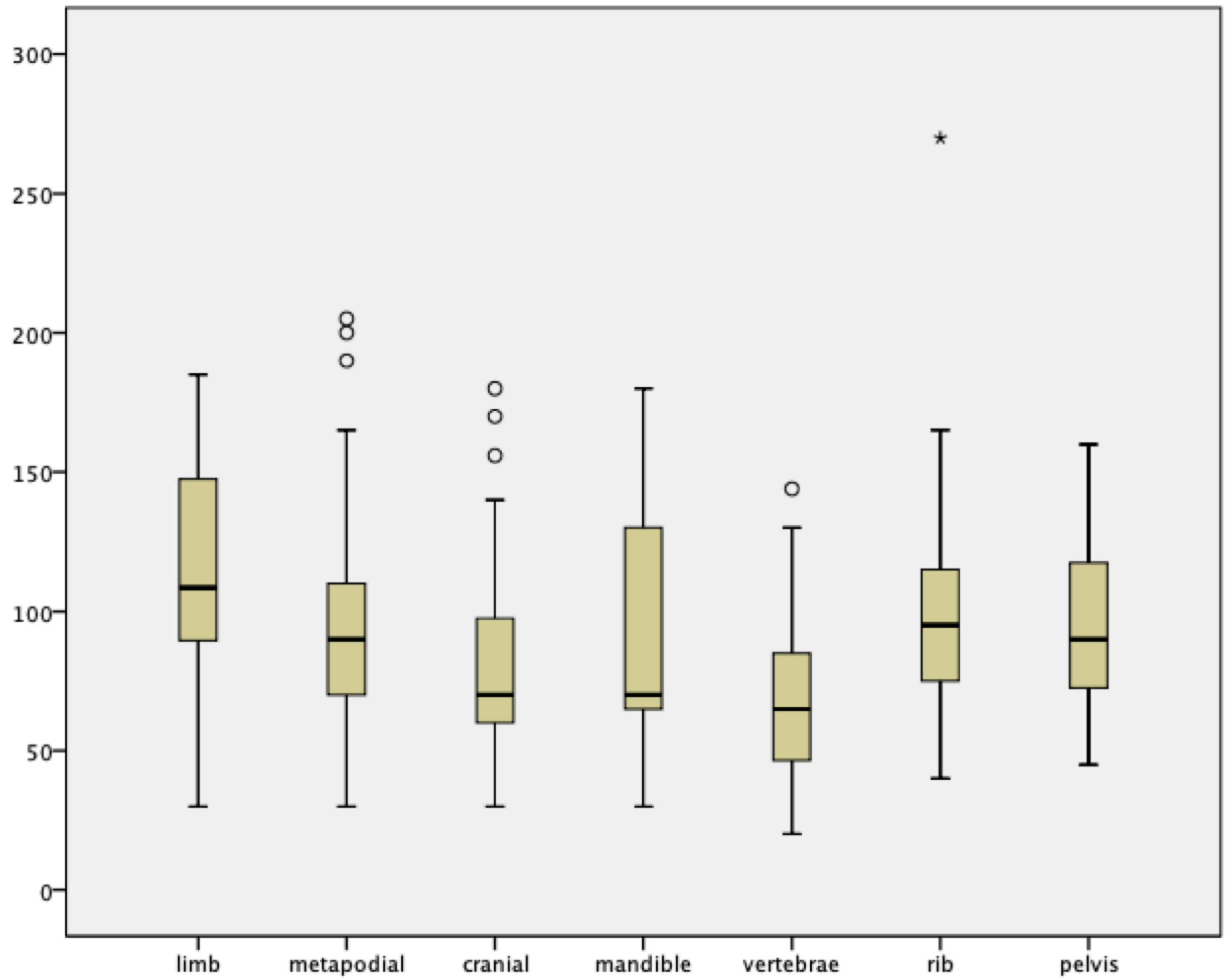


Chart 10.2 Zhougongmiao: dimensions (mm) of old-broken specimens of cattle

10.6.1.2.3 Pigs

As shown in Table 10.6, the pig bone fragments are relatively small on average. Therefore, if the dimension of a *li* tripod is taken as the only variable in selection of cooking pots, most medium-to-large sized *li* tripods could have been used for bone-in pork cooking.

Table 10.6 Zhougongmiao: dimensions (mm) of old-broken specimens of pigs

	NISP	Mean	Median	Std. Dev	Minimum	Maximum
H-F-R-T	30	73.5	80	21.2	40	125
Cranium	24	83.5	70	41.6	30	180
Vertebrae	14	51.7	50	13.0	35	75
Ribs	21	81.4	70	30.9	35	134
Scapula	4	84.5	82.5	28.1	53	120

Pelvis	10	68.7	68.5	20.0	45	110

Keys: H-F-R-T: a total of humerus, femur, radius, and tibia fragments.

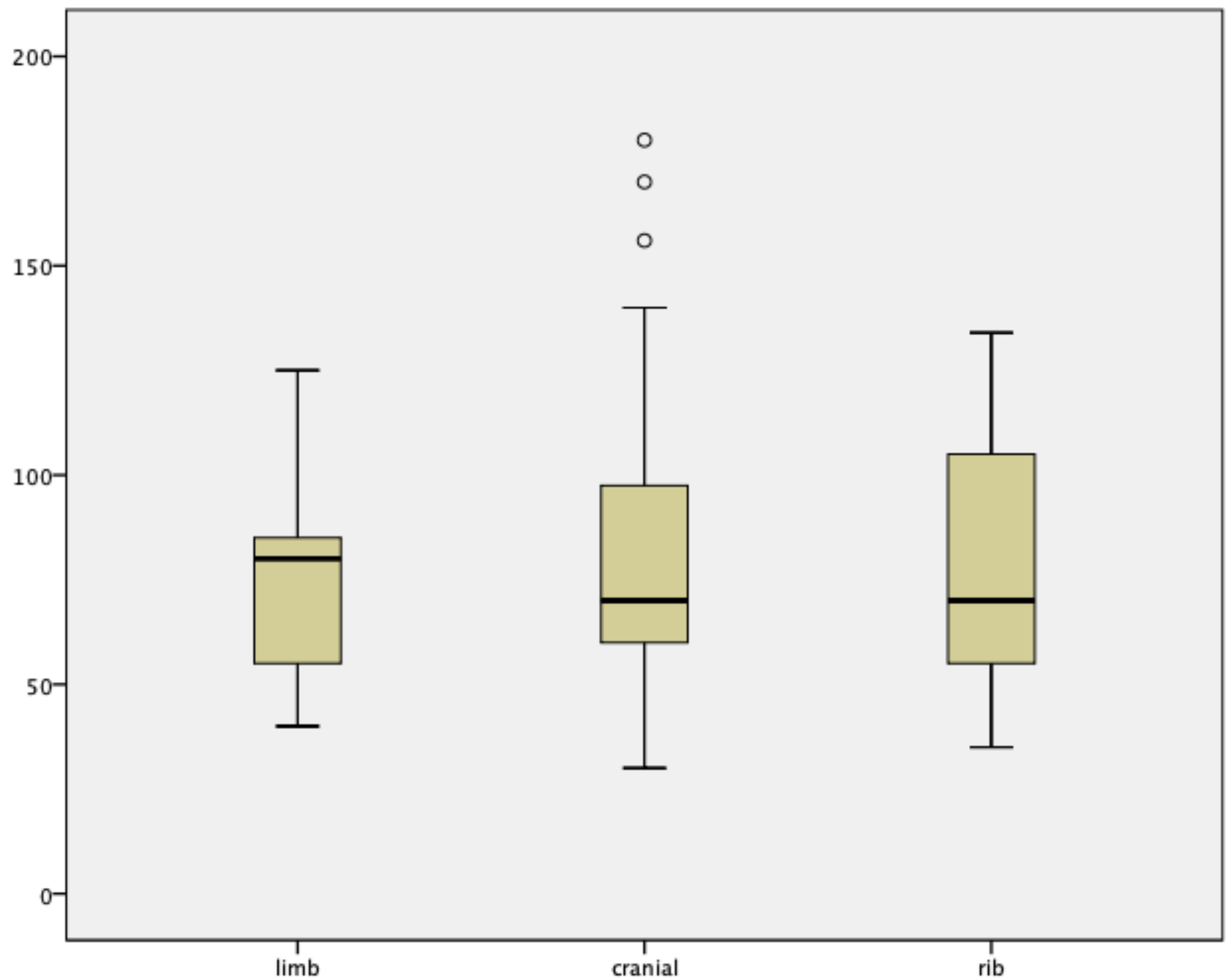


Chart 10.3 Zhougongmiao: dimensions (mm) of old-broken specimens of pigs

10.6.2 Butchery Marks

As already discussed in Section 10.4, both the incidences of butchery marks on cattle and pigs are rather low in Zhougongmiao and cut and chop (+shear) marks are the most. common. Generally speaking, most cut and chop marks are close to joint parts on the carcass, which should have chiefly been caused by disarticulation. The a few cut marks (on bone shafts, especially) and the missing of scoop marks indicate that intensive filleting was rare in Zhougongmiao, while, possibly, only main muscles covering the skeleton were removed. On the contrary, the occurrence of some sheared specimens, as well as the pattern of bone fragmentation, suggests that it was rather a common practice to break large body parts to small meat chunks. Therefore, it can be known that the focus of cattle carcass butchery in Zhougongmiao is efficient disarticulation and filleting as well as intensive fragmentation. To match up with efficient butchery, there must have been experienced butchers who used some highly advanced butchery tools – bronze cutting tools (knives) and chopping tools.

10.6.3 Summary

The above study shows that the intensity of carcass butchery and bone cooking is low in terms of time and labor needed.

The standardized butchering process suggests the existence of skillful butchers and the adoption of advanced butchery tools, both of which should have made cattle and pig butchery highly efficient. Besides, the use of some advanced butchery tools may have also made activities of bone fragmentation rather easy. Bone fragmentation reflects the need for marrow and bone fat exploitation and a consideration to available cooking ware. Most bone-in meat (as represented by bone fragments) can be cooked in proper *li* tripods, so that intensive meat filleting was not always necessary, while the cook and consumption of animal grease was also in a moderate degree.

CHAPTER 11: Discussion and Conclusion: Animal Food Study and the Implications for Reconstructing Lives of Common People

This last chapter aims to directly discuss and answer questions raised in the end of Chapter 4. The first section gives a summary to the detailed descriptions in previous chapters and responds to how animal food was prepared and eaten by non-elites in late Shang and Western Zhou times. It confirms that commoner communities can be distinguished from each other based on foodways taking into consideration the social-political status of settlements and ethnic/cultural group. This is the first time in the study of Chinese zooarchaeology that such issues are discussed. In addition, based on the analyses in previous chapters, some inferences about the life of commoners and the organization of the lower-leveled communities are roughly sketched as a supplement. At last, some future directions of research are discussed.

11.1 Meat Food Preparation and Consumption

This section is organized by following the three main steps from livestock farming to animal butchering, and at last to meat food preparation and consumption.

11.1.1 Meat Animals

A review of animal production in the Chinese Bronze Age shows that meat consumption was based on a relatively stable structure of animal husbandry in this period[129], which offered reliable meat resources for both rural and urban settlements and also allowed the development of some degree of separation and specialization in production at the same time.

[129] Refer to Footnotes 35 and **Error! Bookmark not defined.** for more explanation.

Cattle and pigs were the main sources of animal meat, while sheep/goats, dogs and deer were all supplements. The Guandimiao animal assemblage proves that although cattle were definitely more valuable than other livestock in sacrificial events, there was no clear limitation on cattle consumption based on social status in daily life[130]. However, a comparison of Guandimiao, Xiaomintun, and Zhougongmiao suggests that what separates urban and rural settlements was probably the consumption of sheep/goats and dogs. The urban dwellers in Xiaomintun and Zhougongmiao, at least, may have had more diverse choices of meat food compared to rural residents in Guandimiao. Having both been exotic species introduced at the end of the Neolithic period, the broader adoption of cattle than sheep/goats in the diet of local people in the Central Plains, especially in rural settlements (as Guandimiao), should at least partly be attributed to the significance of cattle in frequently performed ritual sacrifice (including also oracle bone division) and feasting and related food sharing in both urban and rural contexts[131] in the late Shang period (Okamura 2002; Yuan and Flad 2005). When it is considered that the Guandimiao cattle were raised not only for local consumption but also exchange (Hou et al. 2019), there were very likely some small settlements specialized in sheep/goat husbandry.

The urban and rural settlements are separated by the quantity and quality of accessible meat animals. A combination of stable isotope analysis and zooarchaeological study on Guandimiao and Xiaomintun samples inclines to support that the disparity between rural and urban residents in terms of the amount of animal protein intake was not that significant, although Xiaomintun

[130] However, this cannot overturn the traditional belief that, in the Chinese Bronze Age, people of higher status consumed more cattle than lower status. It is still possible that cattle took an even larger portion in the food of elites than in commoner's diet. In order to further discuss this issue, we should expect some new work focus on elite diet based on animal remains.

[131] Not to mention the situation in Anyang, cattle were even a main sacrificial animal in Guandimiao and many oracle bones were also found in the same site (Hou et al. 2018, 2019).

residents may have had more meat from livestock. Profiles of cattle and pig harvest (patterns of sex and age structure) suggest meat animal supply may have partly followed the market model (productor vs. consumer). At the same time, the overall husbandry strategy in Zhougongmiao seems also to be focused on maximum meat production (Zhang 2012), and it is likely even so in the Western Zhou site of Tianma-Qucun (Huang 2000), which may also indicate the separation of production and consumption. Nevertheless, the two large Western Zhou settlements are still not comparable in size to the Shang capital at Anyang and a fuller diachronic comparison is not currently possible.

11.1.2 Animal Butchering

Detailed analyses on butchery of full-sized (subadult and adult) cattle and pigs in Guandimiao, Xiaomintun, Zhougongmiao show that large animal carcasses were processed following roughly similar procedures, and, at the same time, there are some distinguishing differences, especially in cattle butchering concerning butchery techniques. This may indicate the development of varied degrees of specialization and standardization.

11.1.2.1 Dimensions of Cattle Bone Fragments – the Degree of Bone Fragmentation

Cattle bone fragments from Zhougongmiao in general are smaller in dimension than those from Guandimiao and Xiaomintun. This is suggested by many measures, especially means and medians (Table XII-1). Statistic tests (Table XII-2) also confirm the difference (which is not only a random variation affected by samples) and indicates Guandimiao and Zhougongmiao samples are significantly distinguished from each other in terms of fragment dimensions, while Xiaomintun assemblage is in between. In addition, it can directly be observed that some articular joints in the Zhougongmiao assemblage have been split off longitudinally to make the spongy tissue exposed.

In other words, cattle skeletons in Zhougongmiao were more intensively fragmented on average than those of Guandimiao and Xiaomintun.

On the other hand, the maximum length of fragments from Xiaomintun and Zhougongmiao are more densely concentrated into a smaller range than those of Guandimiao (which can be clearly seen by comparison of the distribution of bone dimensions as presented by box plots in Charts XII-1~XII-3). Therefore, it can be argued that there is a tendency toward greater standardization cattle butchery in the two urban settlements (Xiaomintun and Zhougongmiao) than in the rural settlement (Guandimiao). In addition, there are more extremely large fragments in Guandimiao and Xiaomintun (not to mention the whole limb bones which are not presented in charts), while almost all the selected specimens of Zhougongmiao are smaller than 200 mm. This may also inform some differences between Shang and Zhou groups.

In short, the analysis reveals that different butchery strategies were very likely practiced by Shang and Zhou groups as well as by rural and urban residents. This may be related to social, economic, and political reasons, as well as distribution mechanisms. Moreover, as I discussed in the next section, these patterns are also very likely related to butchery techniques as well as cooking and eating habits and preferences.

11.1.2.2 Butchering Tools, Butchers, and Butchery Techniques

This is largely a systematic review of the scattered analyses and discussions in relevant chapters, which aims to highlight the distinct features of three sites separately by butchery techniques (which can partly explain the discrepancy mentioned in the degree of bone fragmentation).

► Guandimiao

In order to discuss animal butchery, several features of cattle and pig butchering should be noted. 1) A similar technique may have been applied and a roughly standardized butchery pattern is seen on both cattle and pig carcass butchering. 2) As shown by butcher marks, the whole process relied mainly on cutting tools. 3) At the same time, several lines of evidence suggest that proper chopping tools were lacking in Guandimiao. The pattern of bone fragmentation indicates that for many specimens only minimal modification/fragmentation was done, and there are also a number of wholly preserved elements. Moreover, it is rare to find clean flat sheared fracture surfaces generated by chopping tools.

Some artifacts recovered from Guandimiao (Li et al. 2008b) can help in the study of butchering tools in this rural settlement. There was very little bronze at Guandimiao in general, and there was only one small bronze knife collected from the site, so that it was unlikely that bronze knives were frequently used in daily life. Local stone tools are mostly made of sandstones. Thus, there were some stone axes that could be used where chopping was necessary, but they are not a good choice for most butchering activities. Suitable chipped stone tools, such as obsidian or chert flakes or knives, are not seen in Guandimiao and are rare in the Central Plains. However, there are a large number of shell knives in this site. These are made of *Sinanodonta woodiana*[132] and have been proved usable for fresh bone-in meat cutting and bone disarticulation (a preliminary experiment was done by Roderick Campbell and Yanfeng Hou in the Henan Provincial Institute of Cultural Relics and Archaeology, in Zhengzhou, in the summer of 2017[133]). Therefore, it is very

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[132] *Sinanodonta woodiana* are huge shells. They are native to china, and shell tools are often seen in archaeological sites in the Central Plains.

[133] In this experiment, shell knives were used to cut fresh meat chunks into small pieces, to deflesh along the bone surface, and even to saw through cattle metapodials from the middle shafts. However, cutting off the tendons and ligaments in order to separate the main muscle groups and to disarticulate the connected elements was not attempted, which should be a main step in butchery. It is certain that shell knives could take on all the necessary butchering tasks, but detailed study is needed.

likely that the Guandimiao butchery tool set was mainly composed of shell knives[134] and stone axes. Compared to bronze knives and axes, shell knives were not sharp enough and the use of stone axes were limited. Therefore, the efficiency of cattle and pig butchery, as well as the delicacy of meat dishes (discussed in the following) in Guandimiao should have been affected.

The patterned cattle and pig butchery procedures indicate that people who carried out the animal butchery were knowledgeable and experienced. Cattle butchery especially requires some experience. Therefore, there should be some butchery experts in Guandimiao - likely part-time considering the nature and scale of Guandimiao community. Judging by the pattern of bone fragmentation and archaeological contexts of ashpits, a butcher should have been in charge of almost all the butchery steps. For cattle butchering, the whole process from animal killing to bone breakage should have been finished by a butcher; and for pig butchering, the last step could be done either by a butcher or in domestic context.

► Xiaomintun

The analysis of butchery marks and bone fragmentation has confirmed the wide use of bronze knives and choppers in Xiaomintun[135]. As has been discussed, although both cattle and pig butchery followed a similar pattern, some specific techniques were slightly different. Pig carcass disarticulation was more reliant on cutting tools, while bronze chopping tools were used more frequently for cattle. Also, cattle and pig vertebrae were treated in different ways during butchery.

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[134] The morphology of butchery marks generated by shell knives can be similar to those of stone knives (Toth and Woods 1989). Though the morphology of butchery marks is not included in this dissertation, there are some differences between cut and chop marks in Guandimiao and in Xiaomintun and Zhougongmiao. Compared to butchery marks seen in Xiaomintun and Zhougongmiao, in the Guandimiao assemblage, many cut marks are relatively short, and many have an open cross section, while many chop marks are shallow and lack very straight chopping edges. Therefore, I believe that shell knives and stone axes were used most for animal butchery. However, it is also possible that bronze knives may also have been used for butchery in some special cases.

[135] Although evidence shows that bronze saws were used in bone production (e.g., Campbell et al. 2011), they were not used in butchery.

The distinction of which can be interpreted directly by a consideration of efficiency – bronze chopping tools could be a more energy-saving way to cope with a large cattle carcass even in the process of filleting. The frequent use of chopping tools also made it possible to make relatively standard-sized beef joints, which is typically seen in vertebrae. Therefore, animal butchery had become highly specialized with the support of advanced butchering tools. This also corresponded to the great need for meat consumption in Xiaomintun which was reflected in the huge quantity of animal food waste. Accordingly, there must have been some highly experienced butchers who owned both bronze cutting and chopping tools. Animal butchering may have been a part-time job for some of these people, or there could also have been full-time butchers in order to meet the huge need in the city. Moreover, it is possible that the same butchers used different butchery techniques on cattle and pigs (possibly in order to most efficiently use valuable bronze tools), and it was also possible that it existed two separate groups of butchers for the butchery of large animals (such as cattle) and relatively small animals (such as pigs, as well as sheep/goats and deer possibly). In addition, considering the nature of Xiaomintun as a large bronze workshop, it may have been relatively easy to obtain bronze tools for butchery. Although it is still unclear if bronze butchering tools were as prevalent in other regions of Anyang as in Xiaomintun, considering the huge scale of meat consumption in Anyang in general, I believe the Xiaomintun case could be a representative of situations of many other neighborhoods of the Great Settlement Shang. I would argue that butchery in Anyang as a whole was highly specialized, standardized, and efficient.

At the same time, it may not have been easy for most households to obtain and use bronze knives and choppers in daily life. Therefore, a further deduction is that most bone fragmentation should have been made by well-practiced butchers, rather than in domestic contexts or during consumption. This is supported by the relatively uniform distribution of cattle bone dimensions, by which I mean that the dimensions of bone fragments from the same element are highly concentrated (as discussed in Section 11.1.1). Meanwhile, based on my observations, for pig tube bones (mainly limb bones and some portion of the pelvis), the morphologies and locations of fracture surfaces are rather stable, which indicates that most pig bone fragmentation was also done by specialists with some sharp chopping tools. This evidence then also suggests the specialization, standardization, and efficiency of animal butchery in Xiaomintun[136].

► Zhougongmiao

Animal butchery in Zhougongmiao in general was also done with high standardization, specialization, and efficiency. Compared Guandimiao and Xiaomintun, cattle (and pig) butchery in Zhougongmiao is characterized by few butchery marks, high degree of bone fragmentation, and regular bone fracture surfaces. Thus, it is certain that butchers in Zhougongmiao adopted some different techniques to process animal carcasses, though they still followed roughly similar butchering steps. This was partly due to the use of bronze knives and chopping tools (no bronze saws) as well as the skill of butchers. Thus, there were rather experienced butchers for cattle carcass processing at Zhougongmiao. Similar to the situation of Xiaomintun, the patterns of bone fragmentation also suggest that some well-practiced butchers took part in almost the whole process of cattle butchering, including the detailed body part disarticulation, bone fragmentation, and even spongy bone splitting, so that fragmented meat joints from the butcher were ready for cooking directly (while the situation of pig butchery is not as clear because of a small sample size). At last, although the requirement for small beef chunks and sometimes splitting spongy bones may have caused increased workload, which suggest a higher degree of intensification in butchery, it seems

[136] Although not included in the dissertation, all the sheep bone fragments (goats are rare in Xiaomintun) from the same collection also show a similar butchery pattern, as I have observed.

this extra work didn't affect the efficiency of butchery very much – the observation of bone fragmentation patterns and most fracture surfaces shows that bone fragmentation was done swiftly and sharply in most cases. In other words, advanced bronze tools and well-practiced butchers had significantly improved butchery efficiency.

To sum up, although cattle and pig butchery followed largely similar processes, many details prove that the three sites are quite distinct from each other, in terms of butchery techniques (including butchering tools and butchers, procedures and techniques) as well as the consequent forms and degrees of butchery standardization, specialization, and efficiency. This fits some common beliefs concerning the distinction of urban and rural settlements as well as the separation of ethnic groups (Shang and Western Zhou). It reflects a high interaction between butchery techniques, available tools, butchery skills, and other cultural variables, such as gustatory preference, preparation and consumption vessels and techniques, and ethnic groups involved (Lyman 1987 archaeofuanals), which is discussed in the following Section 11.1.3.

11.1.3 Meat Food Cooking and Eating

The analyses show that, in all the three sites (both urban and rural settlements), rather than processed domestically, large animal butchering and bone fragmentation was mostly done by butchers, and then well-processed meat joints were cooked and consumed in households and/or some larger groups.

Studies of butchery marks and bone fragmentation reveal that bones were usually cooked with attached meat (and intensive filleting was not common), while people of lower status (commoners) in this period were not starved for animal fat and bone grease was rarely exhausted. Meanwhile, with a consideration of daily cooking vessels (ceramic *li* tripods), it can be known that stewing was the main approach of bone-in meat cooking from late Shang to Western Zhou times.

On the other hand, there must have been different choices of bone-in meat cooking in Guandimiao and Xiaomintun[137] – besides stewing, some large bone elements and portions must have been cooked in other ways (such as roasting). However, it seems bone-in meat chunks were mostly boiled in tripods in Zhougongmiao. Moreover, in Zhougongmiao, the breakage of a few spongy bone portions reveals that bone-in grease was definitely a consideration. Therefore, it is possible that Zhou people in general presented an increased demand for animal fat and/or a food preference that was not shown in Shang people. At last, if the uniformity of meat joints in a dish (as represented by the dimension of bone fragments) is seen as one indicator of the degree of elaboration, Guandimiao cannot be compared to Xiaomintun and Zhougongmiao. In this sense, it can be argued that rural and urban settlements could have been distinguished by ways of meat cooking[138].

At last, the comprehensive study suggests that, for commoners of both Shang and Western Zhou settlements, meat cooking and eating usually happened in small units (possibly a nuclear family). Individual households might have received small quantities of bone-in beef or pork on various occasions via some distribution systems (Campbell et al. 2022). If only the dimension of a *li* tripod is considered (Chapter 8: Chart 1, Chapter 9: Chart 2, Chapter 10: Chart 1), commensal eating could be another factor to separate urban (Xiaomintun and Zhougongmiao) and rural (Guandimiao) settlements by the possible scale of such events – there are some very large *li* tripods in urban settlements which are rare in Guandimiao and it suggests a need to host a large group of people in a commensal activity which did not occur in Guandimiao.

[137] For the Xiaomintun assemblage, some whole limb bones have been moved out in advance and it is unsure what a percentage they may take in the animal assemblage (see Chapter 8 for more information).

[138] Some transmitted texts recorded various well-cooked meat dishes made of either bone-in or boneless meat chunks. Although these are mainly descriptions of the exquisite dishes of elites, they can still help us to imagine the diversity of meat dishes.

11.1.4 Summary

A series of comparisons above reveal roughly the whole process of how meat food was produced and consumed in Guandimiao, Xiaomintun, and Zhougongmiao. This, in a large part, helps us to see the general situation from livestock raising to meat eating in Shang and Zhou times. Generally speaking, meat animal choices and meat food production were supported by a relatively stable social economic environment in the Chinese Bronze Age. Main meat resources were from several kinds of livestock (the so called *liuchu* 六畜), not game animals. It seems the large-scale meat consumption (especially for beef) in this period was unattainable in later times. However, at the same time, it shows a progressive trend in the degree of specialization and standardization in the whole process from livestock raising to meat eating, which was accordant with the general trend of social development. For commoners specifically, meat food consumption was realized in a different way from elites (especially high elites, whose life were recorded in some words and images). The study suggests that meat resource distribution was usually a type of group activity, while daily meat consumption was usually in small groups (households) and usually only small meat packages were consumed. Moreover, the discussion of standardization and specialization indicates that people gave more thought to efficiency rather than diversity[139].

On the other hand, commoners in rural and urban settlements/communities represented by the three sites are clearly differentiated in meat production and consumption. The quantity and quality of meat resource residents received was closely correlated to the size and status of the community. Urban settlements, such as Xiaomintun and Zhougongmiao, were more or less close to the modeled consumer centers. They were densely populated, diverse meat resources arrived

[139] An extreme example is seen in Xiaotun. A great number of domestic and wild animal species were kept for elites in the royal and temple areas of Shang kings (as mentioned in Chapter 4).

via various approaches, and the most advanced bronze tools and well-practiced butchers with more specialized slaughtering techniques were concentrated in these settlements. To meet the great needs of the urban center, animal butchery was highly standardized and efficient, which possibly lead to the development of some more delicate meat dishes. The situation in the rural settlement Guandimiao went to the opposite side. Residents raised limited types of livestock and possibly only consumed part of them, while some livestock were delivered to other settlements. And at the same time, the use of easy-available butchery tools and some simple meat dishes seem match quite well with this small settlement.

In addition, a rough comparison between Xiaomintun and Zhougongmiao suggests the difference between Shang and Western Zhou communities (diachronically, and/or between ethnic groups) in terms of meat preparation and eating practices.

11.2 Meat-eating Groups and the Implications for Social Life

Analyses in this dissertation also offer a chance to sketch the daily life and the community of non-elites. Instead of a systematic discussion (which would be beyond the scope of this dissertation), I will offer a summary of the many details and inferences that touch upon this topic.

Most of the evidence concerning the daily life of non-elites derives from the Guandimiao remains. The study of *li* tripods in this dissertation, as well as excavation of small houses and the distribution of animal bone remains in ash-pits, suggests that food (meat) cooking and consumption was usually in small groups/households composed of no more than 3-5 members, indicating groups no larger than nuclear families. It seems that the quantity of meat acquired by these households was usually small and with little difference between households in terms of the quality of meat chunks. This indicates a degree of equality among households. The Guandimiao residents were generally poor in terms of their economic condition and there was no significant wealth or status disparity among households. And, at the same time, they maintained some very similar customs and ways of life as well. This is observation is supported by a study of other archaeological remains (referring to Li et al. 2018). The people of Guandimiao not only lived in similar small houses, were buried in small narrow tombs, and owned limited low-quality tools, but also consumed similar (and very limited meat) food with similar dietary customs. On the other hand, the analysis of meat resource processes (especially distribution, referring to Chapter 8) gives a hint that the village was organized with some collective aspects. This can also be argued based on the rich sacrificial discoveries and many mortuary remains (Hou et al. 2019; Li et al. 2018). These facts may be related to the activity of pottery production that occurred at the site. In addition, the lack of some special large cookware or tableware for commensal events may also imply a relatively loose village-level organization relationship, for which intensive or repeated ritual activities were not needed, and there was no clear power center or person that could have kept some special artifacts for public use, although commensal activities might have happened. Some of these ideas have been suggested by archaeological evidence from the same site, and the zooarchaeological study here can confirm and even deepen our knowledge from another perspective. As for commoners in Xiaomintun and Zhougongmiao, there were some clues of urban life, which, as least in terms of meat food production and consumption, emphasizes a combination and balance of abundance, efficiency, specialization, and standardization (as summarized in Section 11.1 of this chapter).

In summary, the study of animal foodways shows a potential to contribute widely to a variety of topics such as daily life, social management, and economic systems. These results, moreover, opens a way for further studies and the creation of new hypotheses.

11.3 Further Considerations

As an end of this chapter and this dissertation, I would like to emphasize and rethink 1) the methodology which is developed and practiced here, as well as 2) some future directions of research that the discoveries in this dissertation may lead to.

► A reflection on the Methodology

This dissertation would like to explore a possibility to excavate new information from animal bones in the study of complex societies in China, far beyond information like taxa, quantity, wild/domestic that is usually cited simply as reference data in discussions, or at the most, is summarized to explain some large-scale temporal and/or spatial characteristics and changes (in ecological and economic studies)[140]. The study of daily life remains based on animal bones, which are some of the most common archaeological remains, should actively join in the mainstream discussions of social, economic, and political topics.

As shown in this dissertation, my exploration goes in two directions. On the one hand, bone modification study helps to get information from bones directly. This is borrowed from Paleolithic archaeologists who take animal bones as one of the most significant lines of evidence to study human behaviors. This dissertation demonstrates that detailed information collected from bones can serve well for social meaning studies. On the other hand, when there are various types of archaeological remains from one site, as well as other related writing and pictorial evidence, a combination of several related types of evidence helps to deep and broaden the discussion. As for the first direction, most of the models, patterns and examples that have been referred to are developed based on case studies in other regions outside of China. Therefore, it raises a long-

[140] There have been some studies on special bone collections, such as sacrificial remains and bone-working waste. However, this dissertation focuses on ordinary daily consumption bone waste.

lasting question to consider whether and how existing models may fit with the Chinese case. We can expect various technical and methodological developments in different directions to extract more information from animal bones and push the study forward. For the second direction, the combination and comparison of animal bones, ceramic *li* tripods, and stable isotope results are interesting. However, it is still meaningful to think if there are better ways to make a more rigorous or nuanced analysis understanding based on different types of evidence.

In addition, this study stresses the assessment of taphonomic attrition in zooarchaeological study. Traditionally, this is not well considered in the study of historical sites in China. However, it has to be a necessary step when human behaviors (related to bone modification and site formation) become the priority.

► A Discussion of Research Questions

Non-elites and daily life are two very inconspicuous research directions in the previous study of the Chinese Bronze Age, and both of them have been key foci of this dissertation under the topic of animal foodways study. Theoretically, being food waste, animal bone remains should include rich information related to all steps from animal production to meat-food consumption. As a first try to excavate the connection between animal remains and human behavior and to explore the social meaning of bones, this dissertation has reached the primary goal of summarizing patterns of animal butchery and cooking to reconstruct the possible mode of meat consumption. Based on this, this study has demonstrated the differentiation between non-elite communities in daily life considering urban/rural contexts and the ethnic/cultural differences. This is a preliminary study. Along this line, I hope that similar analyses can be applied to other case studies. It would be interesting to see more cases and ask whether and how groups from different settlements or different neighborhoods in a settlement may be identified (other than the three communities in this dissertation). It is also meaningful to figure out whether and how daily life and ritual life can be separated by meat food study, since sacrificial remains/regions can be identified in some cases (even in the small rural settlement Guandimiao). Broadly speaking, these studies on meat food offer a way to trace the distribution and consumption of social resources, which includes not only meat resource itself but also supporting factors (such as professionals and techniques, tools and utensils, rules and customs, facilities and institutions) in the system. Therefore, this will then lead to studies on social complexity along many lines and will help to make a holistic discussion on social organization and structure in the Chinese Bronze Age.

APPENDIX I: Density-Mediated Attrition

This is a note to roughly explain some of my thoughts on the methodology in studying density-mediated bone attrition. I mainly mean to explain why the traditional methods adopted by scholars in the study of archaeofaunal assemblages in Paleolithic period cannot be applied to my study and how it is possible for me to make some modification. For this reason, it lacks a systematic review of past research on this topic, while the most important works can be found by looking at references cited here.

Many archaeofaunal assemblages have suffered from some degree of (selective) transport, element breakage and/or attrition, and other *in situ* attritions, which were caused by natural and cultural agents. The various bone modification can affect both the survival of individual elements and the relative representation of elements. For this reason, individual elements and the whole element profile can indicate the degree of skeletal completeness and provide information on attritional processes of bones, and, further, help to study various human and non-human treatments of animal carcasses.

It is argued by many scholars that the scope of bone destruction and deletion correlates to a large extent with different densities (e.g., Binford 1981; Brain 1967; Cleghorn and Marean 2004; Lyman 1994). To be specific, human and animal (mainly carnivore) impacts play a main role in animal skeletal modification, while bone/food utility, which is relevant to human activities such as animal butchery, body part transport, and cooking, maintains a weak negative relationship with bone density (when long bones are calculated by the articular ends) (e.g., Lyman 1985, 1992; Grayson 1989), while the attrition of carnivore ravaging is also closely related to density-mediated destruction (for example, some studies show that the greasy bone parts which carnivores prefer are usually of low density; e.g., Brain 1981; Lam et al. 1998; Marean and Spencer 1991), and many other natural attrition process, such as trampling, chemical leaching, and burning, also correlate inversely with bone density (e.g., Lyman 1994). For these reasons, the study of carcass processing (especially body part transport) based on body part profiles was criticized because of equifinality in the analysis. Besides, there are some other processes, such as some extreme environment attrition (e.g., Conard et al. 2008) and some variations caused by human cooking (e.g., Lupo 1995; Thompson and Lee-Gorishti 2007) and bone production (e.g., Campbell et al. 2011; Zhao 2017) that are not density-mediated. Therefore, the study of density-mediated attrition aims to observe the preservation of animal skeletal elements in site and assess the possibility of density-mediated attrition (while the methodology of long bone calculation is also discussed so that long bone shaft should also be considered in such studies). Because inter- and intra-bone densities can be significantly different, in order to discuss the degree of bone attrition, both individual elements and element portions have to be considered (e.g., Lyman 1984, 1985, 1994; Marean and Frey 1997), and the statistical correlation between bone elements or element portions (in terms of quantities) and bone densities (e.g., Lam et al. 1999; Lyman 1994; Symmons 2002) should be tested (during this process, the methodology of long bone calculation is frequently discussed).

However, Stiner (2002) has criticized some unsolved methodological problems of this approach -- there is much variation in the definition of density and its calculation, the structural mechanism of bones' resistance to destruction is not entirely clear but only modelled, while anatomical standards are used as controls. Moreover, there is great variation in bone element densities between measurement techniques. In addition, the feasibility of such a statistical test for studying large animal assemblages typical of complex societies has also been doubted. Firstly, in order to make a comparison, several marked locations on each element have to be recorded during identification, which should match the locations of scan sites on the element in bone density study. This is really a heavy workload for studying thousands of bone fragments from a site of a complex society (such as Guandimiao). In addition, most such analyses are for large and medium sized ungulates (mostly bovids and cervids) since bone density is more sensitive to attrition in animals of larger size and in bovids and cervids, while studies on pigs and dogs (two major domestic animals possibility consumed as meat resources) are missing (Cleghorn and Marean 2004) yet necessary for understanding a site like Guandimiao. In addition, because statistical tests are an analysis of probability, the interpretation of the result may not be straightforward. The test may show a general tendency but is not a one-to-one result (Orton 2012). Thus, even if the result turns out to be highly correlated between the abundance of bone elements/portions and their densities, it is still possible that some elements/portions with high density are not well represented, or vice versa. Even if there proves to be no correlation, it does not mean the attrition is not caused by bone density or equifinal activities at all. For this reason, a visual observation of body part distribution is always needed. Because of all these considerations, it is not a priority in this dissertation to do correlation test between bone elements (or element portions) and bone density.

I mean to take a simplified approach in order to reduce the inconvenience mentioned above, while still using diverse bone densities as a base for my work. I plan to use a qualitative analysis of the pattern of skeletal element distribution instead of a correlation test, and a study of the degree of bone fragmentation is followed in order to better understand the pattern. In doing so, I compared a high- and low-survival element model and related research with my work here.

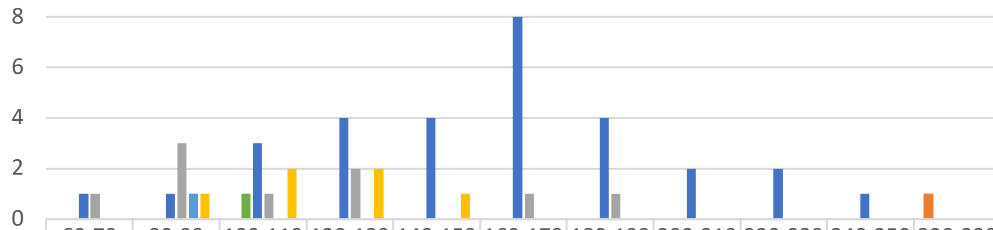
In consideration of archaeological discoveries, experiment results, and results of bone density analyses, it is confirmed by many scholars that cranial and limb bones are relatively better preserved than axial bones on average (e.g., Binford 1981; Lam et al. 1999; Lyman 1994; Marean and Cleghorn 2003; Stiner 2002). Marean, Cleghorn, and colleagues (e.g., Marean and Frey 1997; Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007) have further divided all skeletal elements into high- and low-survival sets by the possibility of survival through various (density mediated) forms of taphonomic attrition (including human and carnivore damage mainly, as well as some other natural processes as well). High-survival elements and element portions are all those high in density, and with large tracts of compact bones but little cancellous bones, including long bone midshafts (femur, tibia, humerus, radius, and, for ungulates, metatarsal and metacarpal), the cranium (mainly teeth and the petrosal), and the mandible. Low-survival elements and element portions are composed of those with grease-rich cancellous bones but low in density, such as vertebrae, ribs, pelvises, and long-bone ends, as well as those easily fractured or totally destroyed, such as scapulae, ulnae for species like bovids and cervids, and small compact bones and phalanges of some species (e.g., Faith and Gordon 2007).

There are also some variations. The final preservation of archaeofaunal assemblage may be affected by ungulate sizes and taxa, so that the situations of different archaeofaunal assemblages can be varied. The relative survivability of elements is also species-dependent, and the situation of many species (e.g., suids, equids, hominids, pinnipeds) differing from bovids and cervids (Cleghorn and Marean 2004), while only the latter two are the main examples discussed in the literature.

The bone high- and low-survival model is for studies of issues such as early hominid behavior and subsistence and the nature and formation of sites, etc. High-survival elements/portions, mainly cranial bones and long bone shafts, in an archaeofaunal assemblage usually hold a high possibility to be preserved after destructive taphonomic processes (e.g., Marean and Spencer. 1991; Marean et al. 1992). So, the composition and frequency of animal high-survival elements/portions in an assemblage is taken, to some degree, as a reflection of the hominin-originated body part profile before carnivore ravaging and other peri-depositional attritions, which indicates early hominin's carcass butchery and transport decisions according to the distinction of cranial and limb bone parts based on food utility (e.g., Cleghorn and Marean 2007; Faith and Gordon 2007; Faith et al. 2009; Saladié et al. 2011; Yravedra and Domínguez-Rodrigo 2009). Accordingly, the low-survival subset as a whole is unreliable for evaluating the degree of destruction or studying hominin behavior because of diverse natures of elements included (Cleghorn and Marean 2004, 2007; Faith and Thompson 2018). However, the different preservation of long bone ends and shafts, which has been noticed by many scholars as a useful indicator of long bone fragmentation (e.g., Blumenschine and Marean 1993; Domínguez-Rodrigo et al. 2002; Marean and Spencer 1991; Nagaoka 2015; Payne 1985; Todd and Rapson 1988), can be used as an index of taphonomic attrition because of its highly significant correlation with the abundance of low-survival elements (i.e., the amount/frequency of each element) (Faith and Thompson 2018).

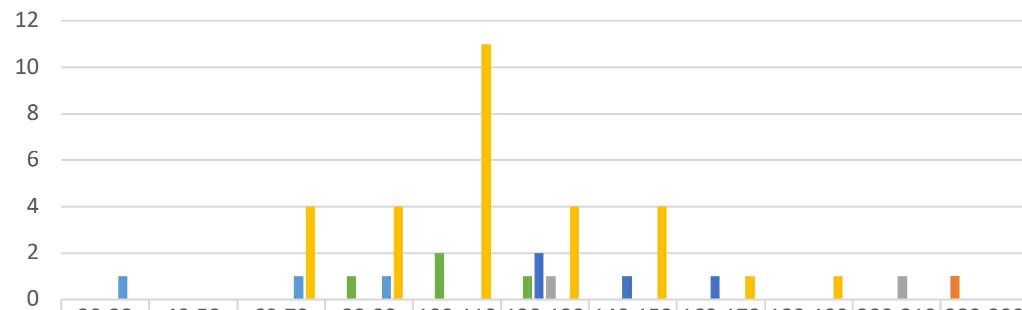
The high- and low-survival element model has been applied to studies of many paleolithic animal assemblages (e.g., Yravedra and Domínguez-Rodrigo 2009) but cannot be directly applied to animal assemblages of complex societies. This model is developed based on studies of mostly wild medium-to-large size ungulates found in many Paleolithic sites. By looking at the high-survival elements (for examples, the long bone mid-shafts), which are likely the best preserved in an assemblage, it is a relatively useful way to control destructive factors in order to approach the scenario of hominin butchery and transport considering the limitations of paleolithic zooarchaeology. Nevertheless, the meaning and value of bone element frequencies is different in sites of complex societies. With exceptions of cattle and horses, many domestic animals are medium to small in size and may be processed under various contexts (e.g., different butchering tools and approaches). The intensity of carcass butchery and meat cooking should be high, and so is dog ravaging. Under these circumstances, the degree of bone fragmentation can be significant. It is quite possible that some high-survival elements have been rendered unidentifiable or even lost when bones are analyzed in the lab (e.g., Atici 2006; Ioannidou 2003). The abundance and evenness of high-survival elements is not useful enough to distinguish the actions of human from those of dogs. Nevertheless, the high-survival subset is used here to suggest the potentially most reliable and helpful elements in a discussion on body part distribution, which can be a main focus. On the other hand, the ratio of long bone ends is needed in my analysis as a valuable substitution to indicate taphonomic attrition. Therefore, high- and low- survival elements can be discussed separately mainly to estimate the degree of destruction, and, if possible, to find clues of mammal body part selection and transport by humans, because inter- and intra-settlements material exchange in complex societies plays a crucial role in social life.

APPENDIX II: Guandimiao: dimensions of animal bone fragments



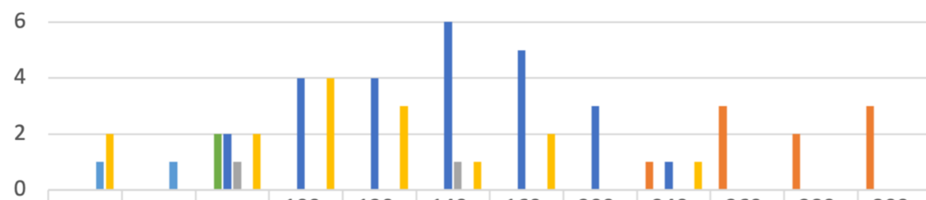
	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	220-239	240-250	320-339
whole	0	0	0	0	0	0	0	0	0	0	1
end	0	0	1	0	0	0	0	0	0	0	0
end-shaft	1	1	3	4	4	8	4	2	2	1	0
shaft_cylinder	1	3	1	2	0	1	1	0	0	0	0
end_splinter	0	1	0	0	0	0	0	0	0	0	0
shaft_splinter	0	1	2	2	1	0	0	0	0	0	0

Chart II–1 Distribution of the maximum length (mm) of cattle humerus specimens grouped by morphological types (calculated by NISP)



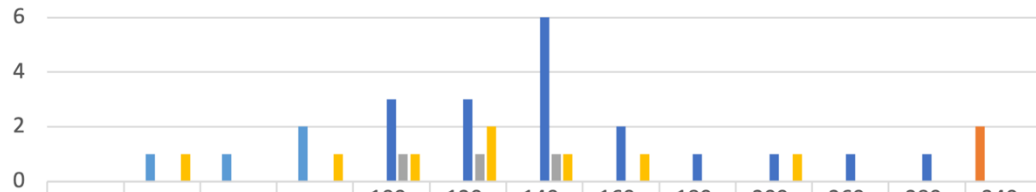
	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	380-399
whole	0	0	0	0	0	0	0	0	0	0	1
end	0	0	0	1	2	1	0	0	0	0	0
end-shaft	0	0	0	0	0	2	1	1	0	0	0
shaft_cylinder	0	0	0	0	0	1	0	0	0	1	0
end_splinter	1	0	1	1	0	0	0	0	0	0	0
shaft_splinter	0	0	4	4	11	4	4	1	1	0	0

Chart II–2 Distribution of the maximum length (mm) of cattle femur specimens grouped by morphological types (calculated by NISP)



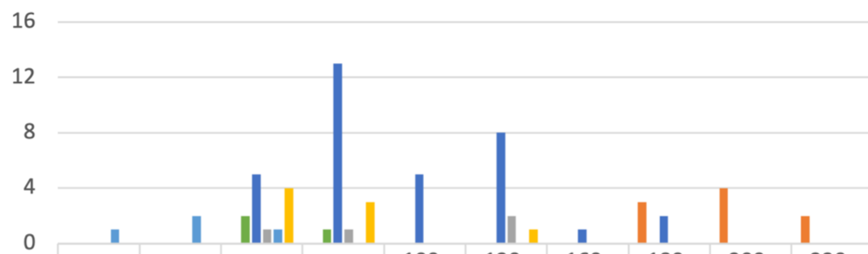
	40-59	60-79	80-99	100-119	120-139	140-159	160-179	200-219	240-250	260-279	280-299	300-319
whole	0	0	0	0	0	0	0	0	1	3	2	3
end	0	0	2	0	0	0	0	0	0	0	0	0
end-shaft	0	0	2	4	4	6	5	3	1	0	0	0
shaft_cylinder	0	0	1	0	0	1	0	0	0	0	0	0
end_splinter	1	1	0	0	0	0	0	0	0	0	0	0
shaft_splinter	2	0	2	4	3	1	2	0	1	0	0	0

Chart II–3 Distribution of the maximum length (mm) of cattle radius specimens grouped by morphological types (calculated by NISP)



	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	260-279	280-299	340-359
whole	0	0	0	0	0	0	0	0	0	0	0	0	2
end	0	1	1	2	0	0	0	0	0	0	0	0	0
end+shaft	0	0	0	0	3	3	6	2	1	1	1	1	0
shaft_cylinder	0	0	0	0	1	1	1	0	0	0	0	0	0
shaft_splinter	0	1	0	1	1	2	1	1	0	1	0	0	0

Chart II–4 Distribution of the maximum length (mm) of cattle tibia specimens grouped by morphological types (calculated by NISP)



	20-39	40-59	60-79	80-99	100-119	120-139	160-179	180-199	200-219	220-239
whole	0	0	0	0	0	0	0	3	4	2
end	0	0	2	1	0	0	0	0	0	0
end-shaft	0	0	5	13	5	8	1	2	0	0
shaft_cylinder	0	0	1	1	0	2	0	0	0	
end_splinter	1	2	1	0	0	0	0	0	0	0
shaft_splinter	0	0	4	3	0	1	0	0	0	0

Chart II–5 Distribution of the maximum length (mm) of cattle metapodial specimens grouped by morphological types (calculated by NISP)

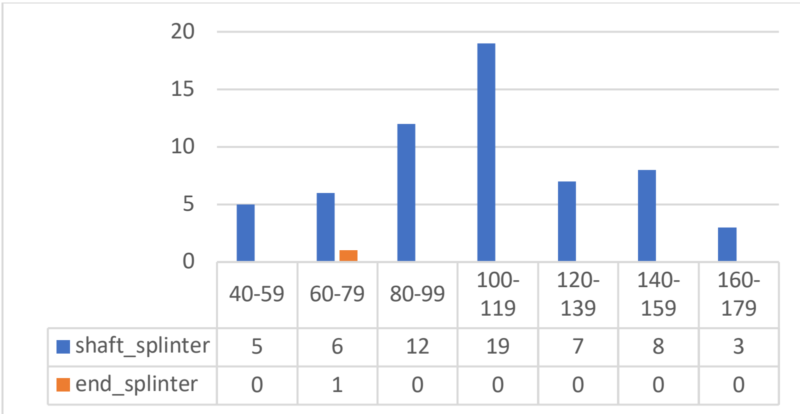


Chart II–6 Distribution of the maximum length (mm) of large mammal long bone specimens grouped by morphological types (calculated by NISP)

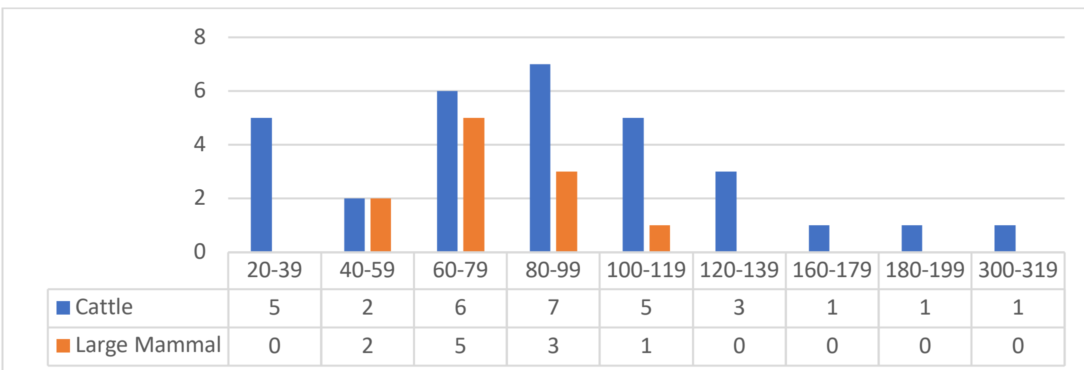


Chart II–7 Dimensions (mm) of old-broken cattle and large mammal skull specimens (calculated by NISP)

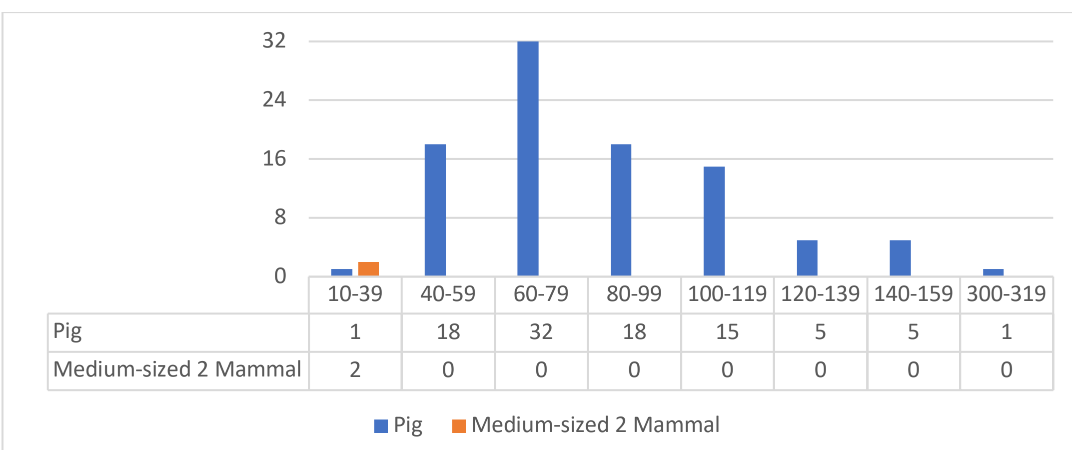
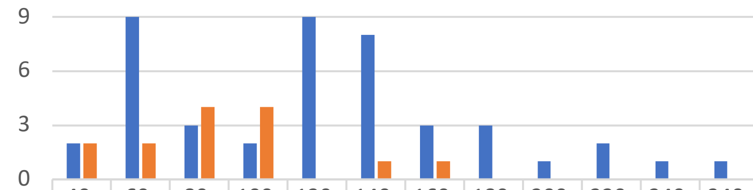
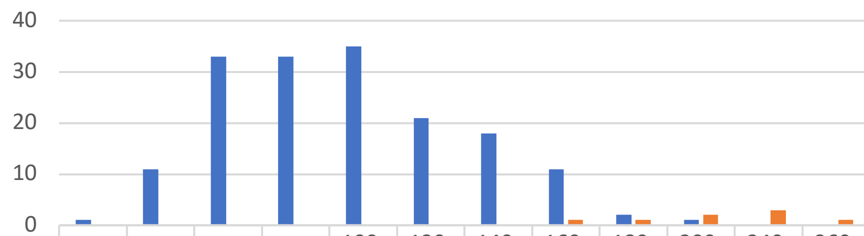


Chart II–8 Guandimiao: Dimensions (mm) of old-broken pig and medium-sized 2 mammal skull specimens (calculated by NISP)



	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	220-239	240-250	340-359
Cattle	2	9	3	2	9	8	3	3	1	2	1	1
Large mammal	2	2	4	4	0	1	1	0	0	0	0	0

Chart II–9 Dimensions (mm) of old-broken cattle and large mammal mandible specimens (calculated by NISP)



	10-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	240-250	260-279
Fragments	1	11	33	33	35	21	18	11	2	1	0	0
Whole	0	0	0	0	0	0	0	1	1	2	3	1

Chart II–10 Dimensions (mm) of old-broken pig mandible specimens (calculated by NISP)

APPENDIX III: Guandimiao: calculations of butchery marks

Table III–1 Four types of butchery marks by taxa/animal sizes (calculated by NISP of bone specimens)

	Butchery mark types					Total		
	Cut	Chop	Scoop	Shear	SUM[1]	Butchery Marks[2]	Total	Butchered (%)
Cattle	175	47	7	15	244	213	775	27.5%
Pigs	131	24	5	26	186	156	1023	15.2%
Dogs	25	6	1	3	35	30	261	11.5%
Sheep/goats	7	2	0	1	10	9	103	8.7%
Deer	7	4	0	2	13	11	95	11.6%
Large mammal	26	10	0	0	36	35	463	7.6%
Medium-large mammal	6	3	0	2	11	9	195	4.6%
Medium-size mammal	5	1	0	4	10	6	189	3.2%
Medium-size-1 mammal	2	0	0	2	4	2	70	2.9%
Medium-size-2 mammal	10	1	1	2	14	10	163	6.1%
Total	394	98	14	57	563	481	3337	14.4%
Butchery marks (%)[3]	70.0 %	17.4 %	2.5%	10.1 %	100.0 %			

Keys:
[1, 2] One specimen can exhibit more than one type of butchery mark. [1] SUM = the sum of specimens with cut, chop, scoop and shear marks, and some specimens with more than one type of butchery marks may be counted several times. [2] Butchery Marks = the number of specimens with butchery marks, which can be equal to or smaller than "SUM". However, the overlap does not affect other calculations or comparisons significantly.
[3] Butchery marks (%) = (the number of specimens with certain type of butchery mark) ÷ SUM × 100%, which represents the relative proportions of cut, chop, scoop, and shear marks.

Table III–2 Cattle: butchery mark frequencies by element (calculated by NISP of bone specimens)

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchery Marks	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
cranium	2	4.4	3	6.7	0		1	2.2	5	5	45	11.1
mandible	16	21.6	4	5.4	1	1.4	3	4.1	20	20	74	27.0

atlas	1	10.0	2	20.0	0		1	10.0	3	3	10	30.0
axis	2	18.2	2	18.2	1	9.1	0		4	4	11	36.4
cervical	3	16.7	1	5.6	0		1	5.6	5	5	18	27.8
thoracic	0		0		0		0		0	0	3	0.0
lumbar	0		0		0		0		0	0	2	0.0
sacral	0		0		0		0		0	0	3	0.0
caudal	0	-	0	-	0	-	0	-	0	0	0	-
VER.FR	0		0		0		0		0	0	7	0.0
rib	13	48.1	5	18.5	2	7.4	6	22.2	17	17	27	63.0
scapula	0		0		0		0		0	0	16	0.0
pelvis	3	13.6	3	13.6	0		1	4.5	5	5	22	22.7
humerus	31	49.2	5	7.9	0		0		33	33	63	52.4
radius	16	22.9	4	5.7	2	2.9	0		18	18	70	25.7
ulna	8	22.9	1	2.9	0		0		9	9	35	25.7
femur	15	23.4	1	1.6	0		0		15	15	64	23.4
tibia	11	23.4	1	2.1	0		0		11	11	47	23.4
metapodial	22	29.3	1	1.3	1	1.3	0		23	23	75	30.7
calcaneum	8	26.7	1	3.3	0		2	6.7	9	9	30	30.0
talus	10	52.6	2	10.5	0		0		11	11	19	57.9
first phalanx	7	41.2	2	11.8	0		0		9	9	17	52.9
second phalanx	4	28.6	0		0		0		4	4	14	28.6
third phalanx	0		2	4.8	0		0		2	2	42	4.8
carpal	3	17.6	2	11.8	0		0		5	5	17	29.4
tarsal	0		0		0		0		0	0	14	0.0
sesamoid	0		1	33.3	0		0		1	1	3	33.3
horn	0		4	14.8	0		0		4	4	27	14.8
Total	175	22.6	47	6.1	7	0.9	15	1.9	213	213	775	27.5
Butchery marks (%)[4]	71.7		19.3		2.9		6.1		100.0			

Keys:
[1,2] One specimen can exhibit more than one type of butchery marks. [1] SUM = the sum of specimens with cut, chop, scoop and shear marks, and some specimens with more than one type of butchery marks may be counted several times. [2] Butchery Marks = the number of specimens with butchery marks, which can be equal to or smaller than "SUM". However, the overlap does not affect other calculations or comparisons significantly.
[3] Butchery marks (%) = (the number of specimens with certain type of butchery mark) ÷ SUM × 100%, which represents the relative proportions of cut, chop, scoop, and shear marks.
[3] The incidence of certain type of butchery mark (%) = (the number of specimens with certain type of butchery marks) ÷ (the total number of specimens) × 100%. So, the sum of the incidences of cut, chop, scoop, and shear marks can be equal to or larger than the incidence of specimens with butchery marks as shown in the last column.
[4] Butchery marks (%) = (the number of specimens with certain type of butchery mark) ÷ SUM × 100%, which represents the relative proportions of cut, chop, scoop, and shear marks.

Table III–3 Pigs: butchery mark frequencies by element (calculated by NISP of bone specimens)

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchery Marks	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
cranium	9	4.3%	4	1.9%	1	0.5%	10	4.8%	24	14	210	6.7%
mandible	21	7.2%	7	2.4%	0		5	1.7%	33	27	293	9.2%
atlas	15	48.4%	0		0		0		15	15	31	48.4%
axis	0		0		0		0		0	0	4	0.0%
cervical	1	16.7%	0		0		0		1	1	6	16.7%
thoracic	2	10.5%	0		0		1	5.3%	3	3	19	15.8%
lumbar	12	46.2%	3	11.5%	0		2	7.7%	17	13	26	50.0%
sacral	0		0		0		0		0	0	1	0.0%
caudal	0	-	0	-	0	-	0	-	0	0	0	-
rib	8	17.8%	1	2.2%	0		4	8.9%	13	11	45	24.4%
scapula	10	23.3%	2	4.7%	2	4.7%	1	2.3%	15	12	43	27.9%
pelvis	5	11.1%	1	2.2%	0		2	4.4%	8	6	45	13.3%
humerus	24	26.1%	4	4.3%	2	2.2%	1	1.1%	31	28	92	30.4%
radius	3	11.1%	0		0		0		3	3	27	11.1%
ulna	4	11.8%	1	2.9%	0		0		5	5	34	14.7%
femur	6	15.8%	0		0		0		6	6	38	15.8%
tibia	9	13.2%	1	1.5%	0		0		10	10	68	14.7%
metapodial	1	4.5%	0		0		0		1	1	22	4.5%
calcaneum	1	9.1%	0		0		0		1	1	11	9.1%
talus	0		0		0		0		0	0	2	0.0%
first phalanx	0		0		0		0		0	0	2	0.0%
carpal	0		0		0		0		0	0	1	0.0%
sesamoid	0		0		0		0		0	0	2	0.0%
Total	131	12.8%	24	2.3%	5	0.5%	26	2.5%	186	156	1022	15.3%
Butchery marks (%)[4]	70.4%		12.9%		2.7%		14.0%		100.0%			

Keys: refer to those in Table III–2.

Table III–4 Cattle: butchery mark frequencies by element portions (calculated by NISP)

	Butchery mark types									Total		
	Cuts		Chops		Scoops		Shears		SUM	Butchered	Total	
	N	%*	N	%*	N	%*	N	%*		N	N	%**
rib-head	6	54.5	3	27.3	1	9.1	2	18.2	12	9	11	81.8
rib-square blade	11	78.6	1	7.1	2	14.3	2	14.3	16	12	14	85.7
rib-flat blade	1	10	1	10	0		2	20	4	3	10	30
pelvis-acetabulum	3	27.3	2	18.2	0		1	9.1	6	4	11	36.4
pelvis-ilium/ischium/pubis	0		1	5	0		0		1	1	20	5
metapodial-P articulation	3	7.5	0		0		0		3	3	40	7.5
metapodial-shaft	15	25	0		0		0		15	16	60	26.7
metapodial-D articulation	11	37.9	1	3.4	1	3.4	0		13	13	29	44.8
limb-P articulation	9	11.7	1	1.3	1	1.3	0		11	13	77	16.9
limb-shaft	44	22.1	5	2.5	1	0.5	0		50	48	199	24.1
limb-D articulation	24	23.3	6	5.8	0		0		30	29	103	28.2
humerus-P articulation	2	22.2	1	11.1	0		0		3	3	9	33.3
humerus-shaft	16	26.7	2	3.3	0		0		18	17	60	28.3
humerus-D articulation	15	39.5	3	7.9	0		0		18	18	38	47.4
radius-P articulation	4	9.5	0		1	2.4	0		5	6	42	14.3
radius-shaft	11	18	2	3.3	1	1.6	0		14	13	61	21.3
radius-D articulation	3	13	2	8.7	0		0		5	5	23	21.7
femur-P articulation	3	20	0		0		0		3	4	15	26.7
femur-shaft	8	18.2	1	2.3	0		0		9	9	44	20.5
femur-D articulation	3	23.1	0		0		0		3	3	13	23.1
tibia-P articulation	0		0		0		0		0	0	11	0
tibia-shaft	9	26.5	0		0		0		9	9	34	26.5
tibia-D articulation	3	10.3	1	3.4	0		0		4	3	29	10.3

Note: because of the differentiated preservation of long bone portions, the distribution of butchery marks on portions of humerus, radius, femur, and tibia are both listed separately based on element and summarized into one "limb" group.
Key: limb-P articulation = proximal articulation of a limb bone; limb-D articulation = distal articulation of a limb bone. Similar expressions are applied to other limb bones.
* Butchery marks (%) = Certain type of butchery marks / Total number of butchery marks × 100%.
** Butchered bones (%) = Specimens with butchery marks / Total specimens × 100%.

Table III–5 Pigs: butchery mark frequencies by element portions (calculated by NISP)

	Butchery mark types									Total		
	Cuts		Chops		Scoops		Shears		SUM	Butchered	Total	
	N	%	N	%	N	%	N	%		N	N	%**
rib-head	7	58.3	0		0		2	16.7	9	9	12	75
rib-square blade	1	2.2	1	2.2	0		3	6.7	5	5	45	11.1
pelvis-acetabulum	4	12.9	1	3.2	0		0		5	4	31	12.9
pelvis-ilium/ischium/pubis	1	5.6	0		0		2	11.1	3	2	18	11.1
limb-P articulation	5	12.5	0		0		0		5	5	40	12.5
limb-shaft	28	11.8	4	1.7	2	0.8	1	0.4	35	31	237	13.1
limb-D articulation	14	16.7	1	1.2	1	1.2	0		16	14	84	16.7
humerus-P articulation	2	33.3	0		0		0		2	2	6	33.3
humerus-shaft	18	17.8	3	3	2	2	1	1	24	20	101	19.8
humerus-D articulation	10	24.4	1	2.4	1	2.4	0		12	10	41	24.4
radius-P articulation	2	10	0		0		0		2	2	20	10
radius-shaft	1	3.8	0		0		0		1	1	26	3.8
radius-D articulation	1	20	0		0		0		1	1	5	20
femur-P articulation	0		0		0		0		0	0	4	0
femur-shaft	3	7.9	0		0		0		3	3	38	7.9
femur-D articulation	2	16.7	0		0		0		2	2	12	16.7
tibia-P articulation	1	10	0		0		0		1	1	10	10
tibia-shaft	6	8.3	1	1.4	0		0		7	7	72	9.7
tibia-D articulation	1	3.8	0		0		0		1	1	26	3.8

Note: refer to the note in Table III–4.

APPENDIX IV: Guandimiao: depiction of butchery marks

As for the drawings included in this appendix, cut marks are marked as red strokes, chop marks as blue strokes, scoop marks labelled in purple circles, and butchery marks on young individuals[141] in green color, while some shear marks can be seen in images shown in Chapter 7. For some specimens, when a certain type of butchery mark appeared in a single location it was calculated as "1" even though it actually included more than one stroke at this location (refer to Chapter 5). In these drawings, I have recorded all the strokes of butchery marks in order to signify the locations with butchery marks. Therefore, the amount of butchery marks shown in these drawings are different from those recorded in Table III–2 and Table III–3 in Appendix III.

1. Cranium

► Pig

Relating to a discussion of the pattern of pig head fragmentation in Sec. 1.2.1 of Chapter 7, the most robust evidence is several posterior cranial bones and facial bone fragments which bear clear sheared breakage surfaces and, sometimes, chop marks as well, representing the process of cranium dismemberment. Then, a cluster of butchery marks, mainly cut marks, occurs around the portion between the maxilla and the zygomatic bone (usually above the first and/or second molar). Some of them are above and parallel to the upper molars, and some are around the inferior of the zygomatic bone (Figure IV–1). These marks are quite possibly related to the activity of cutting the cheek muscles off and disarticulating the mandible (Binford 1981: 109-110, mark S-6, Figure 4.19;

[141] There are three specimens with butchery marks for cattle and seven for pigs, which are not separately discussed.

Nilssen 2000: 170, mark S-6, Figure 4.237)[142]. Besides, four butchery fragments with cut and chop marks on/around the occipital condyles are probably related to separating the skull and the vertebral column.

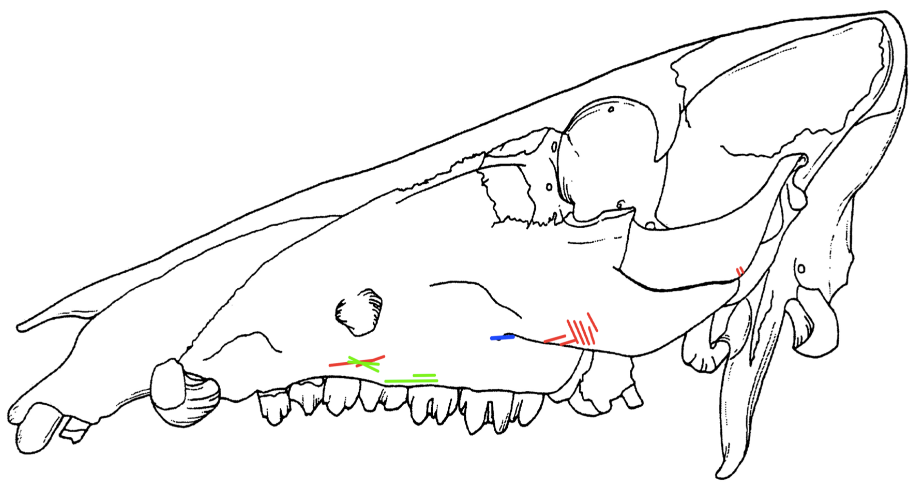


Figure IV–1 Butchery marks on pig cranium _ Guandimiao

2. Mandible

► Cattle

Butchery marks are concentrated on the medial and lateral sides, as well as the bottom of the dentary bone (Figure IV–2). Based on locations of distribution, most butchery marks can be summarized to several groups. Butchery marks around the ascending ramus are mainly on the lateral side, most of which are under the condyle process, along the posterior mandibular edge, and horizontally across the ascending ramus. According to Binford's (1981: 109) observation, these marks are possibly caused by slicing through the cheek muscles and/cutting free the mandible (in order to disarticulate the mandible from the skull). Parts of the butchery marks around the

[142] Similar activities can refer to two videos of pig head butchery YouTube: a) Butchering a Pig Head - How to Debone a Pig Head. Https://www.youtube.com/watch?v=yyAyx32jkAw. b) #63 Debone Pig Head. Https://www.youtube.com/watch?v=xxRBpy_OeF8.

horizontal ramus are possibly related to the defleshing process, while some marks on the medial side may be related to tongue removal (Binford 1981: 109-110, mark M-3) and some on the lateral side may be produced by skinning (Nilssen 2000: 171, mark M-10, M-11, Figure 4.238). Besides, several chop marks around the mandibular diastema and the middle of the horizontal ramus on the lateral side may have some connection with the activities to chop up a mandible to small pieces (which may be corresponding to fragmented mandibular chunks mentioned above, Section 1.2.2).

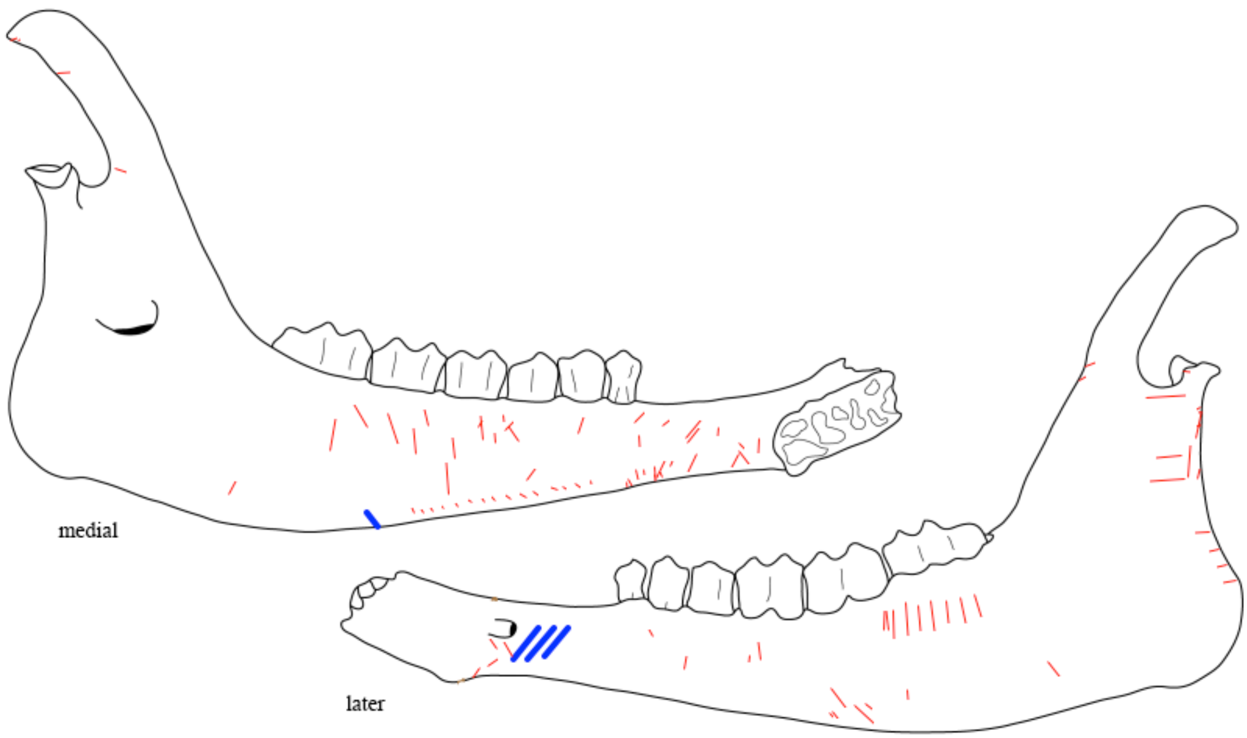


Figure IV–2 Butchery marks on cattle mandible _ Guandimiao

► Pig

Butchery marks are mainly observed in several locations (Figure IV–3). On the medial side of the horizontal ramus, cut marks are mainly under premolars and molars, which is also seen on cattle mandibles and quite possibly originates from cutting out the tongue (Binford 1981: 109, mark M-3; Nilssen 2000: Figure 4.238 a). A few butchery marks around the condyle process should be related to cutting off the ligaments so as to free the mandible. A cluster of cut marks are on the lateral side of the ascending ramus, which are also similar to those of cattle and could be a result of either mandible disarticulation and/or cheek muscle removal. However, unlike cattle, there are a great number of chop marks as well as some cut marks on the lateral side of the horizontal ramus. These marks may be related to meat removal in some cases. Considering the breakage pattern of pig's mandible (see Section 1.2.2 in this chapter), it is more likely that these marks, the chop marks especially, are closely related to activities of cleaving the dentary bone into several parts.

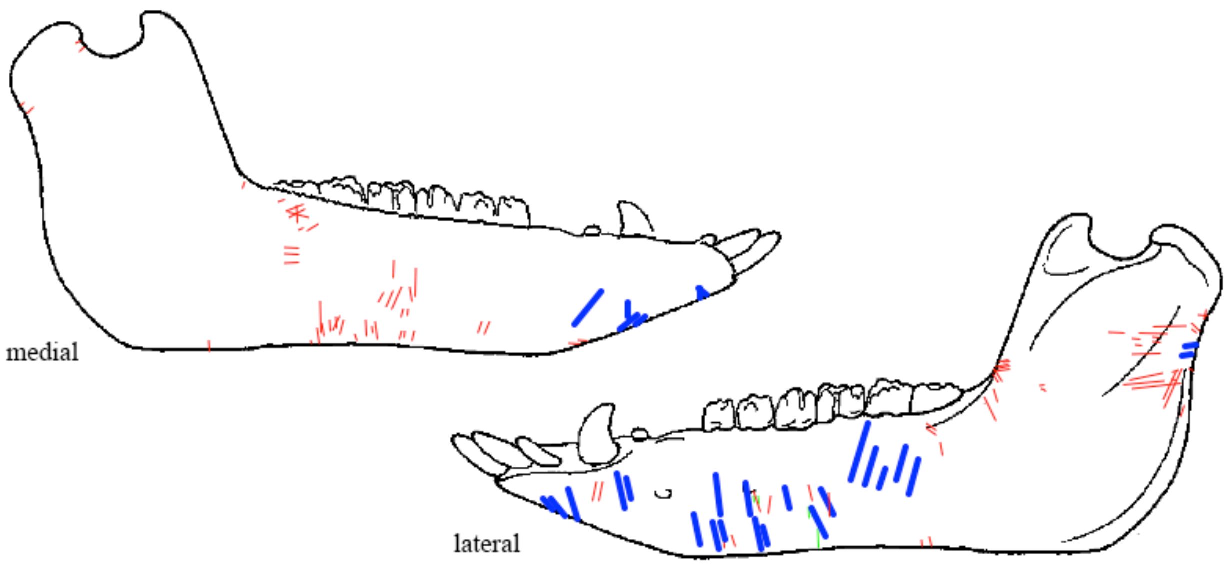


Figure IV–3 Butchery marks on pig mandible _ Guandimiao

3. Vertebrae

► Cattle

Specimens with butchery marks are mainly in subsets of atlas and axis.

Atlas Only three whole-preserved atlases are found with butchery marks. Butchery marks (mostly chop marks) scatter on both the dorsal and ventral sides (Figure IV–4). Some butchery marks around the anterior margin of the atlas are quite possiblely related to the activity of severing the head from the neck (Binford 1981:111, mark CV-1, Figure 4.20). In addition, these chop-mark-dominated specimens may indicate that most of the marks were caused by skull dismemberment.

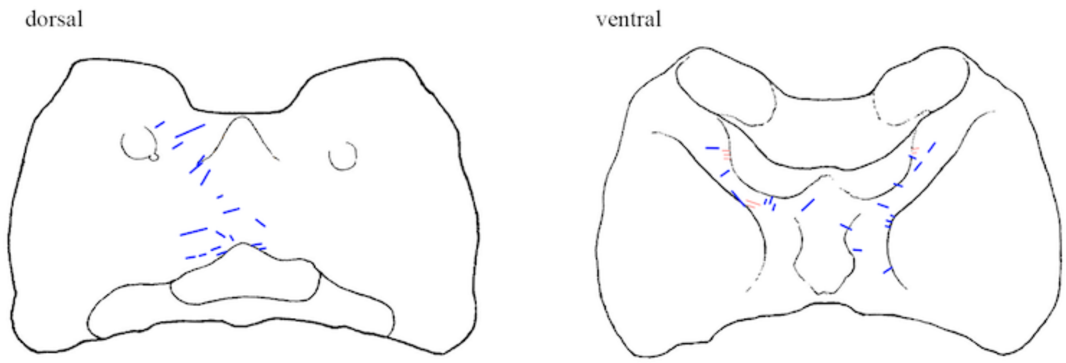


Figure IV–4 Butchery marks on cattle atlas _ Guandimiao

<u>*Axis*</u> Though there are only four axes with butchery marks only, two different types of specimens are distinguished (Figure IV–5), which correspond to two groups of fractured axes (see a description above in Section 1.2.3). One nearly whole axis is covered with short cut marks scattering on four sides (two laterals, dorsal, and ventral) of the bone, while the cranial articulator process and the dens have no marks. As for the three anterior-half-preserved specimens, cut marks are clustered in mainly two locations. Some marks are around the base of the dens (connecting to the anterior articular process), and around and behind the cranial articular process. Accordingly, these marks may represent two ways of vertebra dismemberment and/or filleting[143].

[143] Binford (1981: 137) even supposed that the transverse cut across anterior ventral surface of the axis (CV-3 marks) may be related to dismemberment of a stiff carcass, which is possibly generated by severing the head from the neck. So, it is possible that cattle heads were severed from the neck in different approaches in Guandimiao.

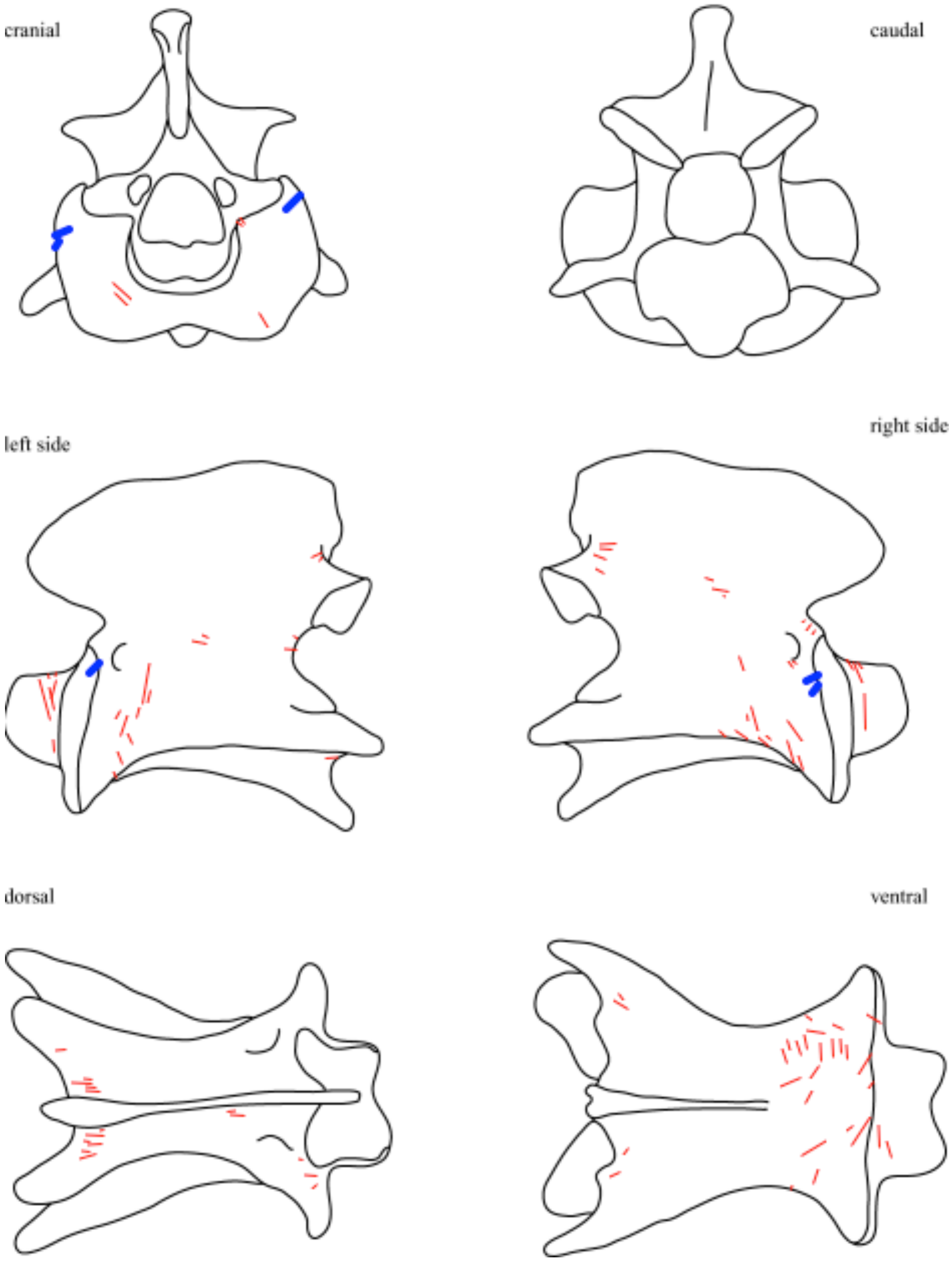


Figure IV–5 Butchery marks on cattle axis _ Guandimiao

<u>*Other vertebrae*</u> Butchery marks on other vertebrae are quite limited. Based on five cervical specimens, butchery marks are mainly on lateral sides (Figure IV–6). Five vertebral fragments of large mammals show butchery marks also on the dorsal side (close to the base of spinous process) and on transverse processes. These marks may have been inflicted either during

steps of dismemberment (e.g., segmenting vertebrae, separating ribs slabs) or filleting (e.g., removing the tenderloin) (Binford 1981:110-113). However, as mentioned earlier in this chapter (Section 1.2.3), almost all the vertebral bodies are completely preserved, and there is no butchery mark (sheared fracture surface) related to behaviors of cleaving a vertebral centrum longitudinally.

Figure IV–6 Butchery marks on cattle cervical _ Guandimiao

► Pigs

Atlas and lumbar vertebrae are relatively well represented and have many more fragments bearing butchery marks than other vertebrae.

<u>*Atlas*</u> This element is relatively well represented (31 specimens) and almost half of them have cut marks. These marks are distributed on both the dorsal and ventral surfaces (Figure IV–7), and many of them run across the cranial margin of the atlas, which is possibly related to the division of the head from the vertebral column (Binford 1981: 137, mark CV-1, Figure 4.20).

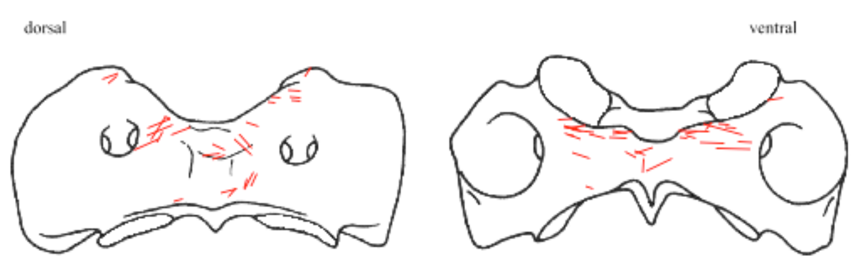


Figure IV–7 Butchery marks on pig atlas _ Guandimiao

<u>*Other vertebrae*</u> Because of poor preservation, no specimens with butchery marks were found on axes and little is known about the treatment of this element. In addition, there are a

few cervical and thoracic bones with butchery marks, while lumbar vertebrae with butchery marks are well represented.

Shear marks are seen on anterior sides of a thoracic centrum and a lumbar centrum, characterized by a flat fracture surface. On another specimen, chop marks are seen on the ventral side of a lumbar centrum, perpendicular to the long axis of the vertebra (Figure IV–8: chop marks in blue), which may facilitate the same purpose. These marks together probably indicate a method for segmenting connected vertebrae with deep chops, which would have employed a heavy tool to chop through the vertebral column. In addition, there is also evidence of cut marks on the ventral sides of anterior and posterior articulator processes (Figure IV–8), which may have been caused during the process of severing the ligaments and may indicate another way/step to divide the vertebrae.

As for lumbar vertebrae, cut marks cluster longitudinally at the base of the transverse processes on the ventral surface. Scholars explain such marks as evidence of cutting off the major muscle groups (the tenderloin) and, sometimes, during the activity to shear off the rib slab (e.g., Binford 1981:113; Rixson 1989).

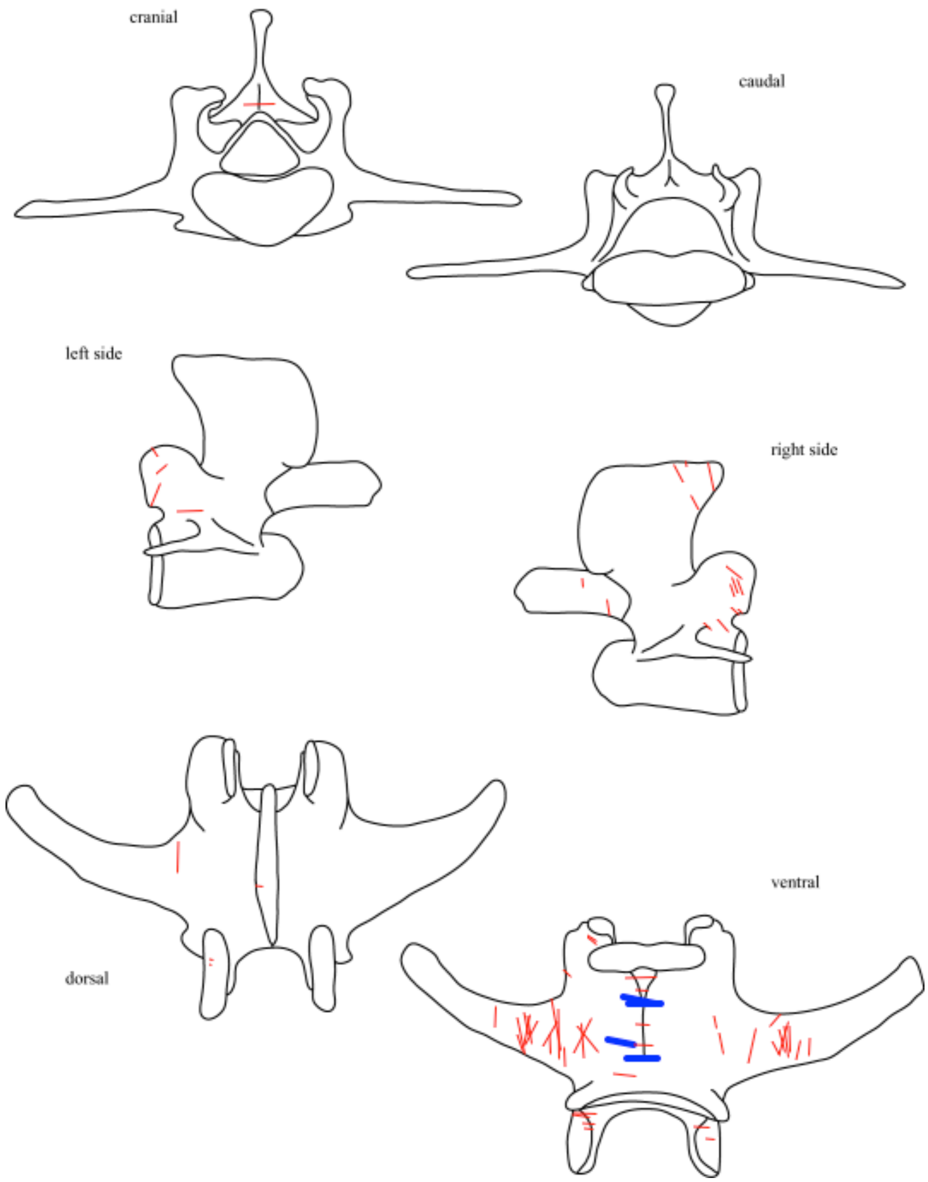


Figure IV–8 Butchery marks on pig lumbar _ Guandimiao

4. Ribs

► Cattle

Most butchery marks concentrate on the portion close to the proximal rib head, and are seen on all four (cranial, caudal, medial, and lateral) sides, especially on the medial and lateral surfaces (Figure IV–9). These butchery marks may be interpreted in three groups based on their locations, orientations, and even morphologies, which are possibly derived from different butchery behaviors. (1) According to Binford (1981:113, cut 20 in Figure 4.05) and Nilssen (2000: 168, mark RS-1, Figure 4.277 b and 4.279 b), transverse marks along the dorsal surface and to the proximal end of a rib are quite possibly generated from muscle removal from the back during secondary butchery. (2) Butchery marks on the medial (ventral) side and on/close to proximal rib heads might be inflicted in a later step to peel off rib slabs from the vertebral column, and some rib heads might be sheared off. This helps to explain the breakage of rib heads as has been discussed in Section 1.6 in Chapter 7 (e.g., Figure 7: c). (3) Scoop marks seen on two specimens are on cranial and caudal surfaces and close to proximal rib heads (Figure 1 in Chapter 5). These marks probably occurred in the last stage of butchery, to take apart individual ribs and remove scraps of meat attached to the bone. The typical scoop marks, which are clear evidence of filleting, are found on two ribs. In addition, three rib blade fragments have sheared fracture surfaces, which are related to rib fragmentation for food preparation (as discussed in Section 1.6)[144].

[144] A few cut marks occur transversely on ventral surfaces of some rib shafts, which may be related to evisceration (Nilssen 2000: 168, Figure 4.276 a and 4.278 a).

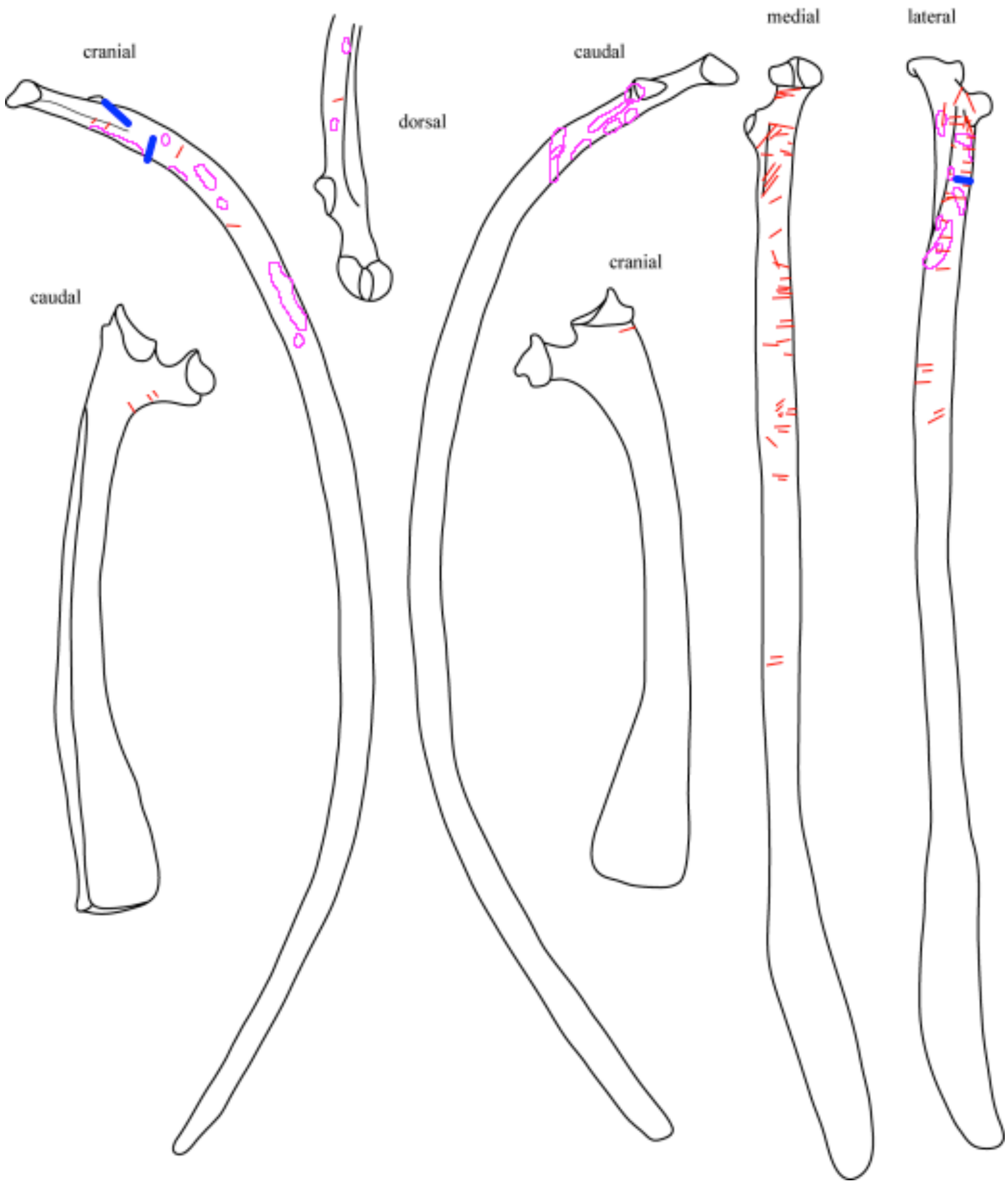


Figure IV–9 Butchery marks on cattle ribs _ Guandimiao

► Pigs

Only a few rib specimens with butchery marks are found. In general, patterns of butchery mark distribution for pigs are quite similar to those of cattle (Figure IV–10). However, butchery marks distributed on pig ribs are much less dense than those on cattle ribs.

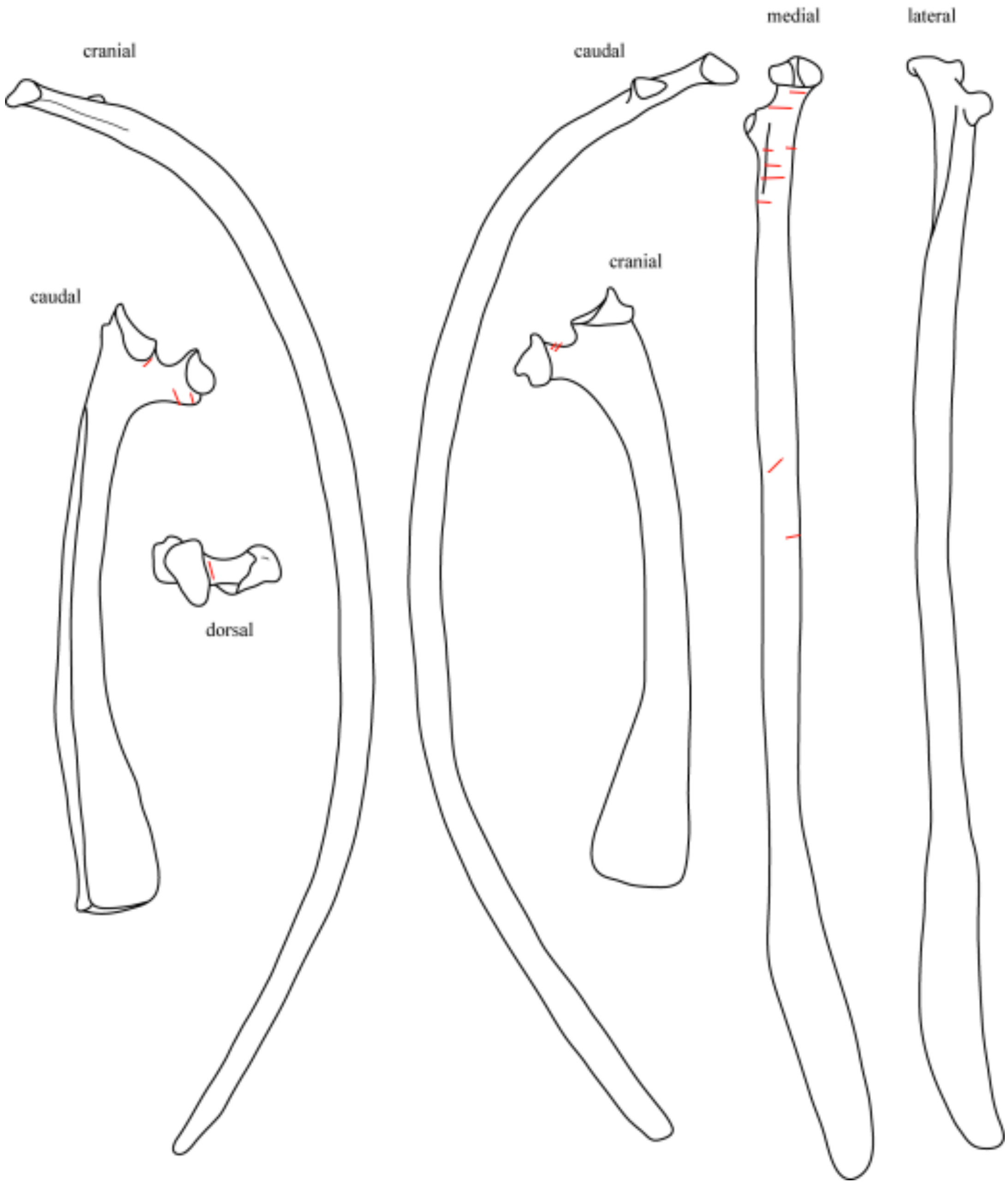


Figure IV–10 Butchery marks on pig ribs _ Guandimiao

5. Scapula

Cattle scapulae are not discussed here.

► Pigs

Most small butchery marks are clustered around the distal portion (below the glenoid cavity and around the neck) of scapulae, along the edge of the spine on the lateral side, and along the superior and lateral borders on the medial surface (Figure IV–11). Chop marks are only found on two specimens, and cut marks are much more common. While butchery marks around the glenoid cavity could be caused by slicing through the ligaments to disarticulate the scapula and/or filleting (Nilssen 2000: 164, mark S-7 and S-9, Figure 4.254 and 4.255 a), other marks are quite possible for the purpose of filleting.

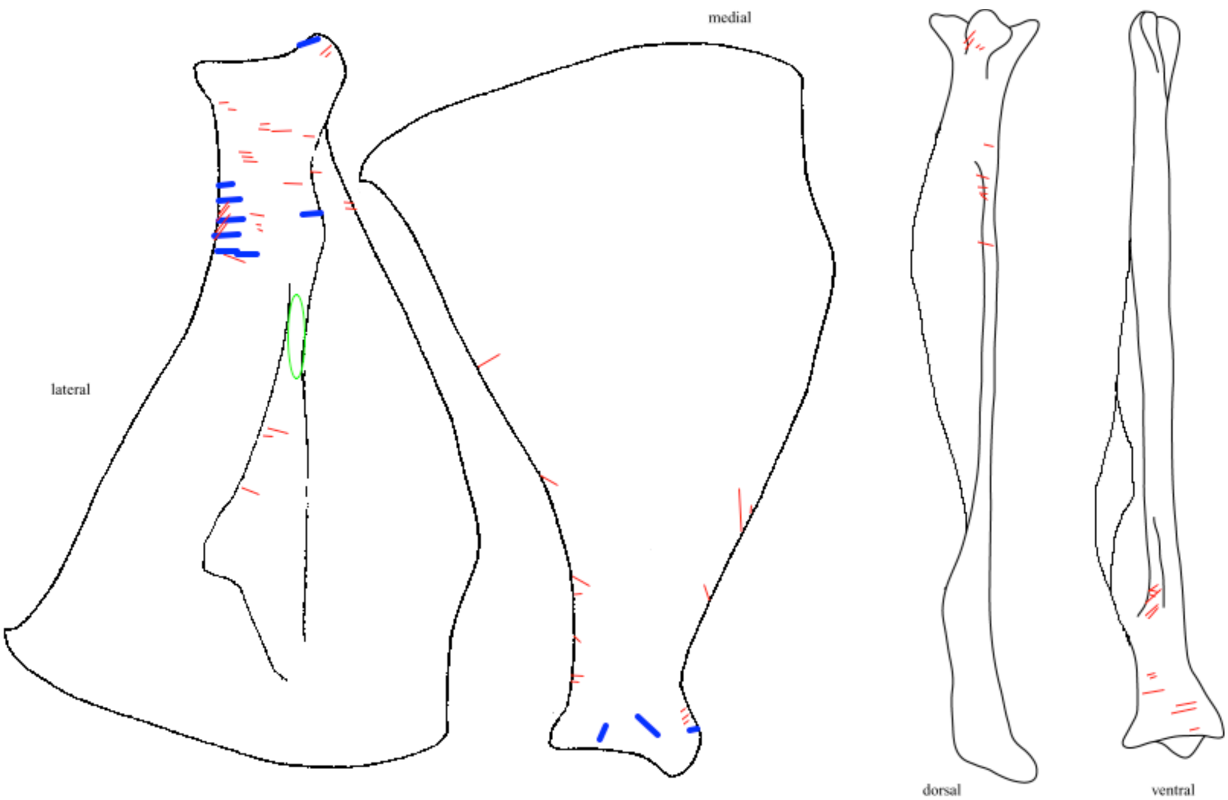


Figure IV–11 Butchery marks on pig scapula _ Guandimiao

6. Pelvis

► Cattle

Most of the butchery marks are around the acetabulum (Figure IV–12). These marks, corresponding to some butchery marks on the proximal end of femurs (Figure IV–17: a), indicate possibly the activity of cutting through ligament within the acetabulum, which aimed to cut the femur free (Binford 1981:113, marks PS-7, PS-8, PS-9, PS-10, Figure 4.22). As discussed in

Section 7.1.8, some ilium/ischium/pubis shafts show butchery marks next to, and parallel with, the straight fracture ridge, which are evidence of secondary butchery.

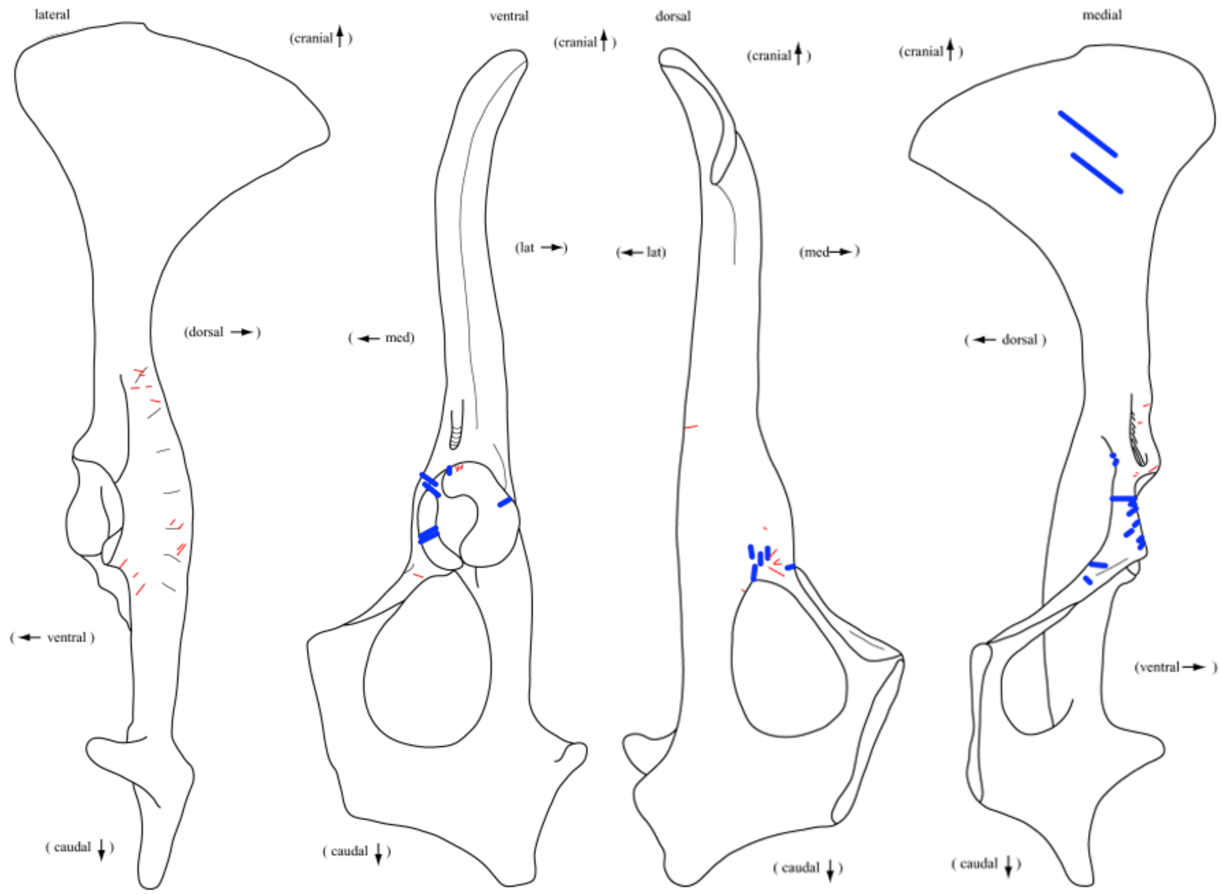


Figure IV–12 Butchery marks on cattle pelvis _ Guandimiao

► Pigs

Compared to the number of pelvis fragments in total, the ratio of specimens with butchery marks is rather small. However, the pattern of butchery mark distribution is similar to that of cattle (Figure IV–13). Some clean sheared fracture surfaces on the mid-shaft of the ilium/ischium/pubis indicate a purposeful breakage of innominate into small portions. The distribution of butchery marks varied in a few cases. There is no clear pattern of butchery marks overall for pig pelvises and the method used to cut free the femur from the acetabulum fossa is unknown. This is due to the small sample size of pelvis specimens and the preserved proximal part of the femur for pigs.

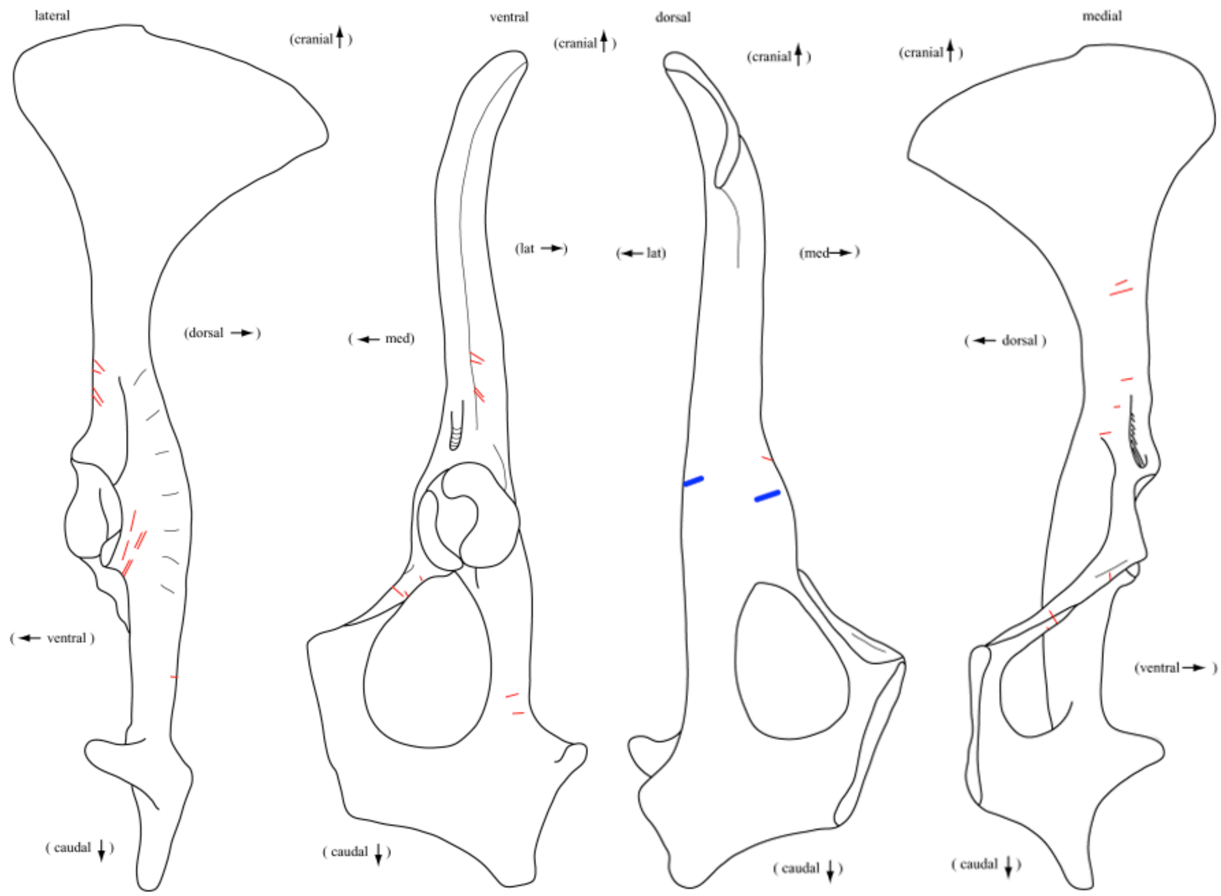


Figure IV–13 Butchery marks on pig pelvis _ Guandimiao

7. Humerus, radius-ulna, femur, tibia

Limb bones in general are characterized by cut marks and a few chop marks as well as a few scoop marks but no shear marks (Figure 14-18). It seems that the usual technique of limb bone disarticulation was cutting off the ligaments around the joints and dividing the two articulated bones, while it is quite rare to have a joint that was directly chopped through.

The four limb bones exhibit a similar patterns of butchery mark distribution. Taking humeri as an example (Figure IV–14), butchery marks cover the surface of the bone and are especially clustered on the distal articulator ends (however, there might be a bias, since only a few specimens keep the portion of proximal epiphysis with butchery marks). Butchery marks around the proximal and distal articulator ends (including both portions of epiphysis and metaphysis) are related to activities of bone disarticulation and meat removal, while butchery marks on shafts are more possibly related to filleting. Cut marks are much more common on humerus than chop marks, even on articular ends (except on one wholly preserved cattle humerus, which is dominated by chop marks for unknown reasons), and scoop marks are even rarer.

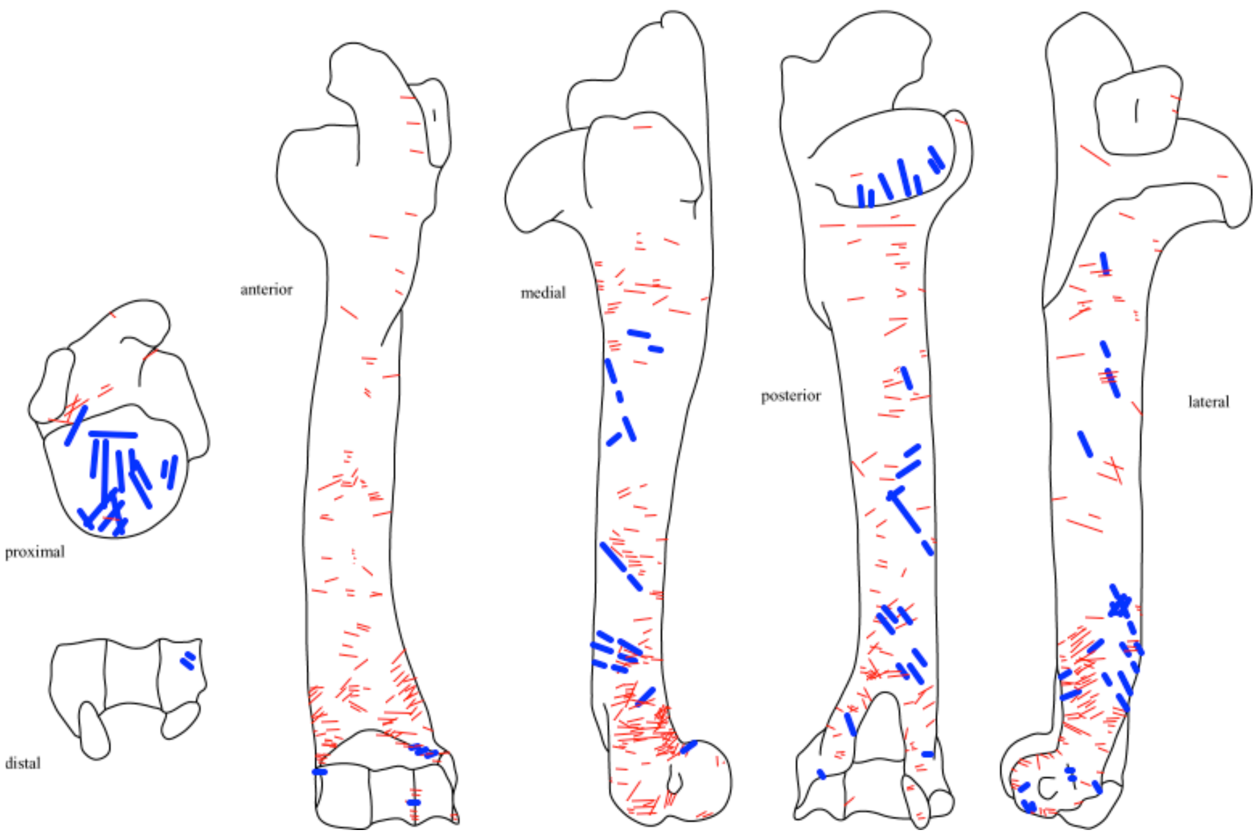


Figure IV–14 Butchery marks on cattle humerus _ Guandimiao

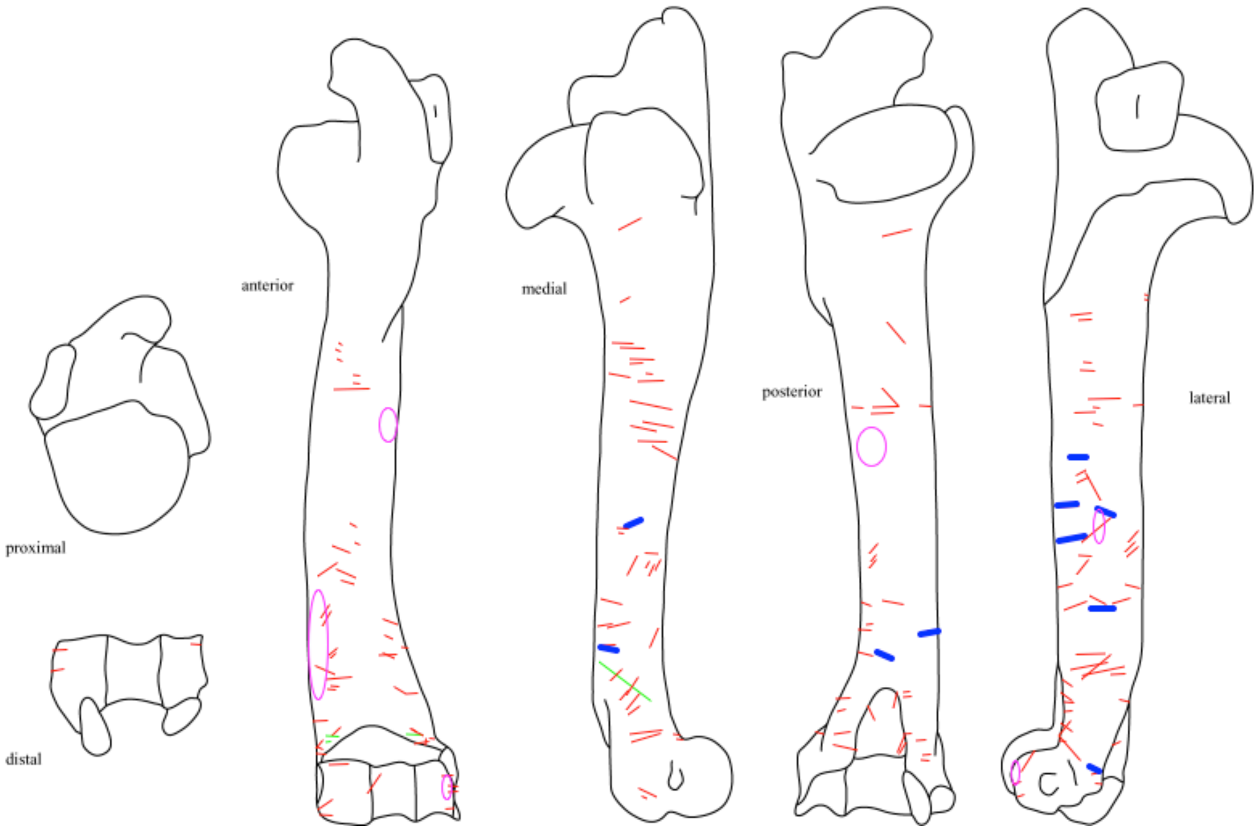


Figure IV–15 Butchery marks on pig humerus _ Guandimiao

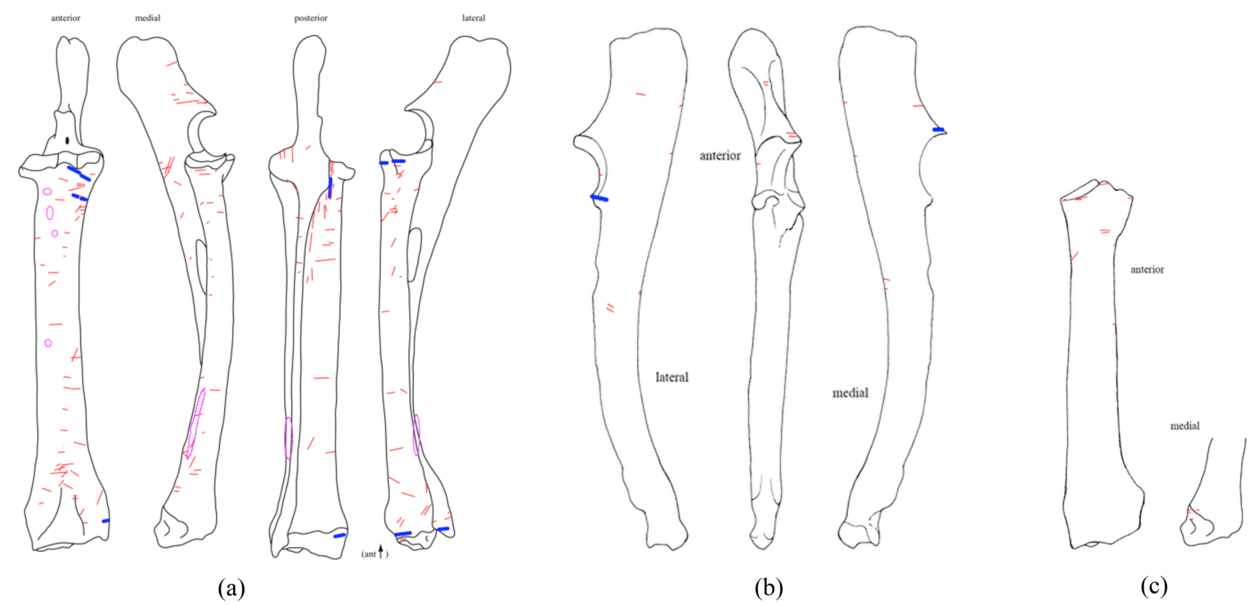


Figure IV–16 Butchery marks on cattle and pig radius and ulna _ Guandimiao

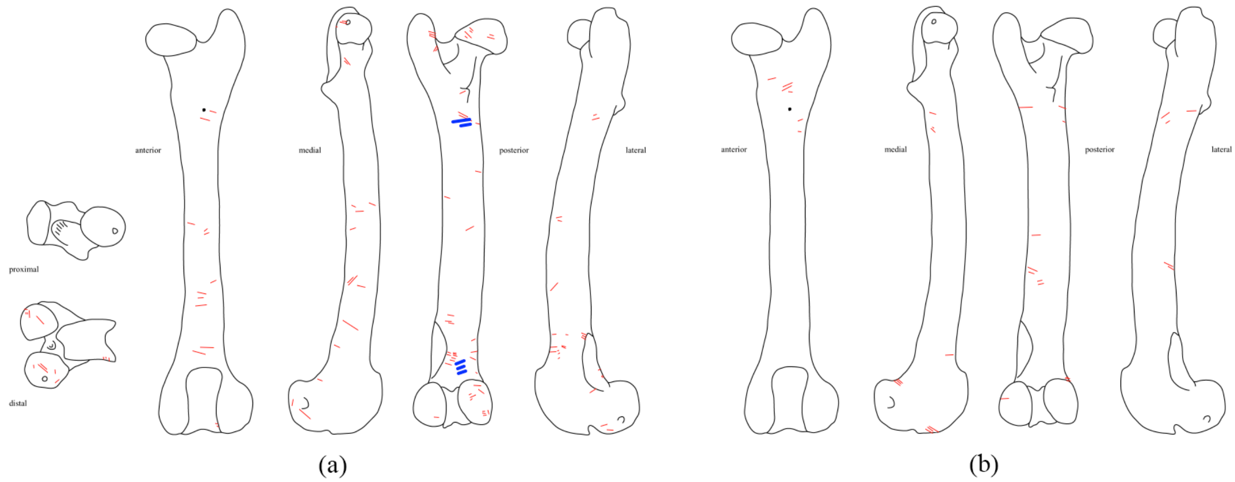


Figure IV–17 Butchery marks on cattle and pig femur _ Guandimiao

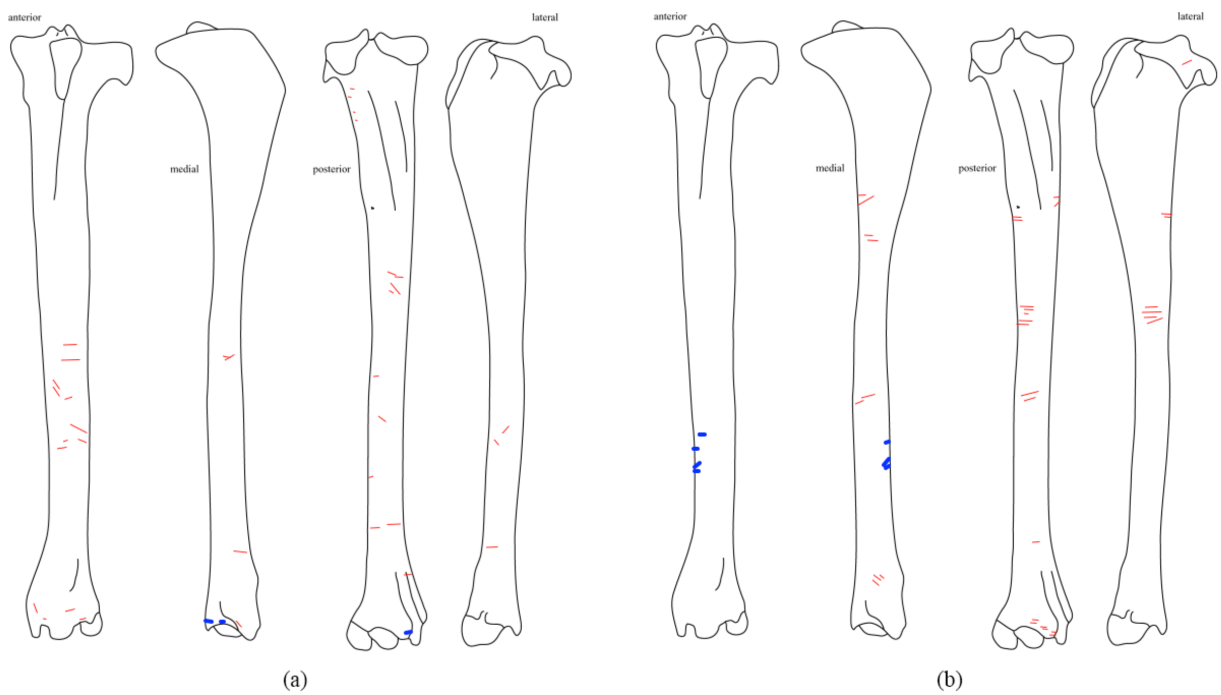


Figure IV–18 Butchery marks on cattle and pig tibia _ Guandimiao

8. Metapodial

Only one specimen in eleven pig metapodials was found with butchery marks, so that the analysis here focuses on cattle only.

► Cattle

Metapodials are well represented, and many fragments have butchery marks. Butchery marks, mostly cut marks, are around the bone shaft (especially the anterior surface) and the two distal trochoid joints (Figure IV–19, Figure IV–20), which may correspond to two types of activities. (1) Most of the cut marks on the shaft are perpendicular (or slightly oblique) to the long axis. A regular interpretation is that these are remains of skinning (Binford 1981:107, 120). In addition, filleting and tendon removing may be another explanation, if metapodials were also eaten as Chinese people do today. (2) Butchery marks circling the distal end of metapodials might also be an indicator of skinning, and/or they may be related to dismemberment (Binford: 1981: 120-121, mark MTd-1, Figure 4.27), which might happen during a process of secondary butchering or marrow processing.

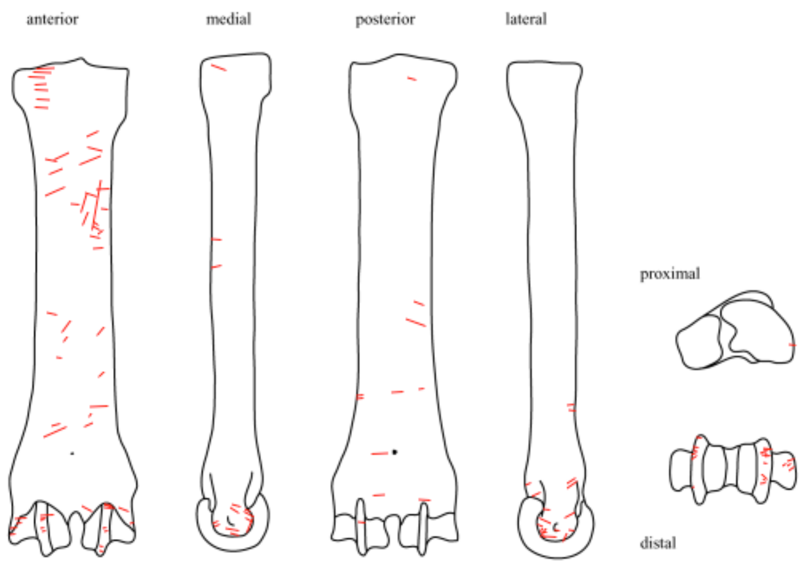


Figure IV–19 Butchery marks on cattle metacarpal _ Guandimiao

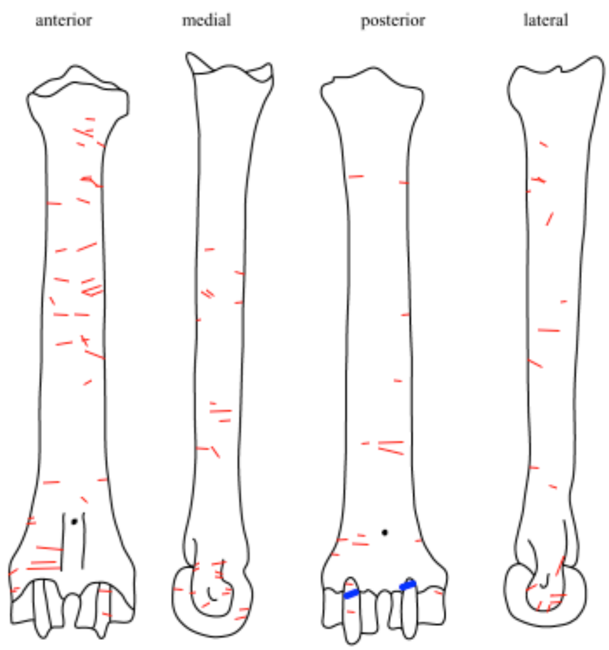


Figure IV–20 Butchery marks on cattle metatarsal _ Guandimiao

9. Tarsals: talus, calcaneum, and central-4th tarsal

► Cattle

Both talus and calcaneum are well represented and a large part of these two elements have butchery marks (Figure IV–21, Figure IV–22). Butchery marks on talus are concentrated on the anterior and medial surfaces, and, sometimes, on the proximal half of the posterior surface, while marks on calcaneum are mostly on the lateral sides. They are very typical remains of disarticulation of the lower limb bones and/or skinning. On the other hand, the situation of fused central-4th tarsals with butchery marks are grossly disproportionate compared to the high frequencies of butchery-mark-bearing talus and calcaneum. No butchery marks are found on a total of eleven wholly preserved central-4th tarsals.

The differentiated distribution of butchery marks on talus, calcaneum and the fused central-4th tarsal should be considered together with that of metatarsals. Except one specimen with a short cut mark, there is no butchery mark around or on the proximal articular surface of any metatarsal.

That is to say, butchery marks produced by disarticulation mainly encircle the proximal portion of the ankle joint. Thus, the usual way of splitting off the lower limb was to cut through the ligaments covering around the ankle joint from the location between talus and calcaneum so as to dislocate the joint and cut off the metatarsal from the tibia (which is quite different from the approach described by Binford (1981: 119, Figure 4.28) or Nilssen (2000: Figure 4.274)). Moreover, cut marks are the most frequent butchery marks left by this process.

Following a similar logic, seeing that quite few butchery marks are found around the articular end of either the distal radius or the proximal metacarpal while some carpals also have such marks, it is possible that the radiocarpal joint was dislocated by cutting off the attached ligaments covering carpals so as to separate radius and metacarpal. In addition, skinning might have been done at the same time (Binford 1981:103, 107).

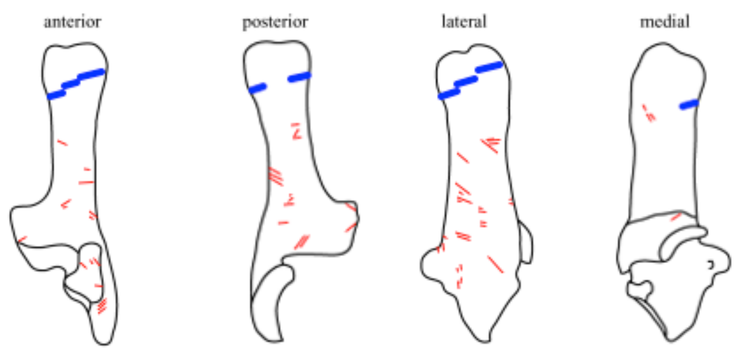


Figure IV–21 Butchery marks on cattle calcaneum _ Guandimiao

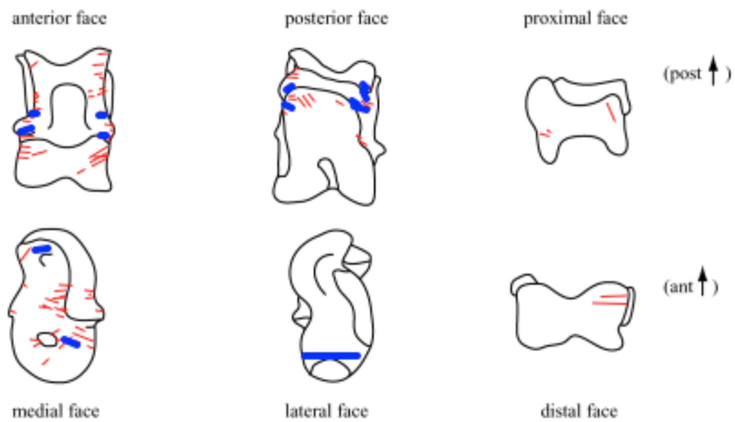


Figure IV–22 Butchery marks on cattle talus _ Guandimiao

► Pigs

In a total of eleven pig calcaneum only one specimen was observed with cut marks (Figure IV–23), which may be related to disarticulation according to the distribution of these marks.

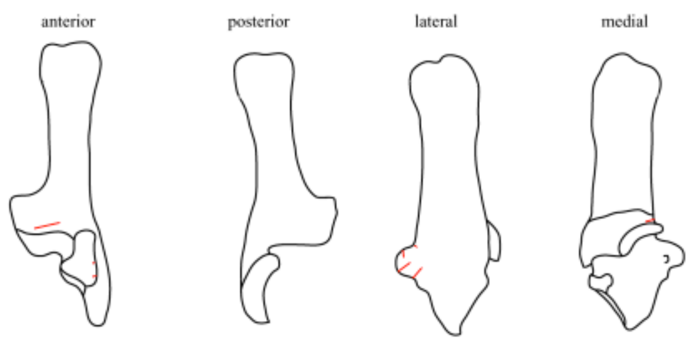


Figure IV–23 Butchery marks on pig talus _ Guandimiao

10. Phlanges

For pigs, there are only two phalanges found and neither of them have butchery marks.

► Cattle

Cattle phalanges in the collection are relatively well represented. Butchery marks are found on all three phalanges, while the frequencies of this type of specimens decrease from the first to the third phalanx. Based on Binford's recording (1981: 103-104), butchery marks, especially those made transversely across the shaft, could be produced by skinning, though there is no typical encircling cut mark (Figure IV–24). It is also possible that cattle phalanges, together with metapodials, were processed for consumption. In this case, butchery marks might also be made in the stage of food preparation.

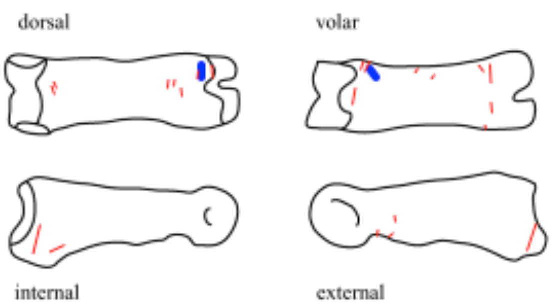
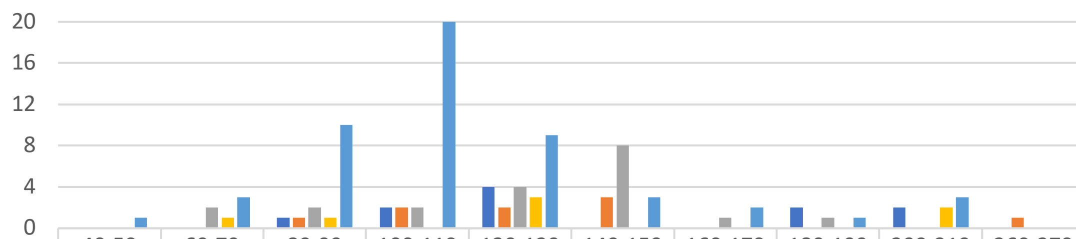


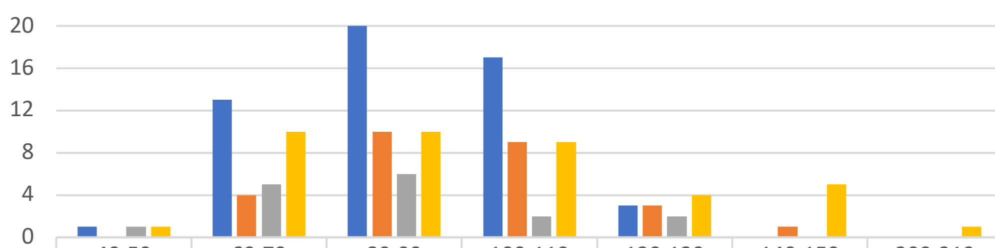
Figure IV–24 Butchery marks on cattle first phalanx _ Guandimiao

APPENDIX V: Xiaomintun: dimensions of animal bone fragments



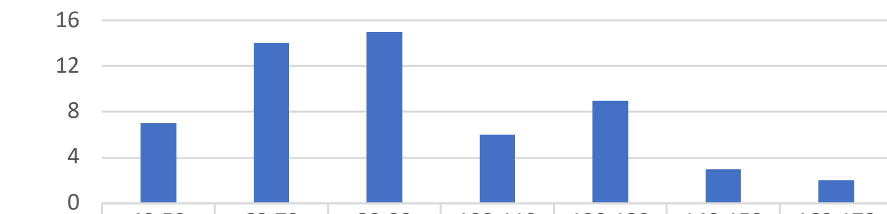
	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	260-279
Humerus	0	0	1	2	4	0	0	2	2	0
Femur	0	0	1	2	2	3	0	0	0	1
Radius	0	2	2	2	4	8	1	1	0	0
Tibia	0	1	1	0	3	0	0	0	2	0
Metapodial	1	3	10	20	9	3	2	1	3	0

Chart V–1 Xiaomintun: distribution of the maximum length (mm) of cattle long bone specimens (including end, end-shaft, end_splinters, and shaft_cylinders; calculated by NISP)



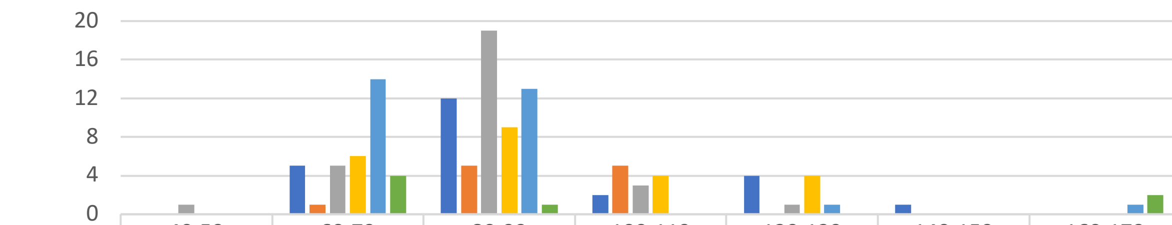
	40-59	60-79	80-99	100-119	120-139	140-159	200-219
Humerus	1	13	20	17	3	0	
Femur	0	4	10	9	3	1	
Radius	1	5	6	2	2	0	
Tibia	1	10	10	9	4	5	1

Chart V–2 Xiaomintun: distribution of the maximum length (mm) of pig long bone specimens (including whole, end, end-shaft, end_splinters, and shaft_cylinders; calculated by NISP)



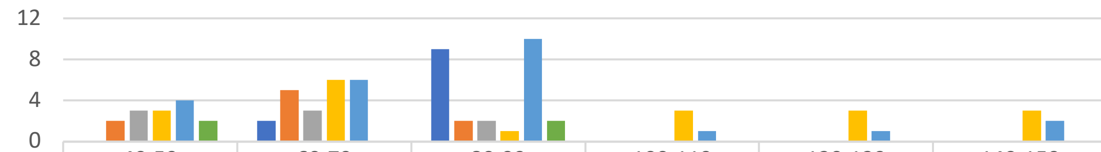
	40-59	60-79	80-99	100-119	120-139	140-159	160-179
Cranium	7	14	15	6	9	3	2

Chart V–3 Xiaomintun: Dimension (mm) of old-broken pig skull specimens (calculated by NISP,)



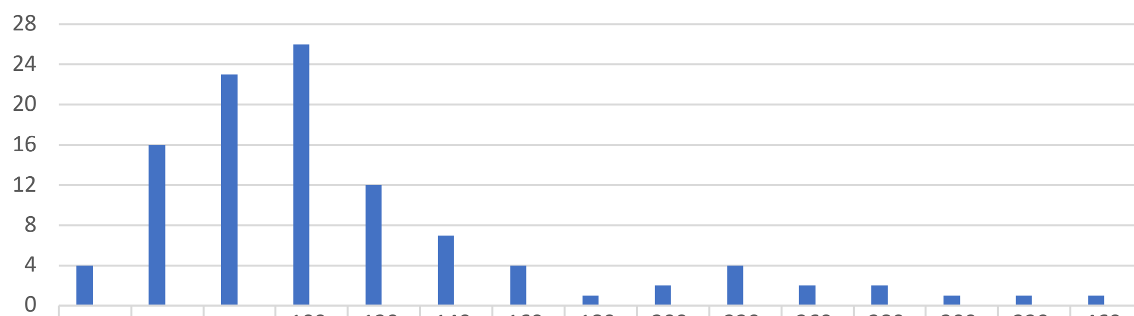
	40-59	60-79	80-99	100-119	120-139	140-159	160-179
atlas	0	5	12	2	4	1	0
axis	0	1	5	5	0	0	0
cervical	1	5	19	3	1	0	0
thoracic	0	6	9	4	4	0	0
lumbar	0	14	13	0	1	0	1
sacral	0	4	1	0	0	0	2

Chart V–4 Xiaomintun: Dimension (mm) of old-broken cattle vertebral specimens (calculated by NISP)



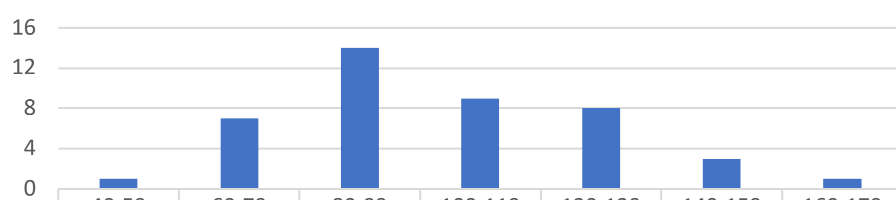
	40-59	60-79	80-99	100-119	120-139	140-159
atals	0	2	9	0	0	0
axis	2	5	2	0	0	0
cervical	3	3	2	0	0	0
thoracic	3	6	1	3	3	3
lumbar	4	6	10	1	1	2
sacral	2	0	2	0	0	0

Chart V–5 Xiaomintun: Dimension (mm) of old-broken pig vertebral specimens (calculated by NISP)



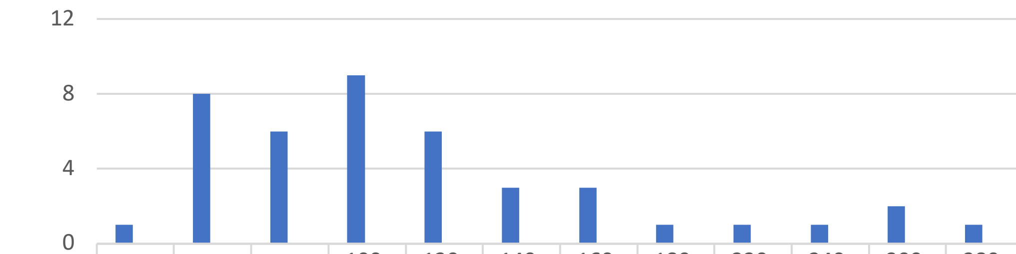
	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	220-239	260-279	280-299	300-319	320-339	460-479
cattle	4	16	23	26	12	7	4	1	2	4	2	2	1	1	1
pig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Chart V–6 Xiaomintun: Dimension (mm) of old-broken cattle and pig rib specimens (calculated by NISP)



	40-59	60-79	80-99	100-119	120-139	140-159	160-179
pig	1	7	14	9	8	3	1

Chart V–7 Xiaomintun: Dimension (mm) of old-broken pig scapula specimens (calculated by NISP)



	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	220-239	240-259	300-319	380-399
cattle	1	8	6	9	6	3	3	1	1	1	2	1
pig	0	0	0	0	0	0	0	0	0	0	0	0

Chart V–8 Xiaomintun: Dimension (mm) of old-broken cattle and pig pelvis specimens (calculated by NISP)

APPENDIX VI: Xiaomintun: calculations of butchery marks

Table VI–1 Xiaomintun: butchery mark frequencies by element (calculated by NISP of bone specimens) _ cattle

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
cranium	2	16.7	2	16.7	0		1	8.3	5	5	12	41.7
atlas	5	17.9	9	32.1	0		14	50.0	28	20	28	71.4
axis	5	33.3	3	20.0	0		4	26.7	12	9	15	60.0
cervical	7	20.6	8	23.5	1	2.9	11	32.4	27	19	34	55.9
thoracic	3	8.3	8	22.2	0		8	22.2	19	15	36	41.7
lumbar	3	7.1	13	31.0	0		6	14.3	22	18	42	42.9
sacral	4	33.3	1	8.3	3	25.0	1	8.3	9	5	12	41.7
caudal	0		0		0		0		0	0	3	0.0
VER.FR	8	14.0	2	3.5	0		1	1.8	11	10	57	17.5
rib	32	19.2	15	9.0	0		14	8.4	61	51	167	30.5
scapula	0	-	0	-	0	-	0	-	0	0	0	-
pelvis	7	13.2	13	24.5	1	1.9	6	11.3	27	21	53	39.6
humerus	11	57.9	0		0		0		11	11	19	57.9
radius	14	40.0	9	25.7	2	5.7	1	2.9	26	19	35	54.3
ulna	8	50.0	2	12.5	1	6.3	1	6.3	12	9	16	56.3
femur	9	42.9	5	23.8	1	4.8	1	4.8	16	11	21	52.4
tibia	7	31.8	3	13.6	1	4.5	0		11	9	22	40.9
metapodial	19	29.7	7	10.9	1	1.6	2	3.1	29	16	64	25.0
calcaneum	10	35.7	1	3.6	1	3.6	1	3.6	13	11	28	39.3
talus	7	43.8	0		0		0		7	7	16	43.8
first phalanx	11	27.5	0		1	2.5	0		12	12	40	30.0
second phalanx	3	15.8	0		0		0		3	3	19	15.8
third phalanx	1	5.0	1	5.0	0		0		2	2	20	10.0
carpal	0		0		0		0		0	0	7	0.0
tarsal	4	28.6	0		0		0		4	4	14	28.6
Total	180	23.1	102	13.1	13	1.7	72	9.2	367	287	780	36.8
Butchery marks (%)[4]	49.0		27.8		3.5		19.6		100.0			

Keys:

1, 2 One specimen can exhibit more than one type of butchery marks. 1 SUM = the sum of specimens with cut marks, with chop marks, with scoop marks, and with shear marks, and some specimens with more than one type of butchery marks may be counted several times. 2 Butchered = the number of specimens with butchery marks, which can be equal to or smaller than "SUM". However, the overlaps cannot affect other calculations or comparisons significantly.
3 The incidence of certain type of butchery mark (%) = (the number of specimens with a certain type of butchery mark) ÷ (the total number of specimens) × 100%. So, the sum of the incidences of cut, chop, scoop, and shear marks can be equal to or larger than the incidence of specimens with butchery marks as shown in the last column.
4 Butchered marks (%) = (the number of specimens with certain type of butchery mark) ÷ SUM × 100%, which represents the relative proportions of cut, chop, scoop, and shear marks.

Table VI–2 Xiaomintun: butchery mark frequencies by element portions (calculated by NISP of bone specimens) _ cattle

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
pelvis-acetabulum	4	11.1	3	8.3	1	2.8	4	11.1	12	10	36	27.8
pelvis-ilium/ischium/pubis	3	11.5	11	42.3	1	3.8	2	7.7	17	14	26	53.8
metapodial-P articulation	5	16.7	1	3.3	1	3.3	0		7	6	30	20.0
metapodial-shaft	12	18.8	5	7.8	0		2	3.1	19	19	64	29.7
metapodial-D articulation	11	50.0	1	4.5	0		0		12	12	22	54.5
limb-P articulation	11	33.3	6	18.2	1	3.0	0		18	16	33	48.5
limb-shaft	28	37.8	8	10.8	2	2.7	0		38	34	74	45.9
limb-D articulation	10	32.3	3	9.7	2	6.5	1	3.2	16	13	31	41.9
humerus-P articulation	4	50.0	0		0		0		4	4	8	50.0
humerus-shaft	5	38.5	0		0		0		5	5	13	38.5
humerus-D articulation	4	40.0	0		0		0		4	4	10	40.0
radius-P articulation	2	14.3	4	28.6	1	7.1	0		7	6	14	42.9
radius-shaft	12	48.0	4	16.0	1	4.0	0		17	15	25	60.0
radius-D articulation	4	30.8	1	7.7	1	7.7	0		6	5	13	38.5
femur-P articulation	3	60.0	1	20.0	0		0		4	3	5	60.0
femur-shaft	6	30.0	3	15.0	1	5.0	0		10	9	20	45.0
femur-D articulation	2	66.7	1	33.3	0		1	33.3	4	3	3	100.0
tibia-P articulation	2	33.3	1	16.7	0		0		3	3	6	50.0

tibia-shaft	5	31.3	1	6.3	0		0		6	5	16	31.3
tibia-D articulation	0		1	20.0	1	20.0	0		2	1	5	20.0

Notes: because of the differentiated preservation of long bone portions, the distribution of butchery marks on portions of humerus, radius, femur, and tibia are both listed separately based on element and summarized into one “limb” group.

Keys: limb-P articulation = proximal articulation of a limb bone; limb-D articulation = distal articulation of a limb bone. Similar expressions are applied to other limb bones.

[1,2] One specimen can exhibit more than one type of butchery mark. [1] SUM = the sum of specimens with cut marks, with chop marks, with scoop marks, and with shear marks, and some specimens with more than one type of butchery marks may be counted several times. [2] Butchered = the number of specimens with butchery marks, which can be equal to or smaller than "SUM". Nevertheless, the overlaps do not affect other calculations or comparisons significantly.

[3] The incidence of certain type of butchery mark (%) = (the number of specimens with certain type of butchery marks) ÷ (the total number of specimens) × 100%. So, the sum of the incidences of cut, chop, scoop, and shear marks can be equal to or larger than the incidence of specimens with butchery marks as shown in the last column.

Table VI–3 Xiaomintun: butchery mark frequencies by element (calculated by NISP of bone specimens) _ pigs

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
cranium	14	10.7	6	4.6	0		15	11.5	35	27	131	20.6
atlas	12	63.2	0		0		0		12	12	19	63.2
axis	2	18.2	1	9.1	0		0		3	3	11	27.3
cervical	3	25.0	1	8.3	0		1	8.3	5	4	12	33.3
thoracic	16	45.7	0		0		1	2.9	17	17	35	48.6
lumbar	17	35.4	0		0		6	12.5	23	22	48	45.8
sacral	0		1	20.0	0		1	20.0	2	1	5	20.0
VER.FR	1	-	0	-	0	-	0	-	1	1	1	-
rib	13	22.4	0		0		1	1.7	14	14	58	24.1
scapula	23	28.8	6	7.5	0		2	2.5	31	29	80	36.3
pelvis	38	41.3	10	10.9	1	1.1	3	3.3	52	49	92	53.3
humerus	43	50.6	11	12.9	1	1.2	4	4.7	59	51	85	60.0
radius	8	32.0	2	8.0	0		0		10	9	25	36.0
ulna	16	40.0	2	5.0	1	2.5	0		19	19	40	47.5
femur	25	30.5	3	3.7	1	1.2	2	2.4	31	28	82	34.1
tibia	21	27.3	9	11.7	2	2.6	4	5.2	36	28	77	36.4
metapodial 3/4	1	3.8	0		0		0		1	1	26	3.8
calcaneum	4	25.0	1	6.3	0		0		5	5	16	31.3
talus	6	75.0	0		0		0		6	6	8	75.0
first phalanx	0		0		0		0		0	0	1	0.0

carpal	1	100.0	0		0		0		1	1	1	100.0
tarsal	0		0		0		0		0	0	10	0.0
Total	264	30.6	53	6.1	6	0.7	40	4.6	363	327	863	37.9
Butchery marks (%)[4]	72.7		14.6		1.7		11.0		100.0			

Keys: refer to those in

Table VI–1.

Table VI–4 Xiaomintun: butchery mark frequencies by element portions (calculated by NISP of bone specimens) _ pigs

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
pelvis-acetabulum	19	34.5	2	3.6	1	1.8	1	1.8	23	23	55	41.8
pelvis-ilium/ischium/pubis	22	28.2	8	10.3	0		0		30	30	78	38.5
limb-P articulation	16	31.4	1	2.0	0		2	3.9	19	19	51	37.3
limb-shaft	62	24.7	22	8.8	5	2.0	2	0.8	91	81	251	32.3
limb-D articulation	42	36.8	2	1.8	1	0.9	4	3.5	49	47	114	41.2
humerus-P articulation	5	45.5	0		0		1	9.1	6	6	11	54.5
humerus-shaft	26	31.7	11	13.4	1	1.2	1	1.2	39	35	82	42.7
humerus-D articulation	27	57.4	0		0		2	4.3	29	29	47	61.7
radius-P articulation	4	26.7	0		0		0		4	4	15	26.7
radius-shaft	7	28.0	2	8.0	0		0		9	8	25	32.0
radius-D articulation	2	28.6	0		0		0		2	2	7	28.6
femur-P articulation	4	40.0	0		0		0		4	4	10	40.0
femur-shaft	15	21.1	3	4.2	0		0		18	18	71	25.4
femur-D articulation	6	20.7	0		1	3.4	2	6.9	9	7	29	24.1
tibia-P articulation	3	20.0	1	6.7	0		1	6.7	5	5	15	33.3
tibia-shaft	14	19.2	6	8.2	4	5.5	1	1.4	25	20	73	27.4
tibia-D articulation	7	22.6	2	6.5	0		0		9	9	31	29.0

Notes and keys: refer to those in Table VI–2.

APPENDIX VII: Xiaomintun: depiction of butchery marks

As for the drawings included in this appendix, cut marks are marked as red strokes, chop marks as blue strokes, scoop marks labelled in purple circles, and some sheared surfaces are circled in yellow (while some other shear marks can be seen in photos shown in Appendix XI). For some specimens, multiple instances of the same butchery marks appeared in the same location, and these were calculated as "1" (refer to Chapter 5). In these drawings, I have recorded all the strokes of butchery marks in order to represent their locations. Therefore, the amount of butchery marks shown in these drawings are different from those recorded in Appendix VI.

1. Cranium

► Cattle

Most of the specimens are too fragmented to reconstruct the butchery process. The existence of fragments with clear chop marks and sheared fracture surfaces indicates at least some cranial bones were chopped into chunks.

► Pigs

There are some specimens showing cut marks around the inferior of the zygomatic bone which are possibly related to cheek muscle removal and mandible disarticulation (Binford 1981: 109-110, mark S-6, Figure 4.19; Nilssen 2000: 170, mark S-6, Figure 4.237), and other specimens with cut marks on and around the occipital condyles which can be related to activities to freeing the head from the body. In addition, as mentioned in Section 3.2, many specimens with clear sheared fracture surfaces are the most direct evidence of cranium segmentation.

2. Vertebrae

► Cattle

Butchered marks are frequently seen on different types of vertebrae.

<u>*Atlas*</u> Butchery marks (mostly chop marks) are mainly scattered on both the cranial and caudal edges of the bone (Figure VII–1), which may be related to head disarticulation (Binford 1981:111, mark CV-1, Figure 4.20). For some specimens, the medal portions of the dorsal or ventral surfaces are sheared off (circled in yellow in Figure VII–1), so are some other margins on the bone.

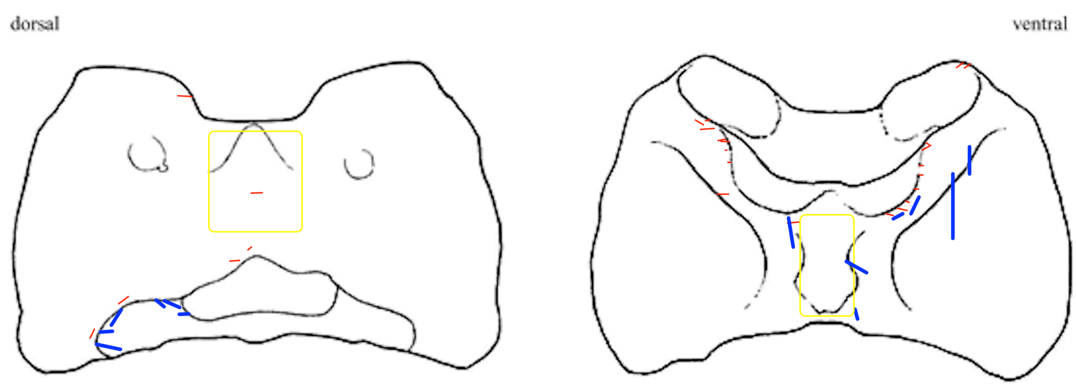


Figure VII–1 Butchery marks on cattle atlas _ Xiaomintun

<u>*Axis*</u> Limited butchery marks are seen (Figure VII–2). Some butchery marks are on the two edges of the dens (connecting to the anterior articular process), some are behind the cranial articular process, and some other marks scatter along the base of the spinous process. They may be caused by filleting and/or dismemberment. Besides, for some specimens, the cranial and/or caudal articular surfaces, some processes, and other edges/surfaces of the bone are more or less sheared off (Figure 3c in Chapter 9).

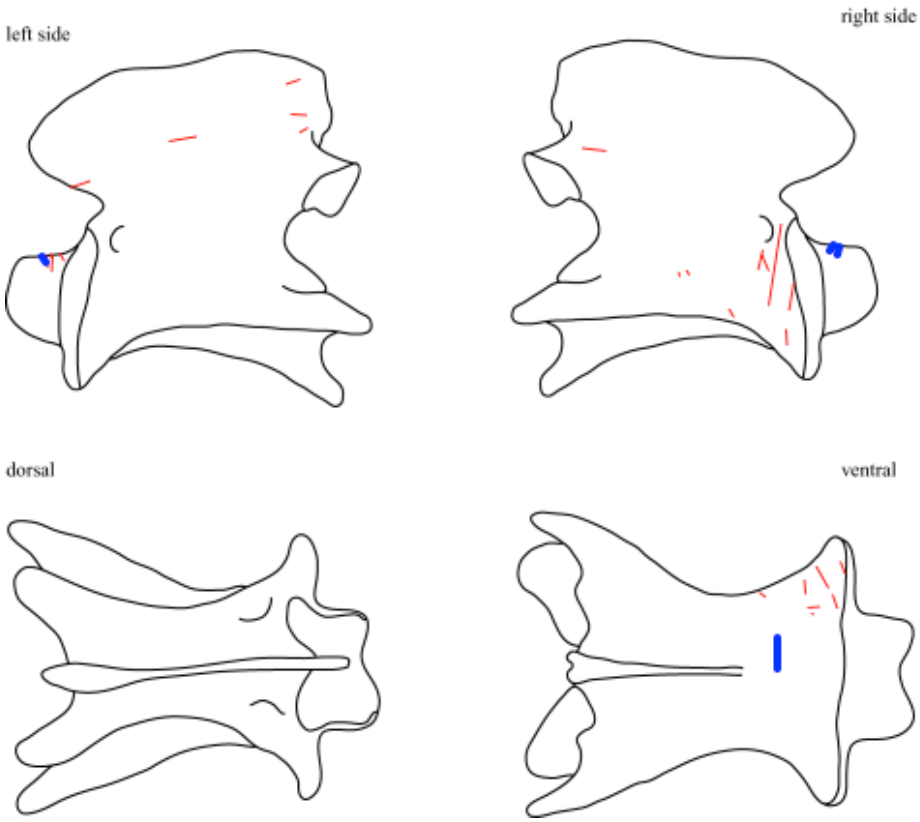


Figure VII–2 Butchery marks on cattle axis _Xiaomintun

<u>*Other vertebrae*</u> For cervical, thoracic and lumbar specimens, incidences of specimens with butchery marks are all high. Chop marks and shear marks are a little more frequent than cut marks, and, in many cases, they may play similar roles in butchery to cut meat off the bone judged by the locations of marks (Figure VII–3, Figure VII–4, Figure VII–5). The difference is probably that, during chopping and shearing, many processes and edges can be hacked off and some surfaces can be damaged (e.g., Figure 3: a, b in Chapter 9), while cutting can represent some relatively mild activities. In addition, some chop marks and sheared surfaces are remains of the division of vertebral column and separating some vertebrae into small chunks (as discussed in Section 3.3, e.g., Figure 3: d in Chapter 9).

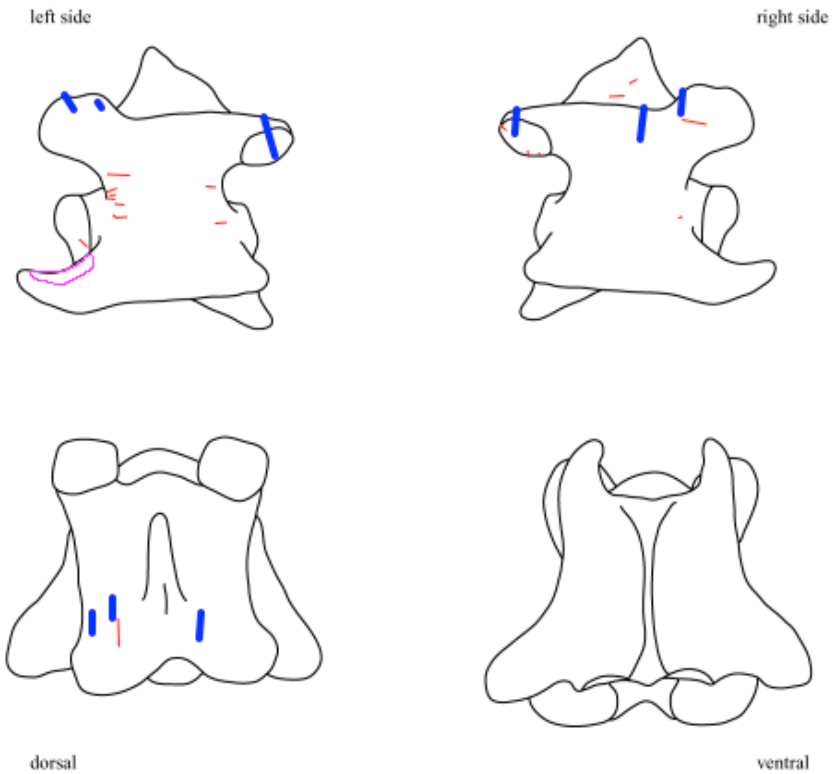


Figure VII–3 Butchery marks on cattle cervical vertebrae _ Xiaomintun

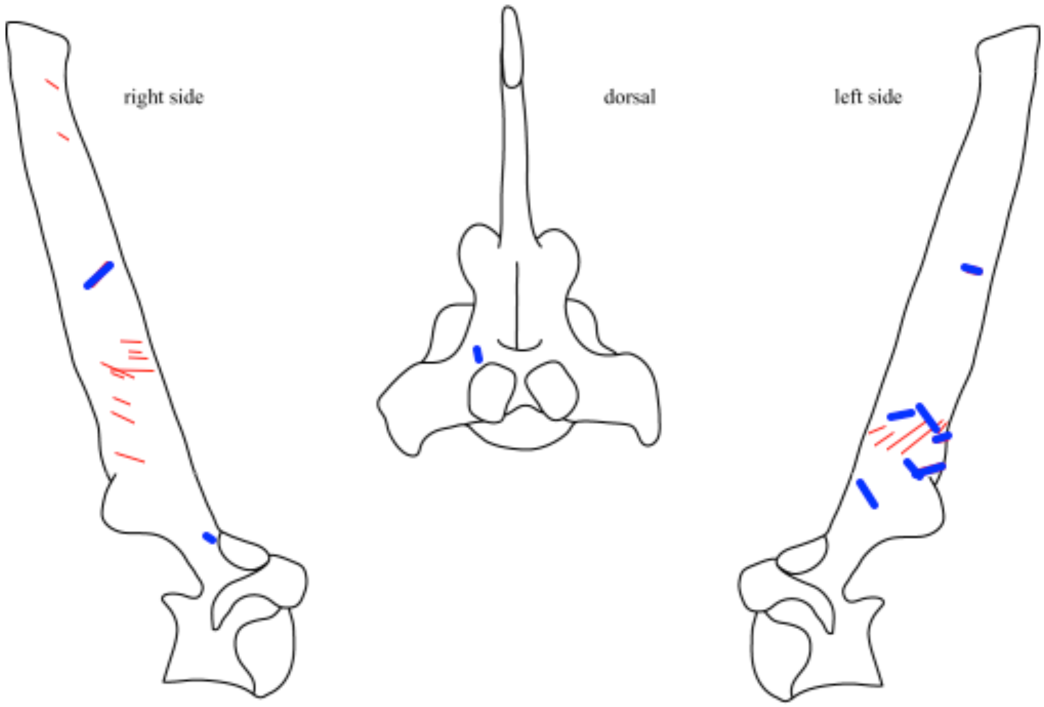


Figure VII–4 Butchery marks on cattle thoracic vertebrae _ Xiaomintun

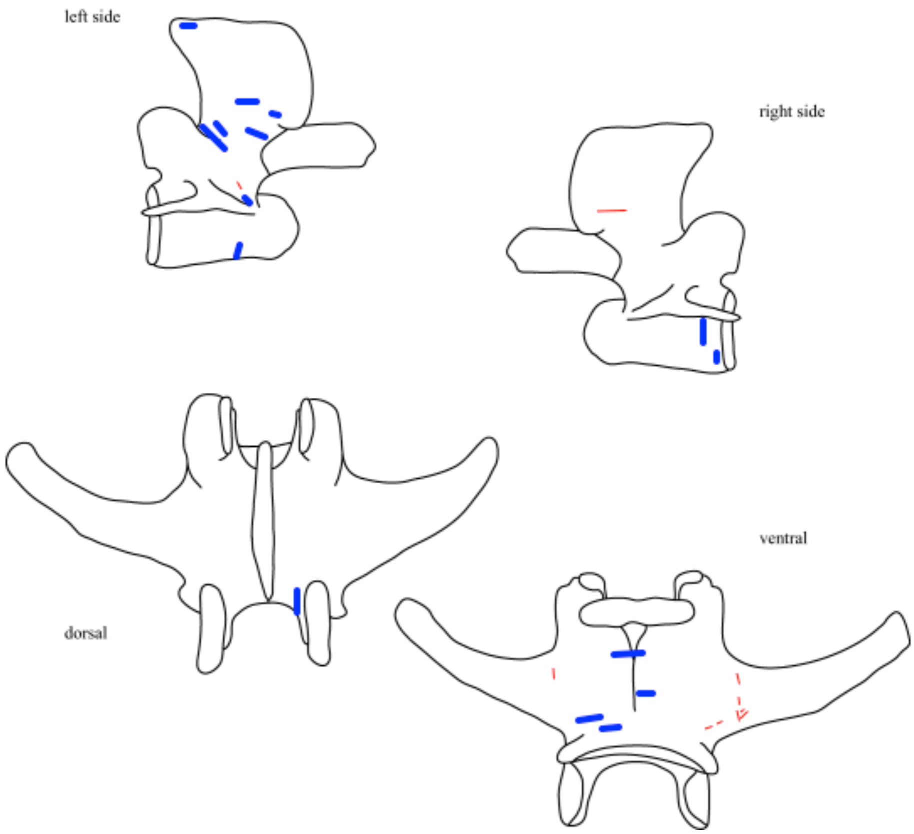


Figure VII–5 Butchery marks on cattle lumbar vertebrae _ Xiaomintun

► Pigs

<u>*Atlas*</u> Cut marks distribute on both the dorsal and ventral surfaces (Figure VII–6), and many of them run across the cranial margin of the atlas, which are possibly related to the activity of severing the head from the body (Binford 1981: 137, mark CV-1, Figure 4.20).

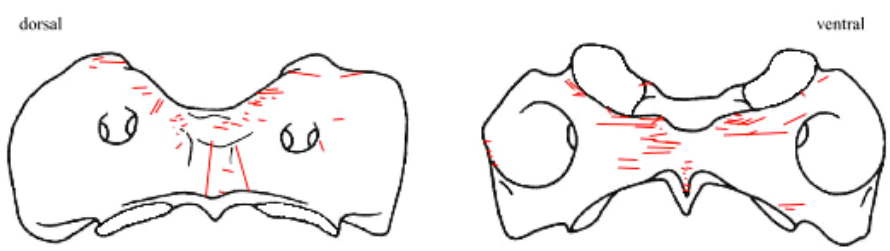


Figure VII–6 Butchery marks on pig atlas _ Xiaomintun

<u>*Other vertebrae*</u> There are a few cervical specimens with butchery marks, while butchered thoracic and lumbar vertebrae are relatively well represented.

In general, cut marks dominate on all the specimens, and they can be seen on both the dorsal and ventral surfaces. Some cut marks are on ventral sides of anterior and posterior articulator processes, which may be generated during the process to divide the articulated vertebrae.

As for some thoracic vertebrae, cut marks concentrate on both sides of the spinous process (Figure VII–7), and, for lumbar vertebrae, cut marks cluster longitudinally at the base of the transverse processes on the ventral surface (Figure VII–8). Both of these marks are probably evidence of cutting off the major muscle groups (Binford 1981: 113; Nilssen 2000: 165, mark TV-2, Figure 4.244).

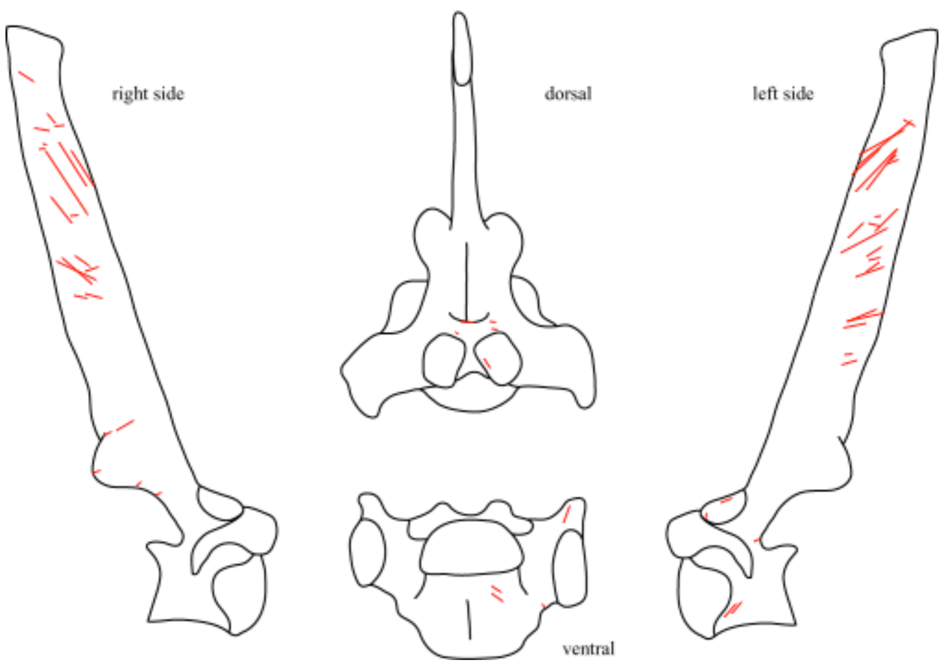


Figure VII–7 Butchery marks on pig thoracic vertebrae _ Xiaomintun

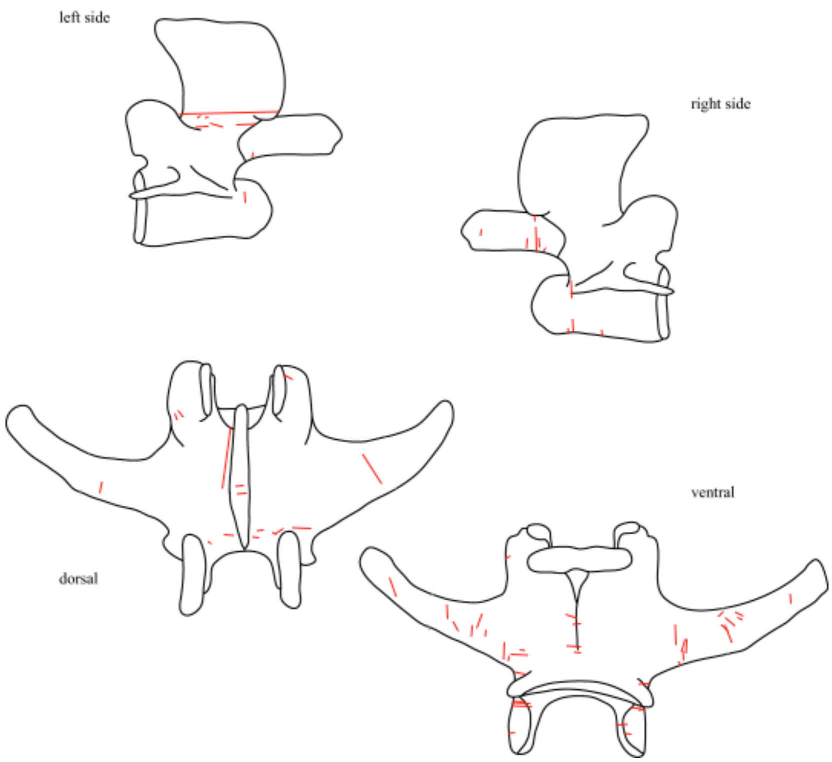
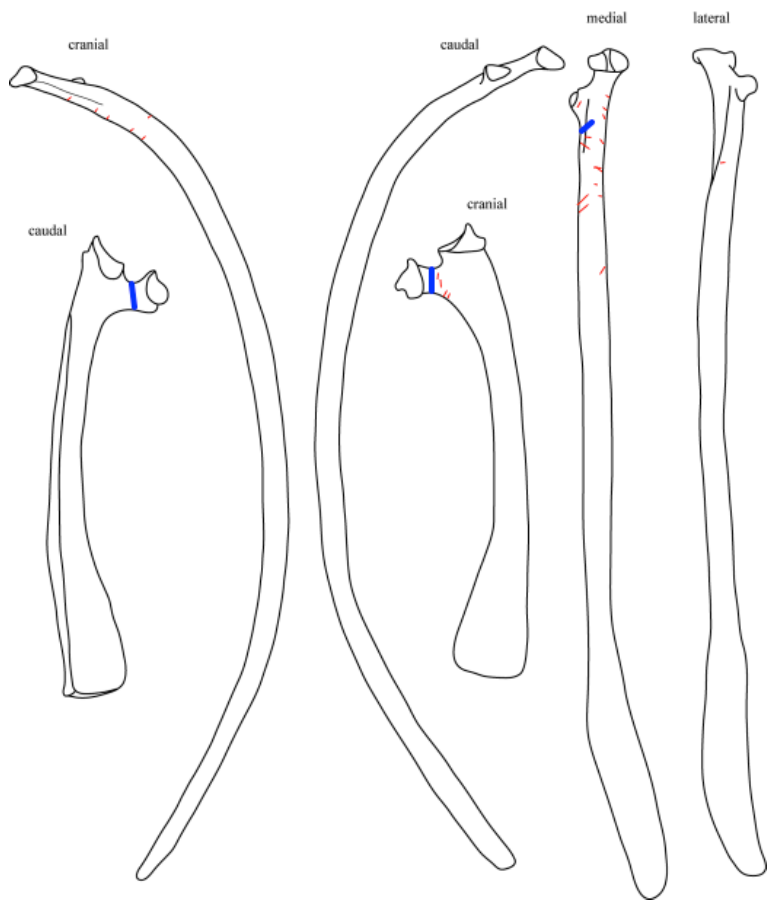


Figure VII–8 Butchery marks on pig lumbar vertebrae _ Xiaomintun

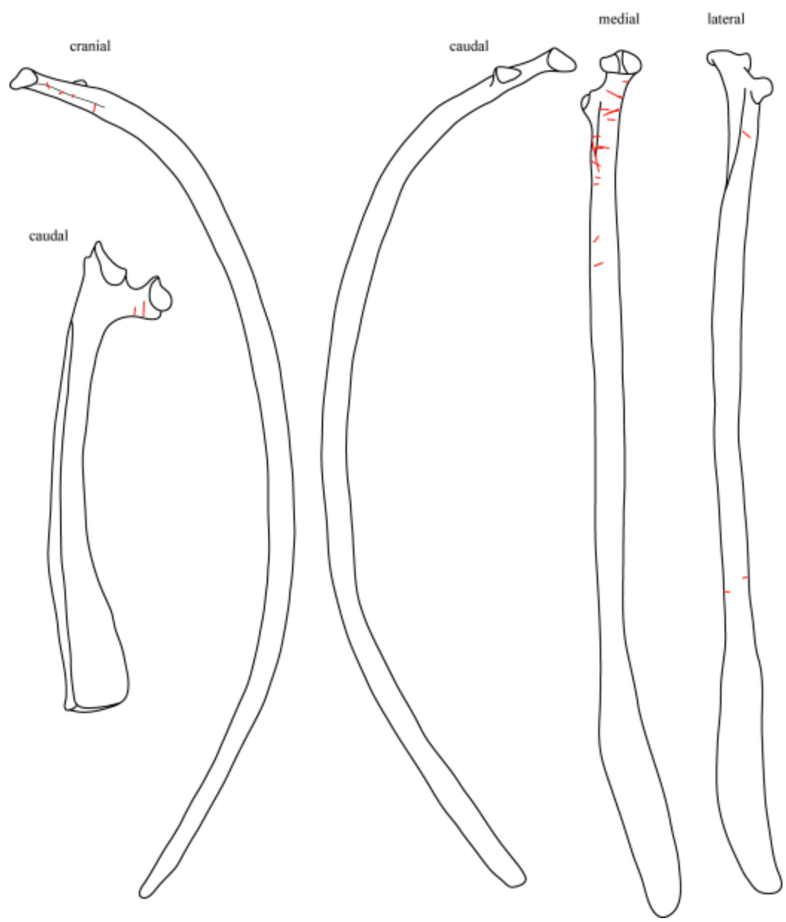
3. Rib

For both cattle and pig rib specimens, many butchery marks are seen on the portion close to the proximal rib head while some scatter on the rest of the body, and they are mainly on the medial surface (Figure VII–9, Figure VII–10). Cut marks are much more common than chop marks, and the later are more frequently seen on cattle ribs. Some butchery marks on/close to proximal rib heads might be related to the activity of peeling off rib slabs from the vertebral column, while other marks in this location and marks on the body of a rib are likely inflicted by filleting or evisceration (Nilssen 2000: 210-211, mark RS-3, RS-5, RS-8, Figure 4.277, 4.278). Fragments with sheared fracture surface are evidence of rib breakage (as discussed in Section 3.4, and Figure XI-13).



Note: butchery marks are recorded on the diagram only when specimens can be identified to a location on a whole rib.

Figure VII–9 Butchery marks on cattle ribs _ Xiaomintun



Note: butchery marks are recorded on the diagram only when specimens can be identified to a location on a whole rib.

Figure VII–10 Butchery marks on pig ribs _ Xiaomintun

4. Scapula

Cattle scapula is not seen in the assemblage.

► Pigs

On the lateral side, most cut marks are around the distal half (close to the glenoid cavity and the neck) of scapula and along the edge of spine, while on the medial surface of the bone, cut marks are along the superior and lateral borders (Figure VII–11). Chop marks, as well as sheared fracture surfaces, are mainly in the medial portion on the later side and transversely across the bone (e.g., Figure XI-14), which are definitely evidence of scapula fragmentation. Most cut marks are possibly remains of filleting, while some marks around the glenoid cavity may be caused by cutting through the ligaments for the purpose of disarticulation and/or filleting (Nilssen 2000: 164, mark S-7 and S-9, Figure 4.254 and 4.255 a).

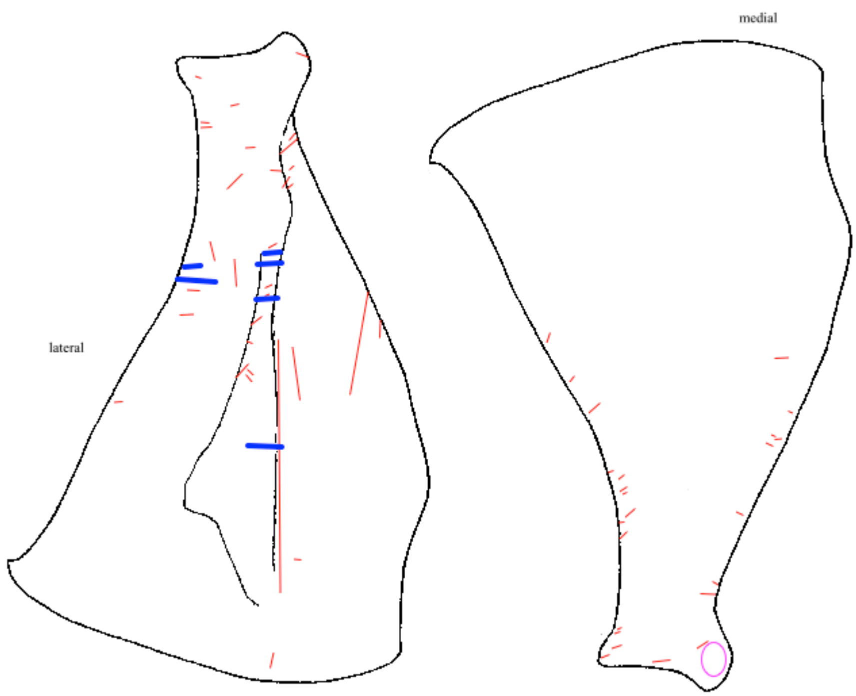


Figure VII–11 Butchery marks on pig scapulae _Xiaomintun

5. Pelvis

► Cattle

Most cut marks are around the acetabulum and along margins of the ilium and ischium shafts (Figure VII–12). The former group of marks are possibly related to activities of femur disarticulation (Binford 1981:113, marks PS-7, PS-8, PS-9, PS-10, Figure 4.22; Cope 1999), which can also leave butchery marks on the proximal articular surface of the femur (Figure VII–16). Cut marks along the shafts of ilium and ischium may be caused by filleting. Then, chop marks are seen on some ilium/ischium/pubis shafts (Figure 7: a, d in Chapter 9, Figure VII–12), sometimes parallel with the straight fracture ridges; while sheared fracture surfaces are also frequently seen on the acetabulum fragments (as discussed in Section 3.6, and Figure 7: b, c in Chapter 9).

Therefore, both chop and shear marks are closely related to activities of splitting large pelvis to smaller chunks which may have happened in the stage of secondary or tertiary butchery.

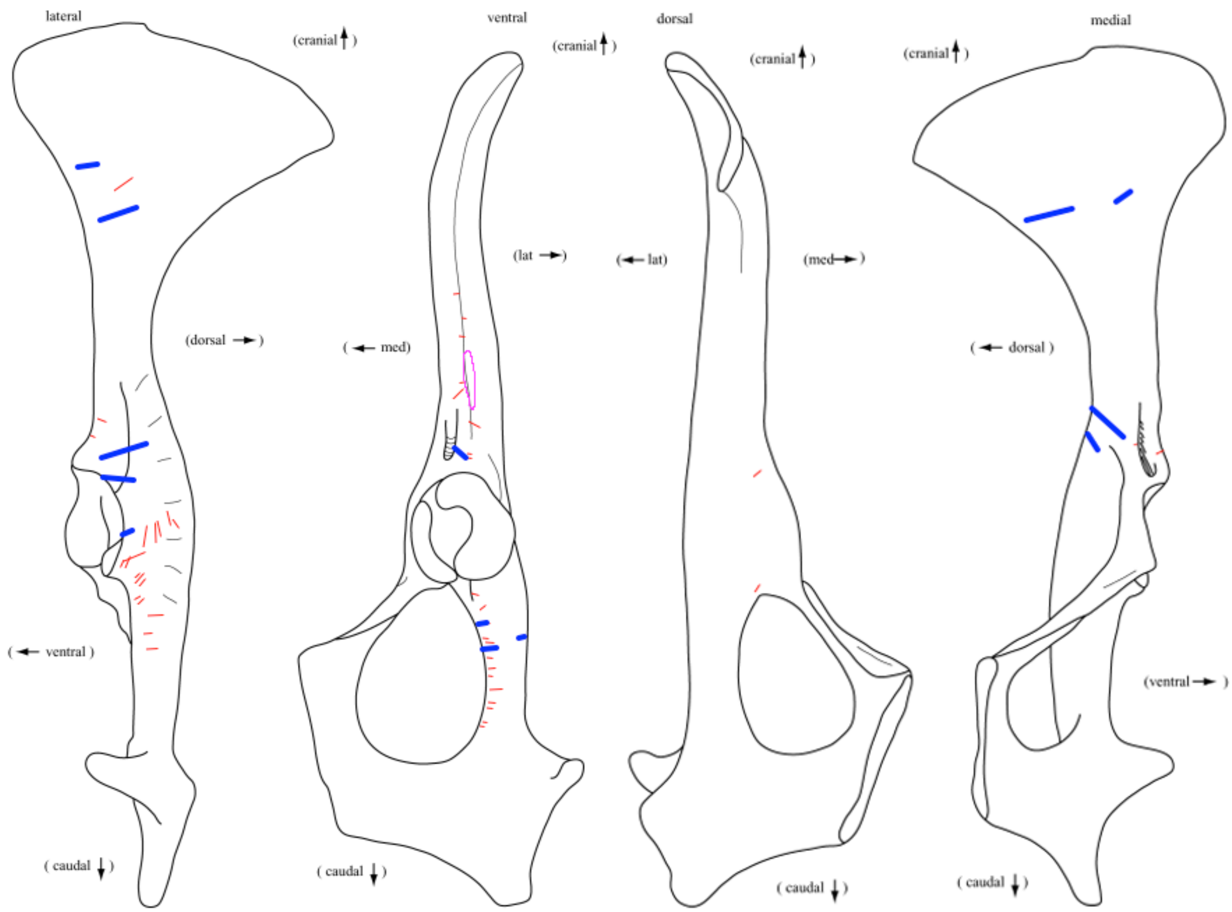


Figure VII–12 Butchery marks on cattle pelvis _ Xiaomintun

► Pigs

Cut marks dominate on pig pelves (Figure VII–13) and they can roughly be grouped to three clusters. Many butchery marks are around the acetabulum, and this pattern is similar to that of cattle and are very likely for the purpose of cutting the femur free. Cut marks on the medial surface of the wing of ilium (the articular surface of the sacroiliac joint) can quite possibly be explained by activities of disarticulating sacrum from pelvis (Nilssen 2000: 166, mark PS-13 (PJN), and Figure 4.264d). Other cut marks, mainly around the obturator foramen and on the lateral surface of the wing of ilium, may be remains of filleting. Then, the distribution of chop marks is also similar to that of cattle and probably indicates a purposeful breakage of innominate into small segments (as discussed in Section 3.6).

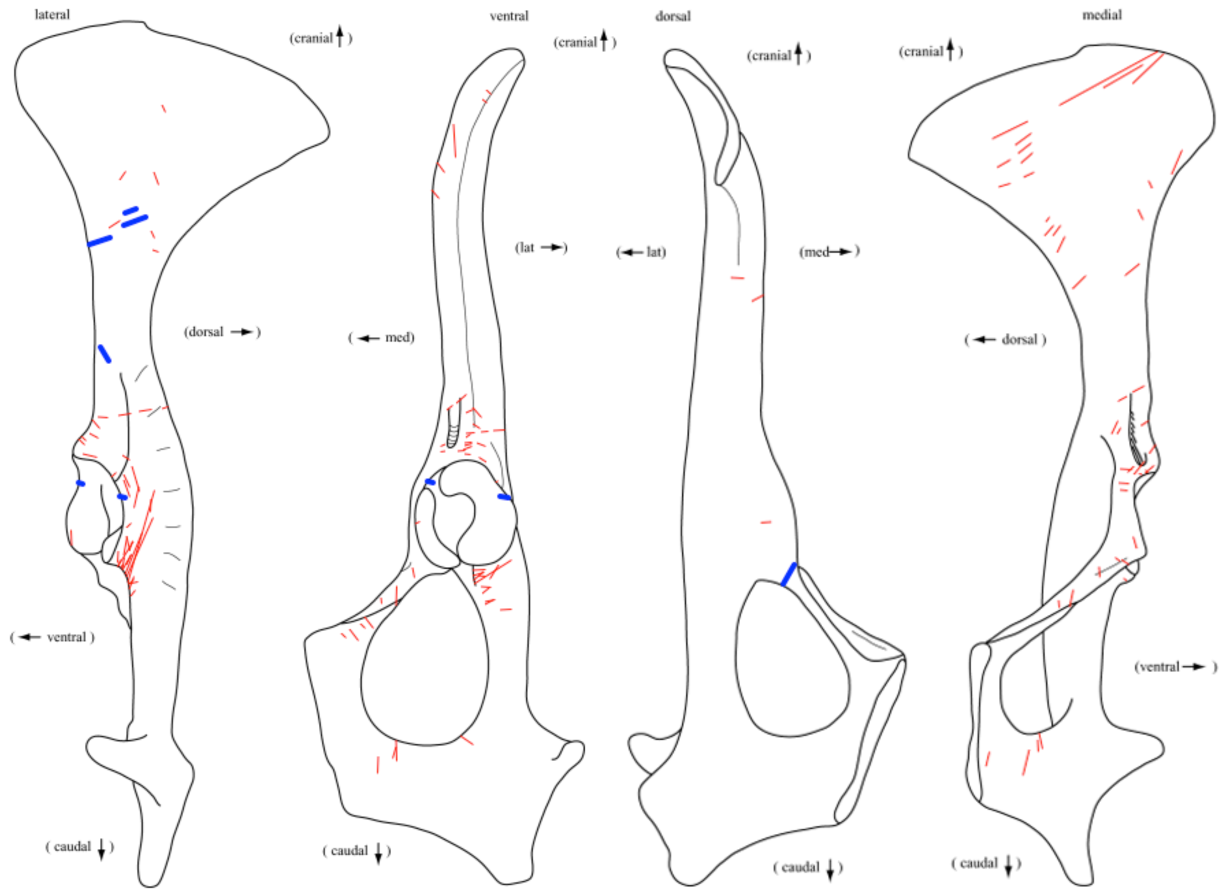


Figure VII–13 Butchery marks on pig pelvis _ Xiaomintun

6. Humerus, radius-ulna, femur, and tibia

In general, cut marks are the most common on the four limb bones, and chop and shear marks are also shown on some specimens, while only a few scoop marks are found on specimens (Tables 1 and 3 in Appendix V, Figure VII–14, Figure VII–15, Figure VII–16, Figure VII–17, Figure VII–18, Figure VII–19, Figure VII–20, Figure VII–21). Similar to the situation of Guandimiao, the domination of cut marks on and around the articular surface and the wholly preserved articular end suggest that limb bone disarticulation was usually done by cutting off the ligament around the joints and separating the two articulated bones. It is so for both cattle and pigs.

Therefore, the distal end of humerus and proximal end of femur, which are most tightly bounded by ligaments, are covered with dense cut marks, and so are other long bone ends. In addition, cut marks on the shafts are possibly generated by filleting.

Moreover, when a few chop marks around the articular ends may also be produced by activities of disarticulating and filleting, chop marks on the shafts of both cattle and pig specimens are directly related to long bone fragmentation which corresponds to the discussion of breakage pattern in Section 3.

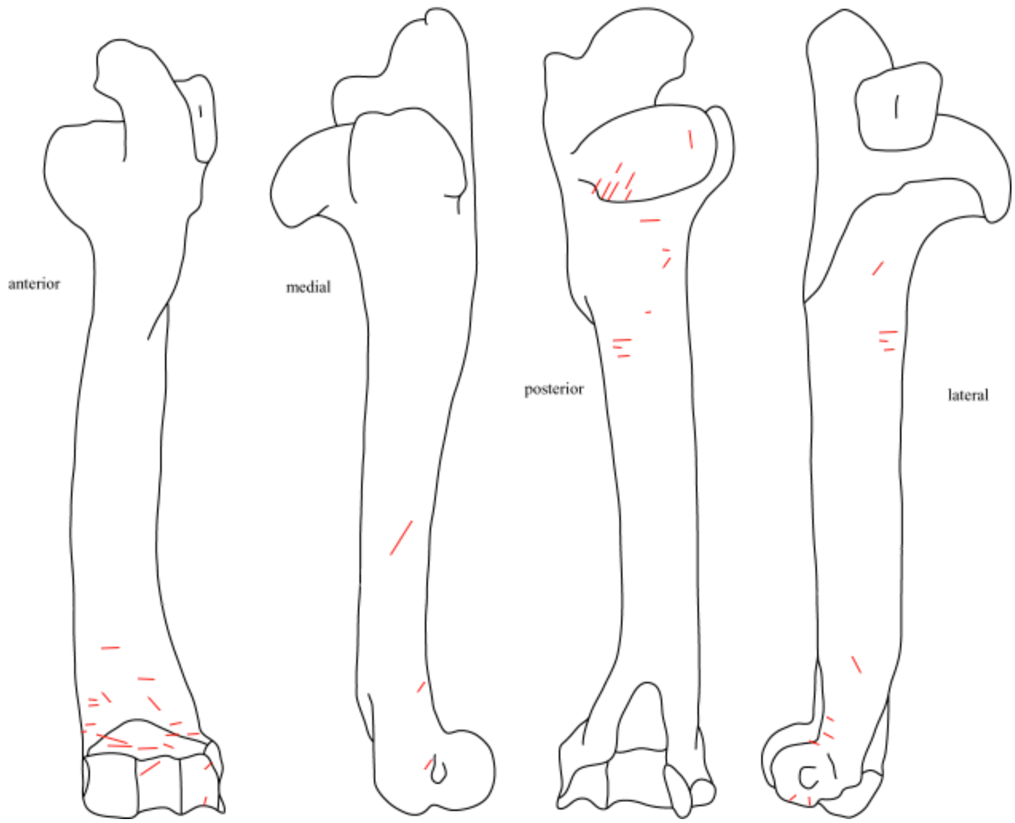


Figure VII–14 Butchery marks cattle humerus _Xiaomintun

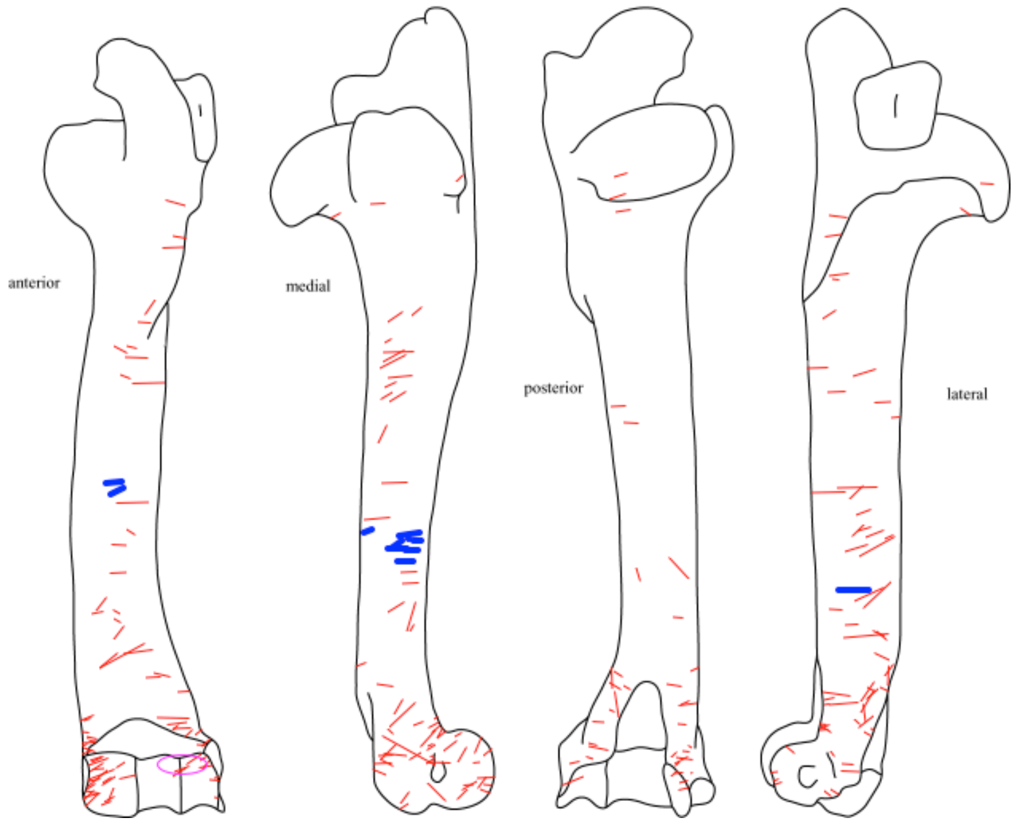


Figure VII–15 Butchery marks on pig humerus _ Xiaomintun

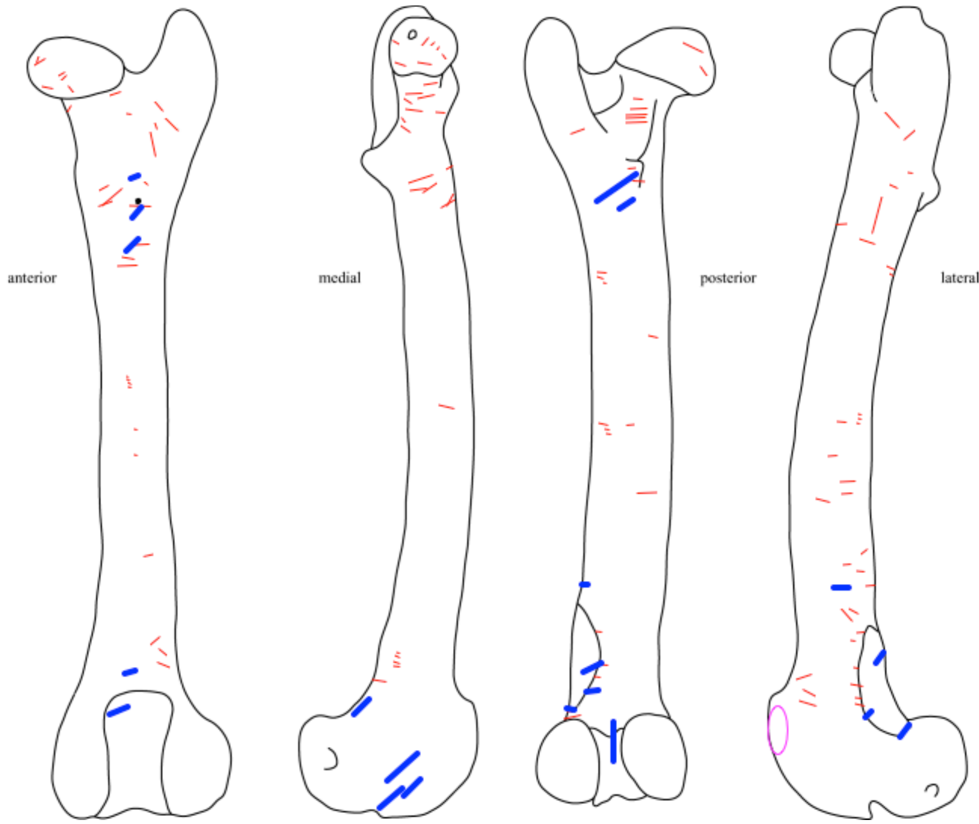


Figure VII–16 Butchery marks on cattle femur _ Xiaomintun

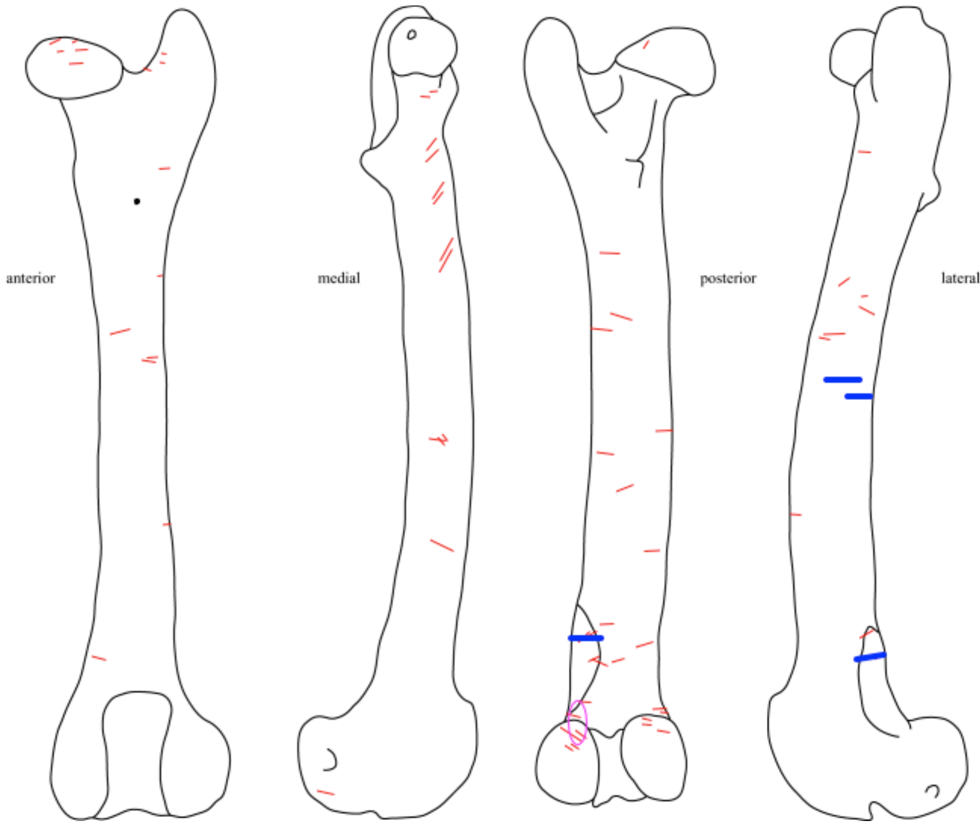


Figure VII–17 Butchery marks on pig femur _ Xiaomintun

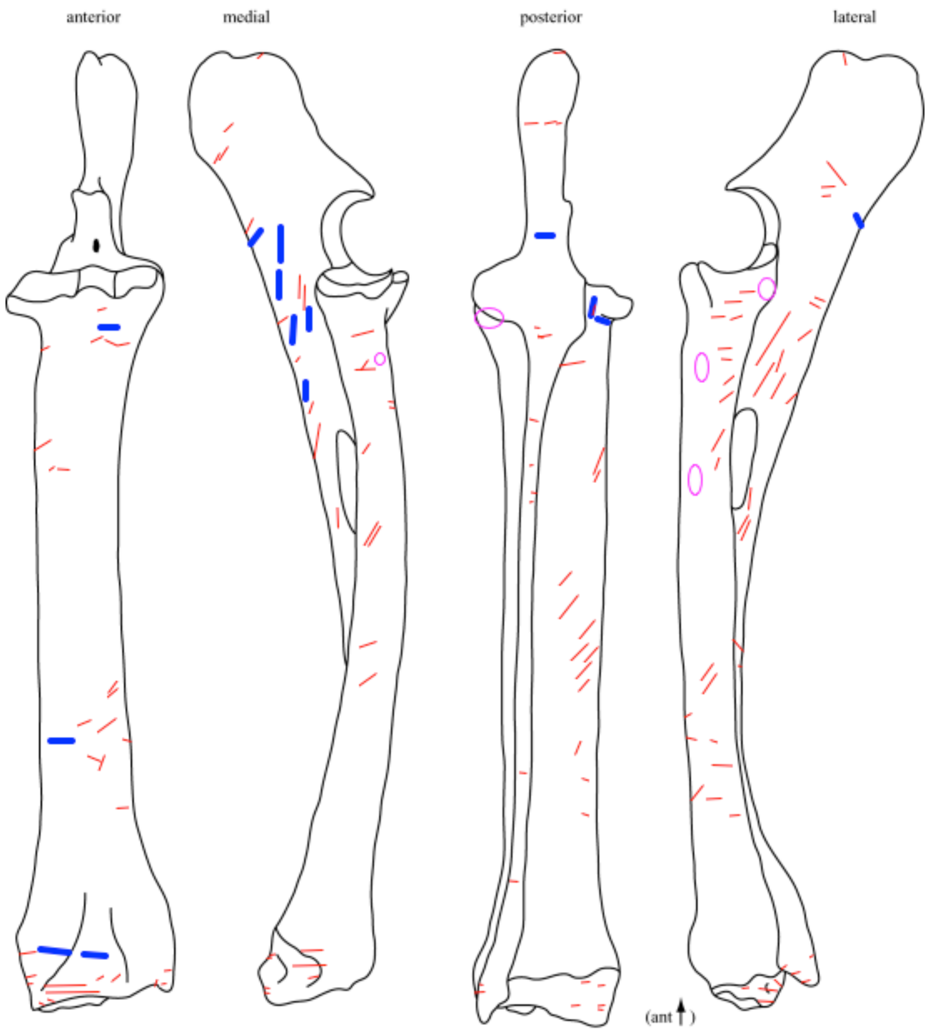


Figure VII–18 Butchery marks on cattle radius-ulna _ Xiaomintun

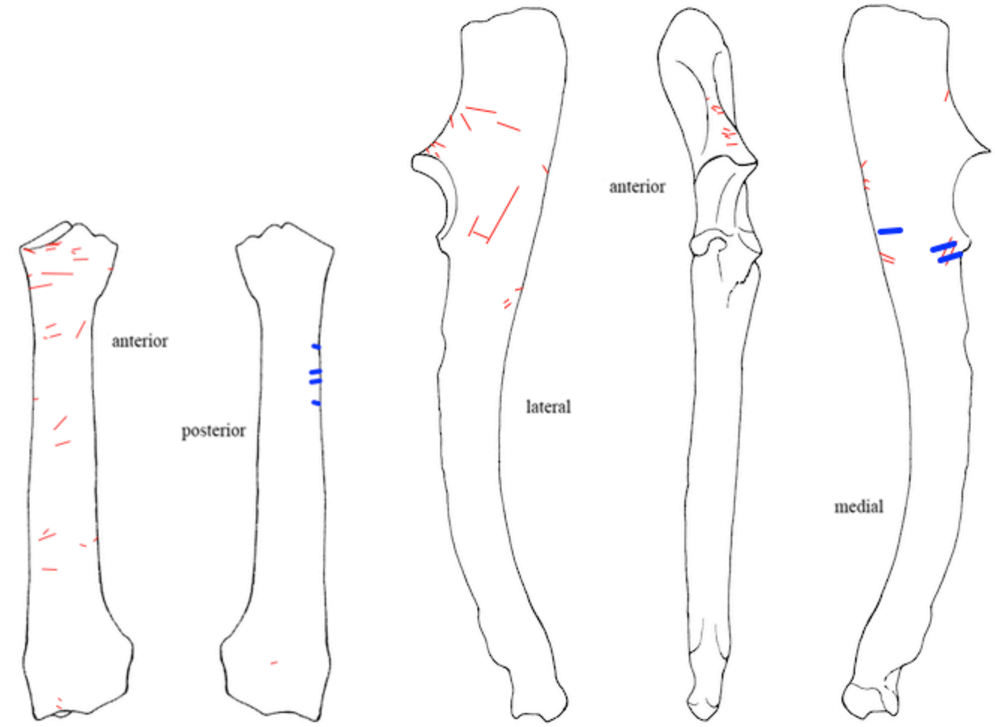


Figure VII–19 Butchery marks on pig radius and ulna _ Xiaomintun

Figure VII–20 Butchery marks on cattle tibia _ Xiaomintun

Figure VII–21 Butchery marks on pig tibia _ Xiaomintun

7. Tarsals: talus, calcaneum, and central-4th tarsal

► Cattle

For the talus, butchery marks are concentrated on the anterior, posterior, and medial surfaces (Figure VII–23). For the calcaneum, butchery marks cover all the bone surfaces but cluster on the lateral side (Figure VII–22). For the central-4th tarsal, butchery marks are located transversely around the four sides (anterior, posterior, medial, and lateral) (Figure VII–24). The distribution of these marks indicates an approach to foot bone disarticulation. The domination of cut marks suggests the process of disarticulation was realized by cutting off the ligaments encircled the ankle joint. It is also possible that some cut marks on the proximal margin of some metatarsal specimens (Figure VII–27: a) were produced in the same process. (Nevertheless, it is not clear the wrist joint was disarticulated, though some cut marks on the distal end of radius (Figure VII–18) may be related.)

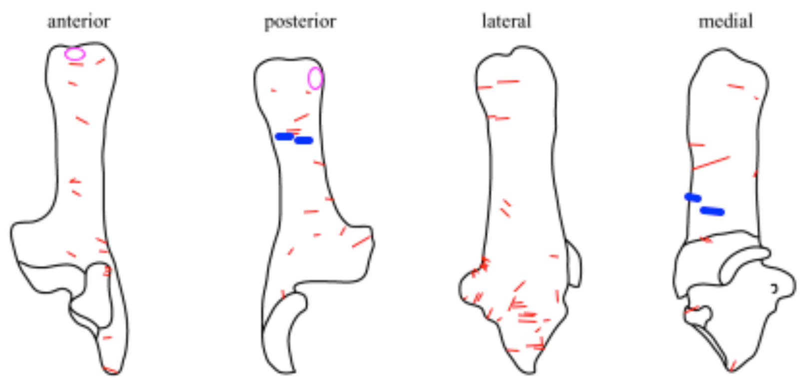


Figure VII–22 Butchery marks on cattle calcaneum _ Xiaomintun

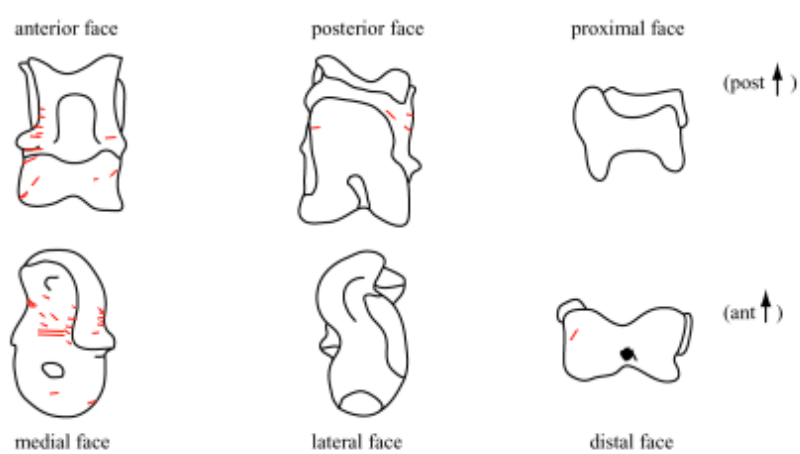


Figure VII–23 Butchery marks on cattle talus _ Xiaomintun

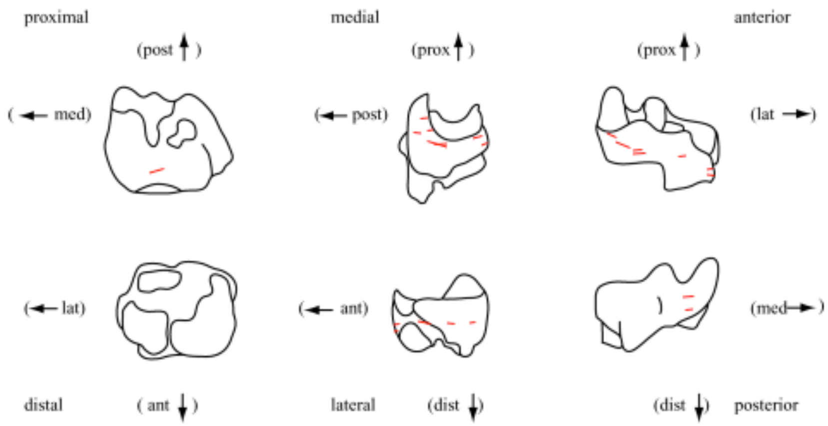


Figure VII–24 Butchery marks on cattle central-4th tarsal _ Xiaomintun

► Pigs

The distribution of butchery marks on pig calcaneus and talus (Figure VII–25, Figure VII–26) are roughly similar to that of cattle bones, which should also be related to disarticulation from the ankle joint.

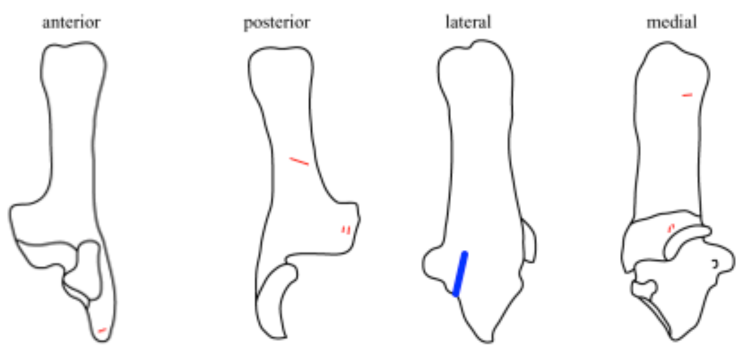


Figure VII–25 Butchery marks on pig talus _ Xiaomintun

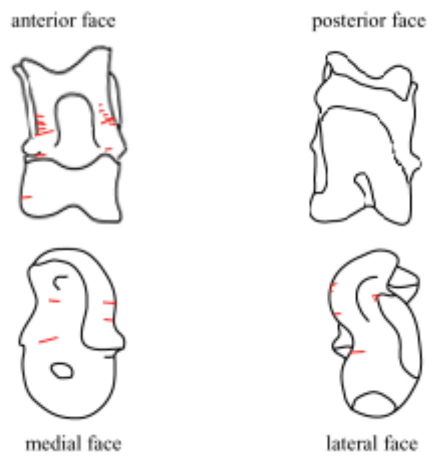


Figure VII–26 Butchery marks on pig talus _ Xiaomintun145

8. Metapodials

For pig's metapodials, only one specimen is found with cut marks around the distal articular surface.

► Cattle

Many fragments are with butchery marks. Butchery marks, mostly cut marks, are around the bone shaft and on the two distal trochoid joints (Figure VII–27). Judged by location of butchery marks, cut marks on the shaft may be inflicted by skinning or filleting (including tendon removing), and those around the distal end of metapodials might be related to disarticulation as phalanges were cut off from metapodials (Binford: 1981: 120-121, mark MTd-1, Figure 4.27), while some cut marks close to the proximal end were possibly generated during the disarticulation the ankle joint. In addition, chop marks are primarily on the midshaft and some of them are close to and parallel with the transverse fracture surface. That is, these chop marks are remains of bone breakage and possibly for marrow exaction, which has been discussed in Section 3.1.

[145] The template is modified from Popkin (2005).

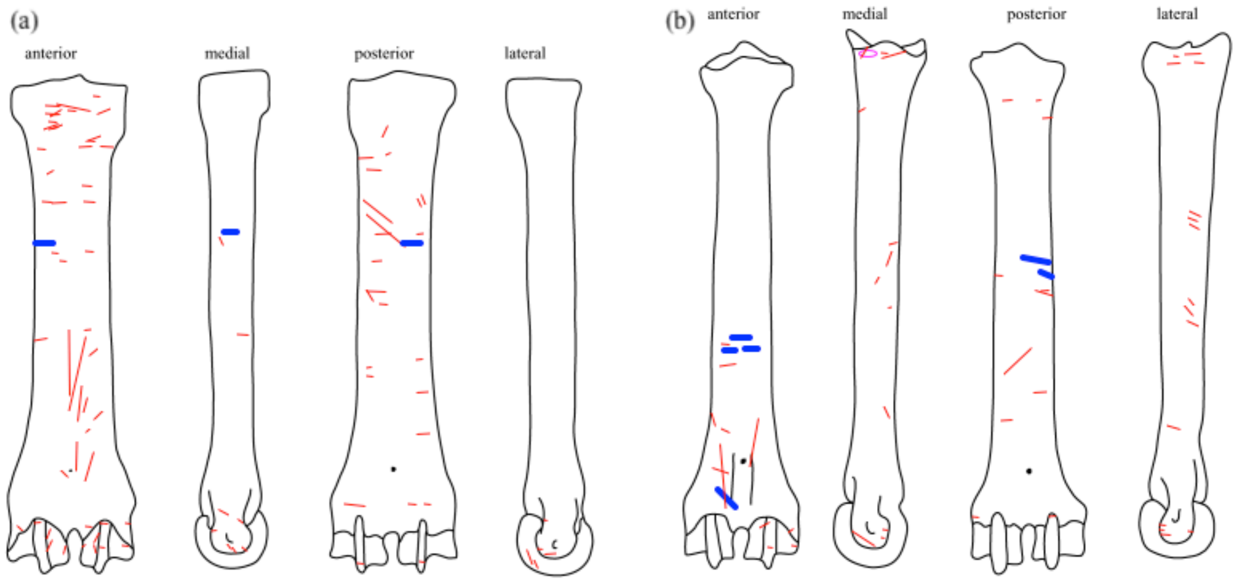


Figure VII–27 Butchery marks on cattle metacarpal (a) and metatarsal (b) _ Xiaomintun

9. Phalanges

For pigs, only one specimen of the first phalanx is seen in the collection with no butchery marks.

► Cattle

It is common to find butchery marks on the first phalanges (Figure VII–28: a), and there are also a few butchery marks on the second (Figure VII–28: b) and third phalanx. All the butchery marks as a whole prove that extremities of cattle were also processed and quite possibly cooked. Specifically, some cut marks around the proximal articular end of the first phalanges may correspond to butchery marks on the distal trochoid joints, both of which may originate from separation of extremities.

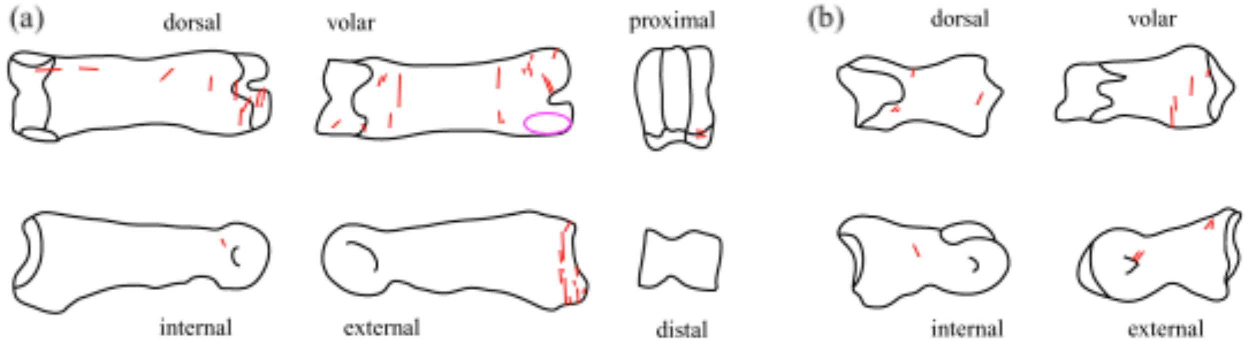
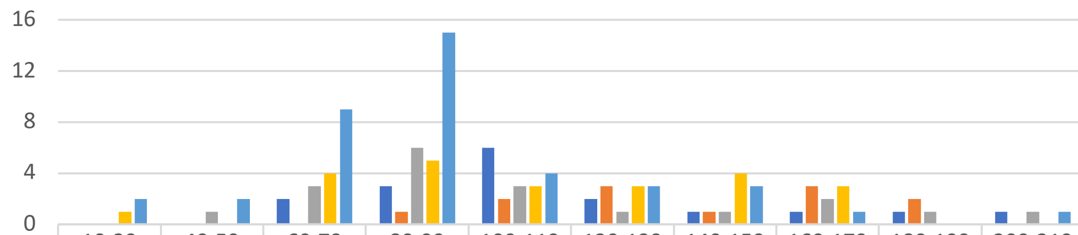


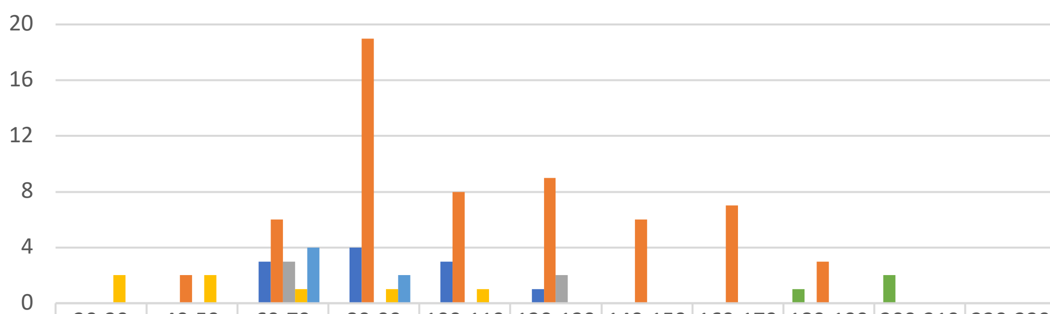
Figure VII–28 Butchery marks on cattle first phalanx (a) and second phalanxl (b) _ Xiaomintun

APPENDIX VIII: Zhougongmiao: dimensions of animal bone fragments



	10-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219
Humerus	0	0	2	3	6	2	1	1	1	1
Femur	0	0	0	1	2	3	1	3	2	0
Radius	0	1	3	6	3	1	1	2	1	1
Tibia	1	0	4	5	3	3	4	3	0	0
Metapodial	2	2	9	15	4	3	3	1	0	1

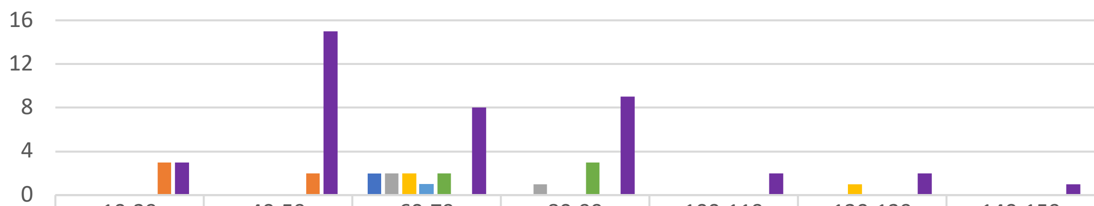
Chart VIII–1 Zhougongmiao: distribution of the maximum length (mm) of cattle long bone specimens (including end, end-shaft, end_splinters, and shaft_cylinders; calculated by NISP)



	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	220-239
whole	0	0	0	0	0	0	0	0	1	2	0
end	0	0	3	4	3	1	0	0	0	0	0
end-shaft	0	2	6	19	8	9	6	7	3	0	0
shaft_cylinder	0	0	3	0	0	2	0	0	0	0	0
end_splinter	2	2	1	1	1	0	0	0	0	0	0
shaft_splinter	0	0	4	2	0	0	0	0	0	0	0

Chart VIII–2 Zhougongmiao: distribution of the maximum length (mm) of types of cattle long bone specimens ((including end, end-shaft, end_splinters, and shaft_cylinders; calculated by NISP)[146]

[146] The extremely large number of specimens in the category of end-shaft of 80-99 mm long is largely a reflection of many metapodial specimens (12 metapodial specimens in this group).



	10-39	40-59	60-79	80-99	100-119	120-139	140-159
atlas	0	0	2	0	0	0	0
cervical	0	0	2	1	0	0	0
thoracic	0	0	2	0	0	1	0
lumbar	0	0	1	0	0	0	0
sacral	0	0	2	3	0	0	0
caudal	3	2	0	0	0	0	0
fragments	3	15	8	9	2	2	1

Chart VIII–3 Zhougongmiao: distribution of the maximum length (mm) of cattle vertebral specimens (calculated by NISP)

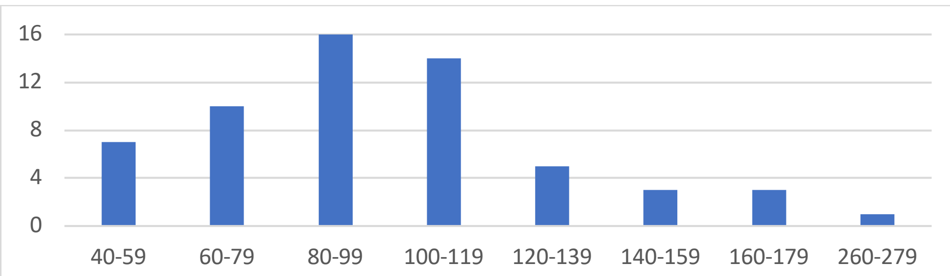


Chart VIII–4 Zhougongmiao: distribution of the maximum length (mm) of cattle rib specimens (calculated by NISP)

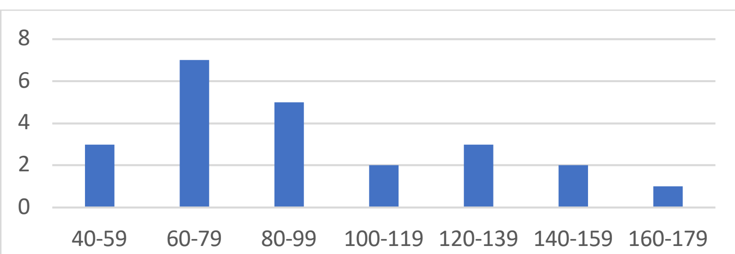


Chart VIII–5 Zhougongmiao: distribution of the maximum length (mm) of cattle pelvis specimens (calculated by NISP)

APPENDIX IX: Zhougongmiao: calculations of butchery marks

Table IX–1 Zhougongmiao: butchery mark frequencies by element (calculated by NISP of bone specimens) _ cattle

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
cranium	4	1.7	2	0.9	0		3	1.3	9	8	231	3.5
mandible	0		1	4.3	0		2	8.7	3	3	23	13.0
atlas	0		1	33.3	0		1	33.3	2	1	3	33.3
axis	0	-	0	-	0	-	0	-	0	0	0	-
cervical	0		0		0		1	33.3	1	1	3	33.3
thoracic	0		1	20.0	0		2	40.0	3	2	5	40.0
lumbar	1	25.0	2	50.0	0		0		3	2	4	50.0
sacral	1	20.0	1	20.0	0		0		2	1	5	20.0
caudal	0		0		0		0		0	0	6	0.0
VER.FR	7	10.1	5	7.2	0		5	7.2	17	11	69	15.9
rib	10	12.5	5	6.3	0		11	13.8	26	22	80	27.5
scapula	0		0		0		0		0	0	4	0.0
pelvis	1	4.2	2	8.3	0		3	12.5	6	5	24	20.8
humerus	0		0		0		0		0	0	11	0.0
radius	0		2	10.5	0		0		2	2	19	10.5
ulna	0		1	8.3	0		0		1	1	12	8.3
femur	2	14.3	1	7.1	0		0		3	3	14	21.4
tibia	1	4.0	2	8.0	0		1	4.0	4	3	25	12.0
metapodial	5	11.6	4	9.3	0		5	11.6	14	9	43	20.9
calcaneum	2	16.7	0		0		1	8.3	3	3	12	25.0
talus	2	22.2	1	11.1	0		1	11.1	4	3	9	33.3
first phalanx	1	5.0	0		0		0		1	1	20	5.0
second phalanx	0		0		0		0		0	0	27	0.0
third phalanx	0		0		0		0		0	0	22	0.0
carpal	0		0		0		0		0	0	24	0.0
tarsal	0		0		0		0		0	0	17	0.0
Total	37	5.2	31	4.4	0	0.0	36	5.1	104	81	712	11.4

Keys:
[1, 2] One specimen can exhibit more than one type of butchery marks. 1. SUM = the sum of specimens with cut marks, with chop marks, with scoop marks, and with shear marks, and some specimens with more than one type of butchery marks may be counted several times. 2. Butchered = the number of specimens with butchery marks, which can be equal to or smaller than "SUM". However, the overlaps do not affect other calculations or

comparisons significantly.

[3] The incidence of certain type of butchery mark (%) = (the number of specimens with certain type of butchery marks) ÷ (the total number of specimens) × 100%. So, the sum of the incidences of cut, chop, scoop, and shear marks can be equal to or larger than the incidence of specimens with butchery marks as shown in the last column.

[4] Butchered marks (%) = (the number of specimens with certain type of butchery mark) ÷ SUM × 100%, which represents the relative proportions of cut, chop, scoop, and shear marks.

Table IX–2 Zhougongmiao: butchery mark frequencies by element portions (calculated by NISP of bone specimens) _ cattle

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
pelvis-acetabulum	0		1	11.1	0		2	22.2	3	2	9	22.2
pelvis-ilium/ischium/pubis	1	5.9	1	5.9	0		1	5.9	3	3	17	17.6
metapodial-P articulation	1	4.5	1	4.5	0		2	9.1	4	3	22	13.6
metapodial-shaft	2	5.9	2	5.9	0		3	8.8	7	5	34	14.7
metapodial-D articulation	3	15.8	0		0		0		3	3	19	15.8
limb-P articulation	2	8.0	1	4.0	0		1	4.0	4	3	25	12.0
limb-shaft	3	6.5	1	2.2	0		0		4	4	46	8.7
limb-D articulation	0		1	2.8	0		0		1	1	36	2.8
humerus-P articulation	0	-	0	-	0	-	0	-	0	0	0	-
humerus-shaft	0		0		0		0		0	0	7	0.0
humerus-D articulation	0		0		0		0		0	0	8	0.0
radius-P articulation	1	9.1	0		0		0		1	1	11	9.1
radius-shaft	1	7.7	0		0		0		1	1	13	7.7
radius-D articulation	0		0		0		0		0	0	7	0.0
femur-P articulation	1	33.3	0		0		0		1	1	3	33.3
femur-shaft	1	9.1	0		0		0		1	1	11	9.1
femur-D articulation	0		1	14.3	0		0		1	1	7	14.3
tibia-P articulation	0		1	9.1	0		1	9.1	2	1	11	9.1
tibia-shaft	1	6.7	1	6.7	0		0		2	2	15	13.3
tibia-D articulation	0	0.0	0	0.0	0	0.0	0	0.0	0	0	14	0.0

Notes: because of the differentiated preservation of long bone portions, the distribution of butchery marks on portions of humerus, radius, femur, and tibia are both listed separately based on element and summarized into one "limb" group.

Keys: limb-P articulation = proximal articulation of a limb bone; limb-D articulation = distal articulation of a

limb bone. Similar expressions are applied to other limb bones.
1,2 One specimen can exhibit more than one type of butchery marks. 1 SUM = the sum of specimens with cut marks, with chop marks, with scoop marks, and with shear marks, and some specimens with more than one type of butchery marks may be counted several times. 2 Butchered = the number of specimens with butchery marks, which can be equal to or smaller than "SUM". However, the overlaps cannot affect other calculations or comparisons significantly.
3 The incidence of certain type of butchery mark (%) = (the number of specimens with certain type of butchery marks) ÷ (the total number of specimens) × 100%. So, the sum of the incidences of cut, chop, scoop, and shear marks can be equal to or larger than the incidence of specimens with butchery marks as shown in the last column.

Table IX–3 Zhougongmiao: butchery mark frequencies by element (calculated by NISP of bone specimens) _ pigs

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
cranium	0		0		0		0		0	0	23	0.0
mandible	3	13.6	2	9.1	1	4.5	2	9.1	8	5	22	22.7
atlas	0		1	50.0	1	50.0	0		2	1	2	50.0
axis	0		1	100.0	0		1	100.0	2	1	1	100.0
cervical	0	-	0	-	0	-	0	-	0	0	0	-
thoracic	0	-	0	-	0	-	0	-	0	0	0	-
lumbar	1	16.7	0		0		0		1	1	6	16.7
sacral	0		0		0		0		0	0	2	0.0
VER.FR	0	-	2	-	0	-	3	-	5	3	7	-
rib	4	13.3	4	13.3	0		6	20.0	14	11	30	36.7
scapula	2	28.6	2	28.6	0		1	14.3	5	3	7	42.9
pelvis	1	8.3	1	8.3	1	8.3	2	16.7	5	3	12	25.0
humerus	2	11.1	1	5.6	0		2	11.1	5	3	18	16.7
radius	1	10.0	1	10.0	0		0		2	2	10	20.0
ulna	2	25.0	0		0		1	12.5	3	3	8	37.5
femur	1	10.0	1	10.0	0		0		2	2	10	20.0
tibia	0		0		0		0		0	0	5	0.0
Metapodial 3/4	2	16.7	0		0		1	8.3	3	3	12	25.0
calcaneum	0		0		0		0		0	0	4	0.0
talus	0		0		0		0		0	0	3	0.0
first phalanx	0		0		0		0		0	0	3	0.0
carpal	0		0		0		0		0	0	1	0.0
tarsal	0	-	0	-	0	-	0	-	0	0	0	-
Total	19	10.2	16	8.6	3	1.6	19	10.2	57	41	186	22.0

Butchery marks (%)[4]	33.3	28.1	5.3	33.3	100.0

Keys: refer to those in Table IX–1.

Table IX–4 Zhougongmiao: butchery mark frequencies by element portions (calculated by NISP of bone specimens) _ pigs

	Butchery mark types									Total		
	Cut		Chop		Scoop		Shear		SUM	Butchered	Total	Butchered
	N	%[3]	N	%	N	%	N	%	N[1]	N[2]	N	%
pelvis-acetabulum	0		0		0		0		0	0	1	0.0
pelvis-ilium/ischium/pubis	1	8.3	1	8.3	1	8.3	2	16.7	5	3	12	25.0
limb-P articulation	1	11.1	1	11.1	0		0		2	2	9	22.2
limb-shaft	3	7.7	2	5.1	0		2	5.1	7	6	39	15.4
limb-D articulation	0		0		0		0		0	0	13	0.0
humerus-P articulation	0		0		0		0		0	0	1	0.0
humerus-shaft	1	5.9	1	5.9	0		2	11.8	4	3	17	17.6
humerus-D articulation	0		0		0		0		0	0	8	0.0
radius-P articulation	1	20.0	0		0		0		1	1	5	20.0
radius-shaft	1	10.0	1	10.0	0		0		2	2	10	20.0
radius-D articulation	0		0		0		0		0	0	1	0.0
femur-P articulation	0		1	100.0	0		0		1	1	1	100.0
femur-shaft	1	12.5	0		0		0		1	1	8	12.5
femur-D articulation	0		0		0		0		0	0	2	0.0
tibia-P articulation	0		0		0		0		0	0	2	0.0
tibia-shaft	0		0		0		0		0	0	4	0.0
tibia-D articulation	0		0		0		0		0	0	2	0.0

Notes and keys: refer to those in Table IX–2.

APPENDIX X: Zhougongmiao: depiction of butchery marks

As for the drawings included in this appendix, cut marks are marked as red strokes, chop marks as blue strokes, scoop marks labelled in purple circles, and some sheared surfaces are circled in yellow (while some other shear marks can be seen in photos shown in Appendix XI). For some specimens, when the same type of butchery mark appeared multiple times on one location they were calculated as "1" even though there were actually more than one stroke on this location (refer to Chapter 5). In these drawings, I have recorded all the strokes of butchery marks in order to signify the locations with butchery marks. Therefore, the amount of butchery marks shown in these drawings are different from those recorded in Appendix IX.

1. Cattle

Vertebrae Based on a few specimens with butchery marks, there is no definite difference between types of vertebrae. Chop and shear marks are the most common and likely indicate the separation of adjacent vertebrae and splitting of vertebra into pieces (e.g., Appendix XI: Figure 18). Several cut marks are shown on fragments of spinous and transverse processes, which could be related to muscle removal.

Ribs Chop and shear marks are much more common than cut marks on rib specimens, suggesting the activities of chopping ribs into small sections (e.g., Appendix XI: Figure 19). There were also a few cut marks randomly scattered on the specimens.

Pelvis Several chop and shear marks are seen on some acetabulum chunks, which indicates the activity of bone fragmentation.

Humerus, Femur, Radius, and Tibia It is relatively uncommon to find butchery marks on the four limb bones. Roughly, a few butchery marks cluster around the articular ends and shaft portions close to the epiphyses (Figure X–1, Figure X–2, Figure X–3), which might suggest the purpose of disarticulation.

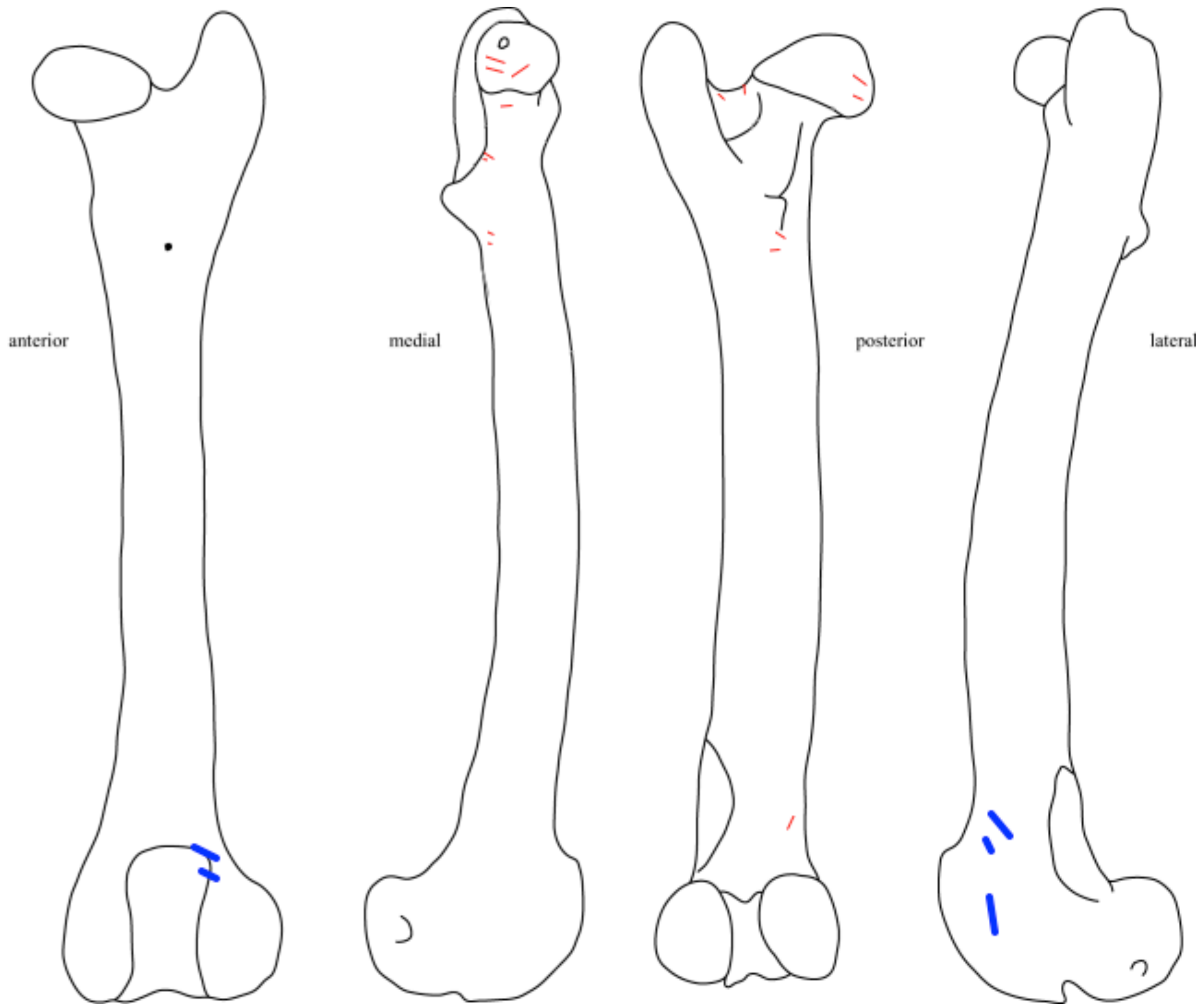


Figure X–1 Butchery marks on the cattle femur _ Zhougongmiao

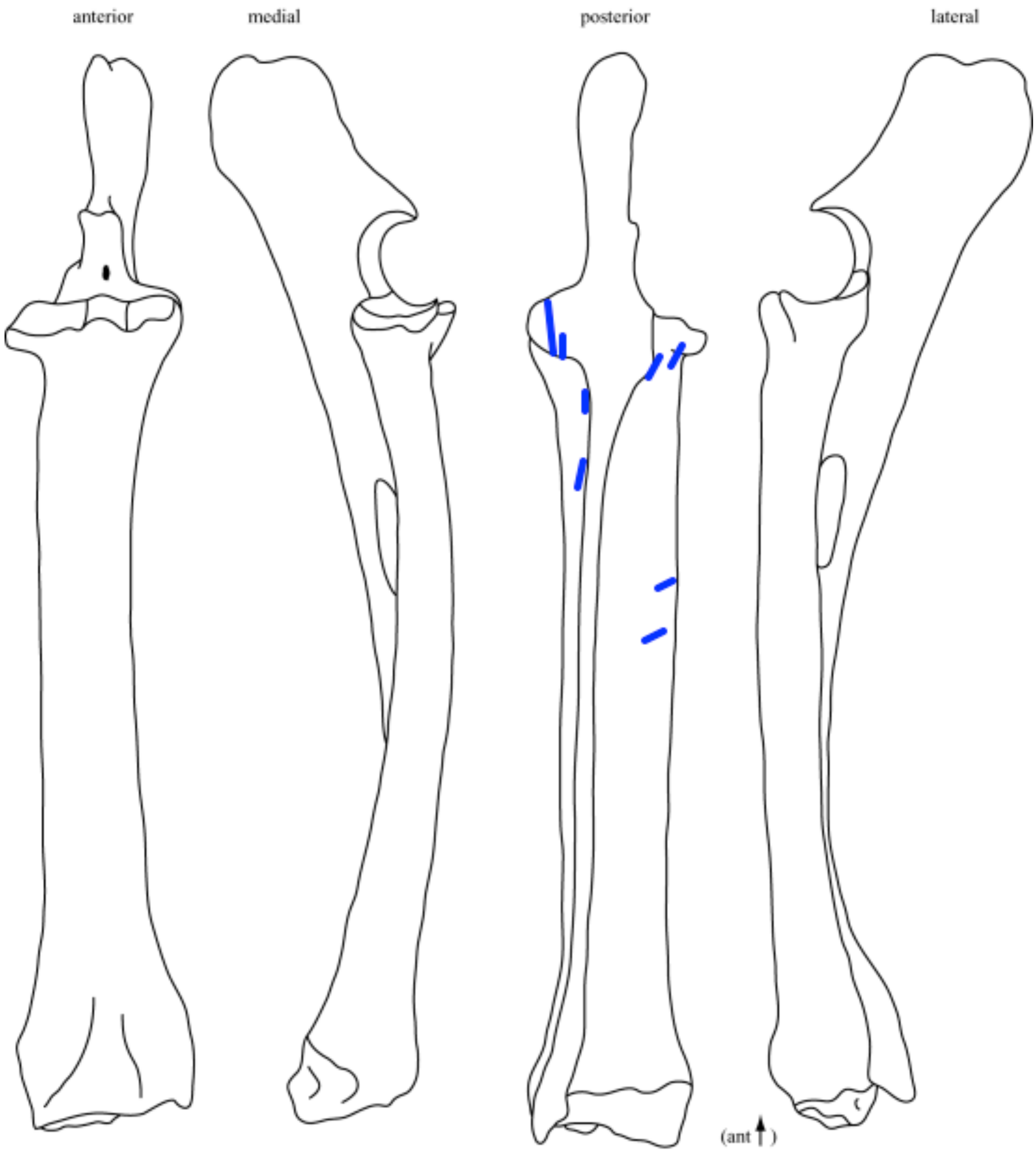


Figure X–2 Butchery marks on the cattle radius _ Zhougongmiao

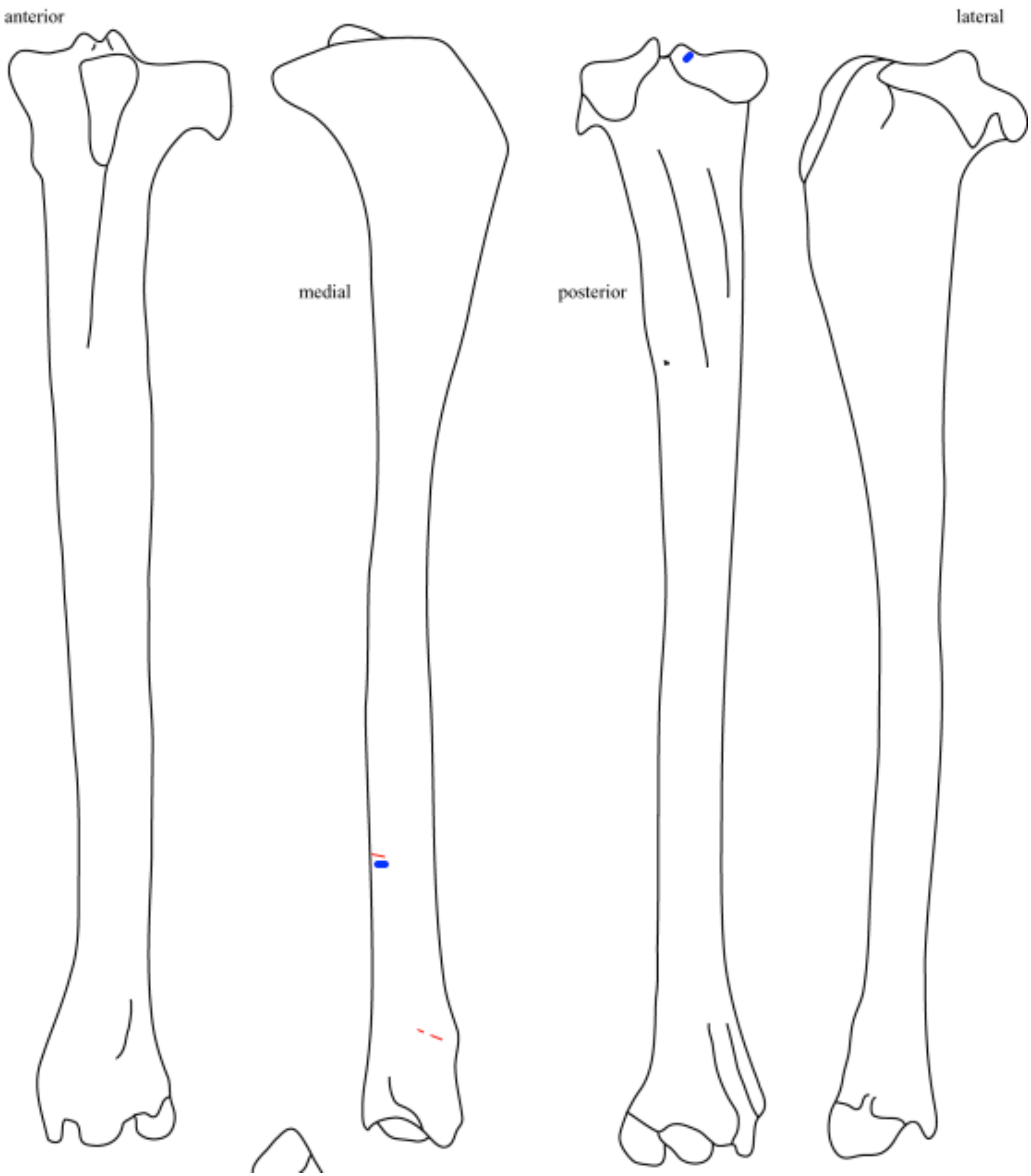


Figure X–3 Butchery marks on the cattle tibia _ Zhougongmiao

Tarsals: talus, calcaneum, and central-4th tarsal Cut and chop marks are mostly around the anterior, posterior, and medial surfaces of the talus (Figure X–4), and they cover all the bone surfaces of the calcaneum but cluster on the lateral side (Figure X–5), which is quite similar to the case of Xiaomintun. However, there is no specimen in the total of fourteen central-4th tarsals with butchery marks. Considering there are few butchery marks on the distal end of the tibia or the proximal end of the metatarsal, the approach to foot bone disarticulation can be deduced. It is mainly by cutting/chopping off ligaments encircled the ankle joint that a cattle foot was separate from the body, which can leave few marks on the bone.

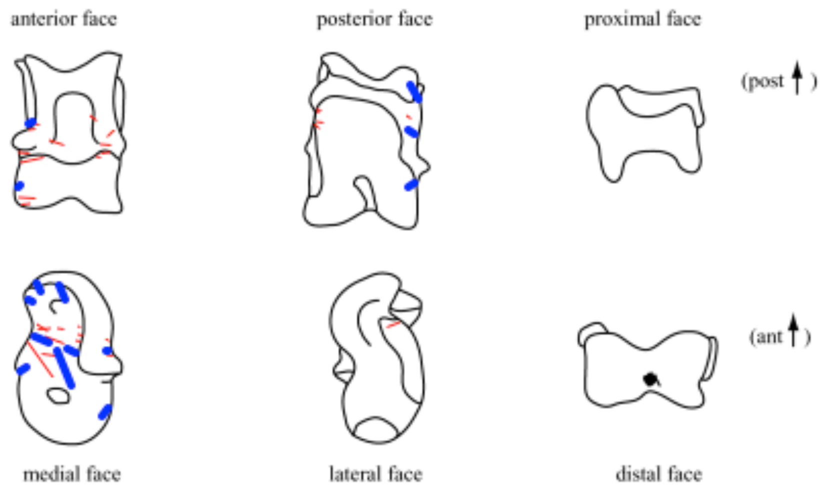


Figure X–4 Butchery marks on the cattle talus _ Zhougongmiao

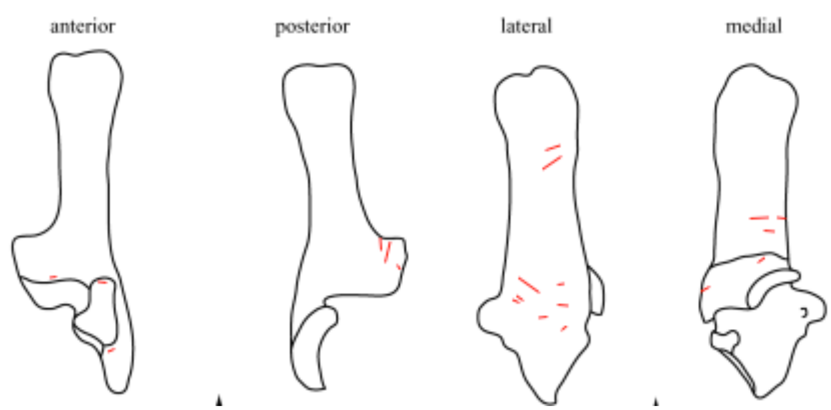


Figure X–5 Butchery marks on the cattle calcaneum _ Zhougongmiao

However, with no butchery marks on any carpals (24 specimens totally) and few marks on the distal radius end or proximal metacarpal end, it is not clear how the wrist joint was disarticulated.

Metapodials There are only a few specimens with butchery marks. Roughly, it seems butchery marks are not scattered on the bone surface but concentrated on portions close to the articular ends (Figure X–6).

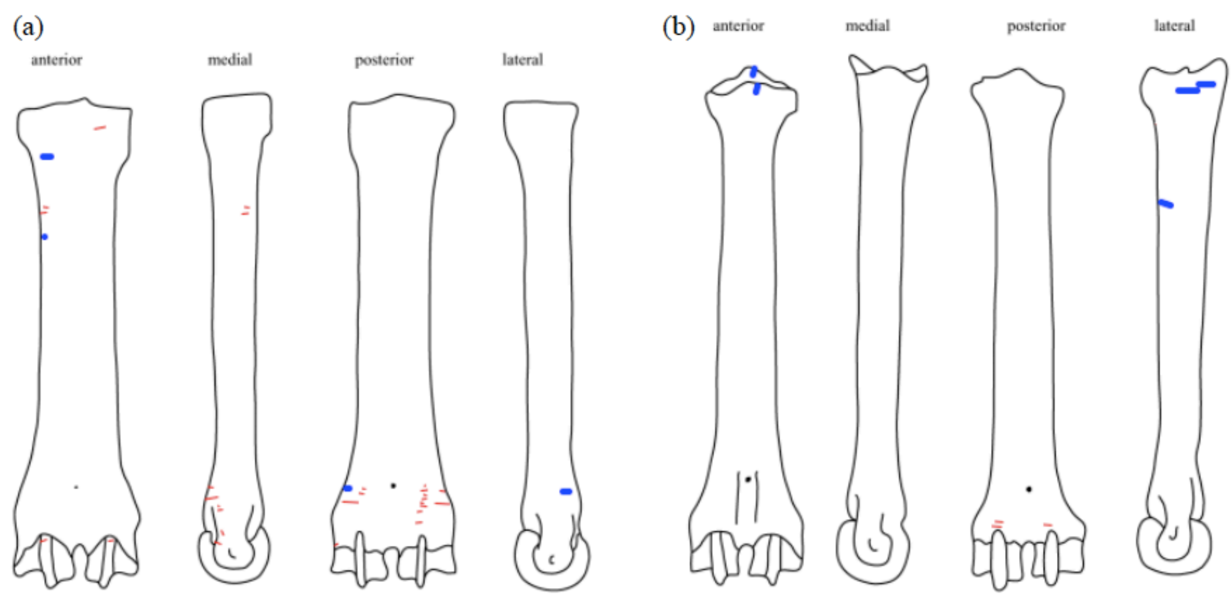


Figure X–6 Butchery marks on cattle metacarpal (a) and metatarsal (b) _ Zhougongmiao

<u>Other elements</u> Butchery marks randomly appear on the severely fragmented cranial bones, which makes it impossible to figure out the related butchery activities. It is also difficult to have a better understanding of human activity based on the small number of mandible and scapula fragments. On the other hand, since there is only one from 69 phalanges with cut marks, it is quite possible that Zhou people in Zhougongmiao did not use cutting or chopping tools on phalanges.

2. Pigs

Given the small sample size, it is only possible to summarize the distribution of butchery marks on several elements.

Mandibles Butchery marks are on both the medial and lateral surface (Figure X–7), and the pattern is similar to that seen at Guandimiao, though much simplified. Butchery marks around the condyle process might be connected to the activity of disarticulating the mandible and filleting.

Chop marks under premolars and molars might be related to filleting or cleaving the dentary bone into several parts.

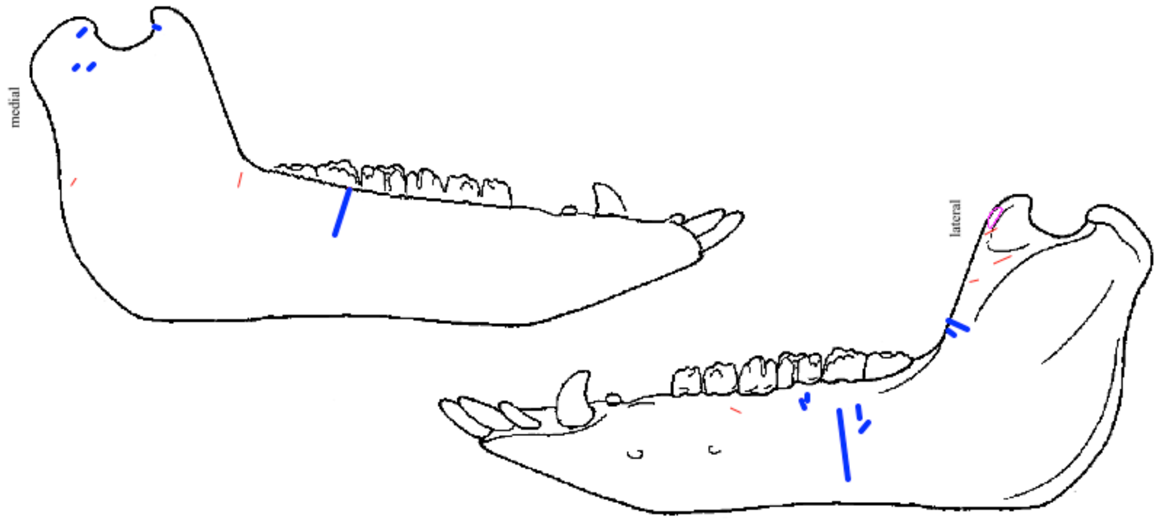


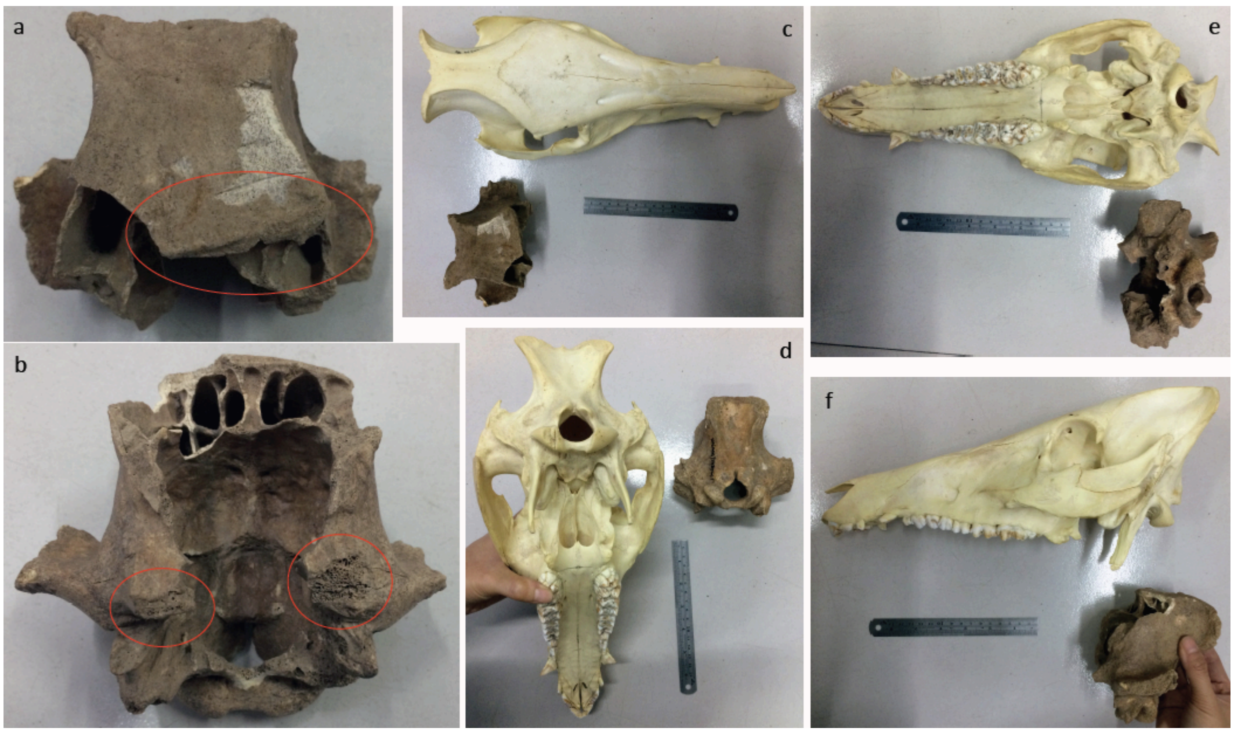
Figure X–7 Butchery marks on pig mandibles _ Zhougongmiao

Ribs Chop and shear marks dominate on rib specimens. Butchery marks close to the proximal rib head shows activities of peeling off rib slabs from the vertebral column. Other chop and shear marks are closely related to activities of chopping ribs to small sections.

Other elements For long bones, there are only a few butchery marks scattered around and close to the articular ends, which is quite similar to the situation of cattle bones. Butchery marks on the scapula, pelvis, vertebrae, and metacarpals indicate these elements were processed by tools, but they can give away little detailed information on the butchery pattern. The lack of small compact bones in general also cause difficulty in understanding foot bone disarticulation.

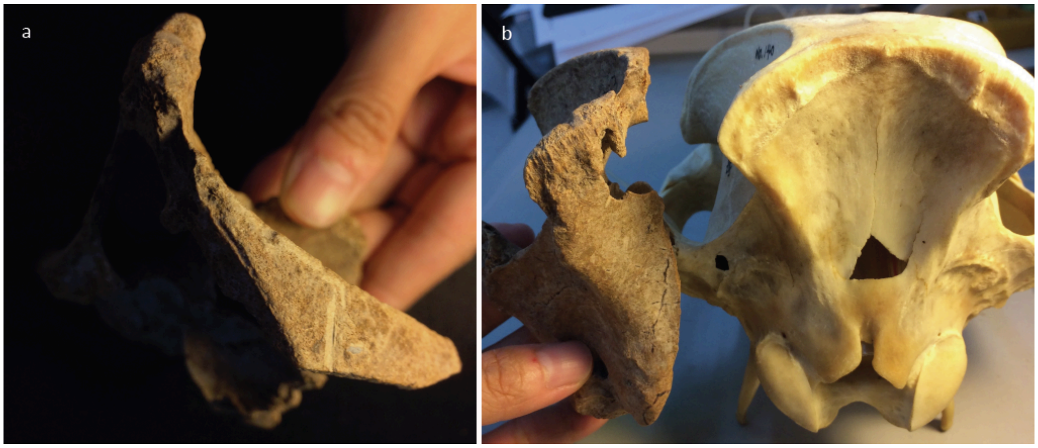
APPENDIX XI: Examples of animal bone fragments (photos)

1. Guandimiao



06HXYGT3318H201(1): a. Vertical view: with a sheared fracture surface circled in red; b. Anterior-inferior view: with shear fracture surfaces circled in red; c-f. Comparison with a cranium of modern collection.

Figure XI–1 Guandimiao: An example of chopping though pig's cranial bone transversely



06HXYGT3213H344(3): a. Vertical view: with a chopped fracture surface; b. Posterior view: comparison with a cranium of modern collection.

Figure XI–2 Guandimiao: An example of pig's cranial fragment

a. 06HXYGT3213H344(1): medial side of a maxilla, with a flat sheared fracture surface; b. 07HXYGT3821H749(9): lateral and anterior views of a maxilla and connected facial bones, with a flat fracture surface; c. 07HXYGT4212H1250(1): left side of frontal bone, with chop marks and regular fracture surfaces.

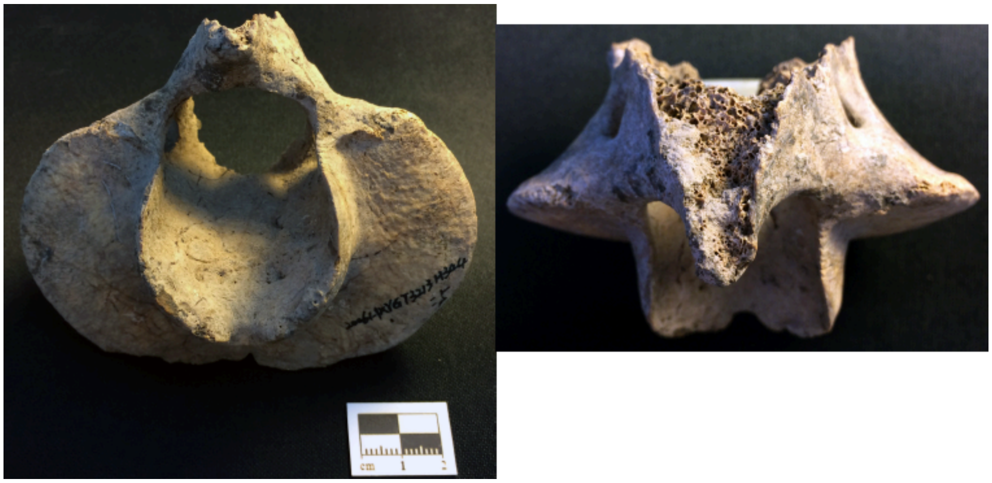
Figure XI–3 Guandimiao: Examples of pig's cranial (maxilla) fragments

a. 07HXYGT4221H1308(1): medial view of a mandible (ascending ramus) fragment; b. 07HXYGT3720H747(11): lateral view of a coronoid process fragment, with flat fracture surface; c. 07HXYGT4121H1168(1): lateral view of a mandible (anterior half of the body) fragment, with the anterior end chopped off; d. 06HXYGT3113H524(6): lateral view of a mandible (main part of the body) fragment.

Figure XI–4 Guandimiao: Examples of cattle's mandible fragments

a. 06HXYGT3216H126(2): vertical and inferior views of a mandibular symphysis fragment; b. 07HXYGT3919H656(1): medial view of a mandible fragment divided through the diastema; c. 07HXYGT4213H1178(5): lateral view of a mandible with a flat fracture surface in front of M1 and the coronoid process and condyle process chopped off (a chopped surface is circled in red); d. 07HXYGT3615-L5(3): medial view of a mandible with a flat fracture surface in front of M2 and part of the ascending ramus broken; e. 06HXYGT3113H315(30): medial and lateral views of a mandible fragment (premolar portion) with chop marks circled in red.

Figure XI–5 Guandimiao: Examples of pig's mandible fragments

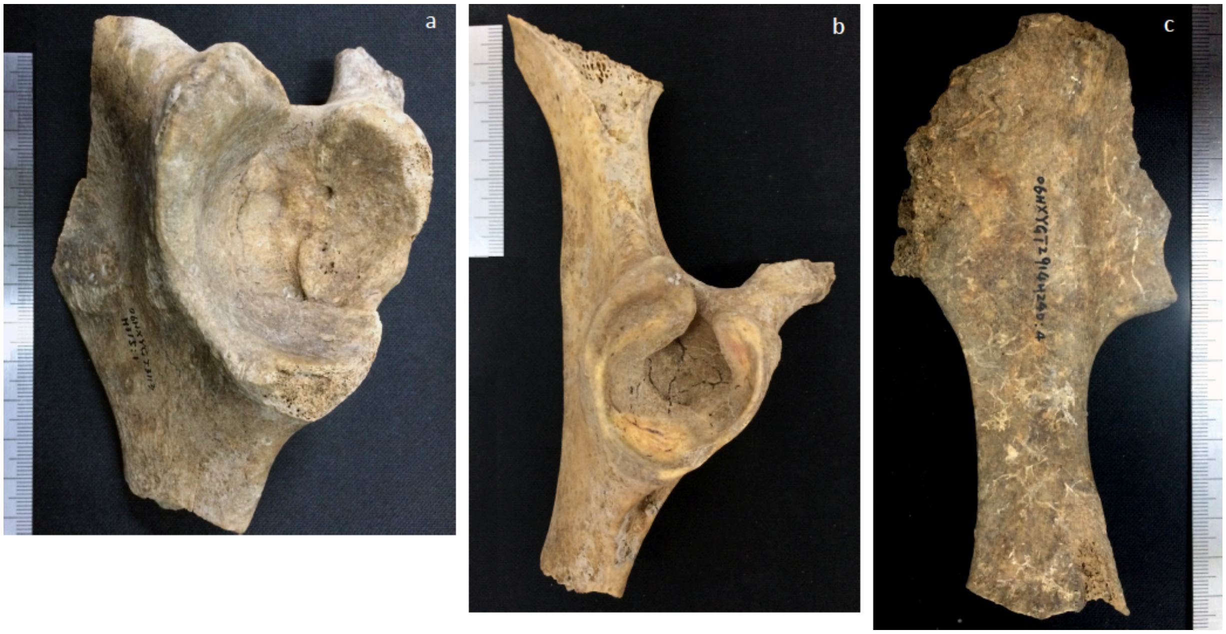


06HXYGT3213H344(5): anterior portion of an axis.

Figure XI–6 Guandimiao: An example of cattle's atlas fragment

a. 06HXYGT2813H245(4): vertebral portion of a pig rib, with chopped fracture surface; b. 07HXYGT4112H1095(18-20): sections of pig ribs from the same pit (the small fragment is with a new break in the body); c. 07HXYGT3818H677(1-1): vertebral portion of a cattle rib, with the head sheared off.

Figure XI–7 Guandimiao: Examples of rib fragments of cattle and pigs



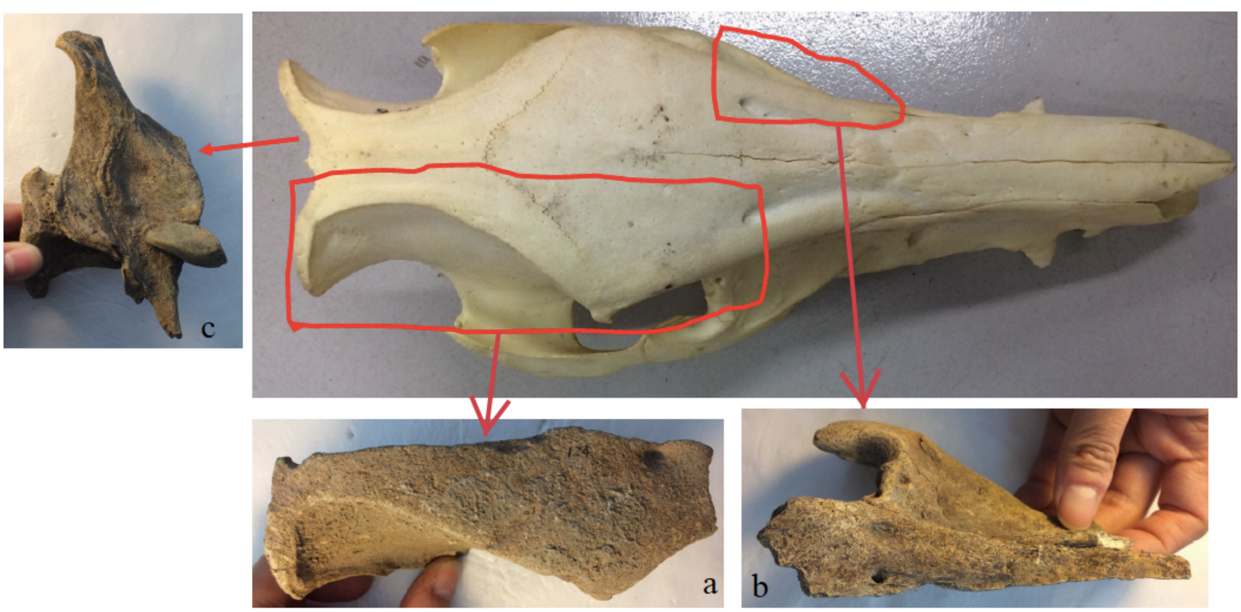
a. 06HXYGT3113H315(1): a whole cattle acetabulum; b. a pig's innominate fragment with a whole acetabulum and portions of the ilium, ischium, and pubis, and the three fractures are possibly human made;, c. 06HXYGT2914H240(4): a pig's ilium fragment (part of the shaft and wing).

Figure XI–8 Guandimiao: Examples of innominate fragments of cattle and pigs

2. Xiaomintun

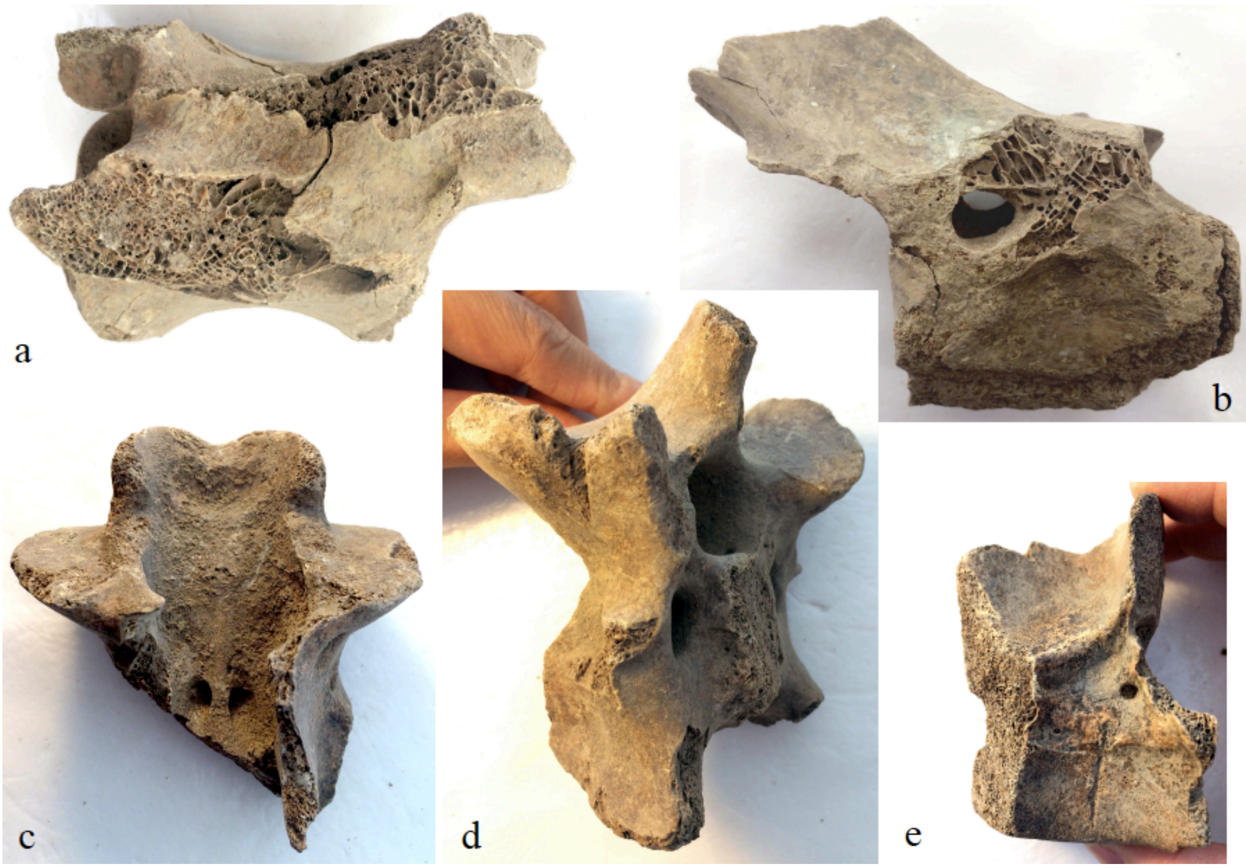
03AXST2003H226(7): 26: distal half of a right-side humerus

Figure XI–9 Xiaomintun: an example of pig's humerus



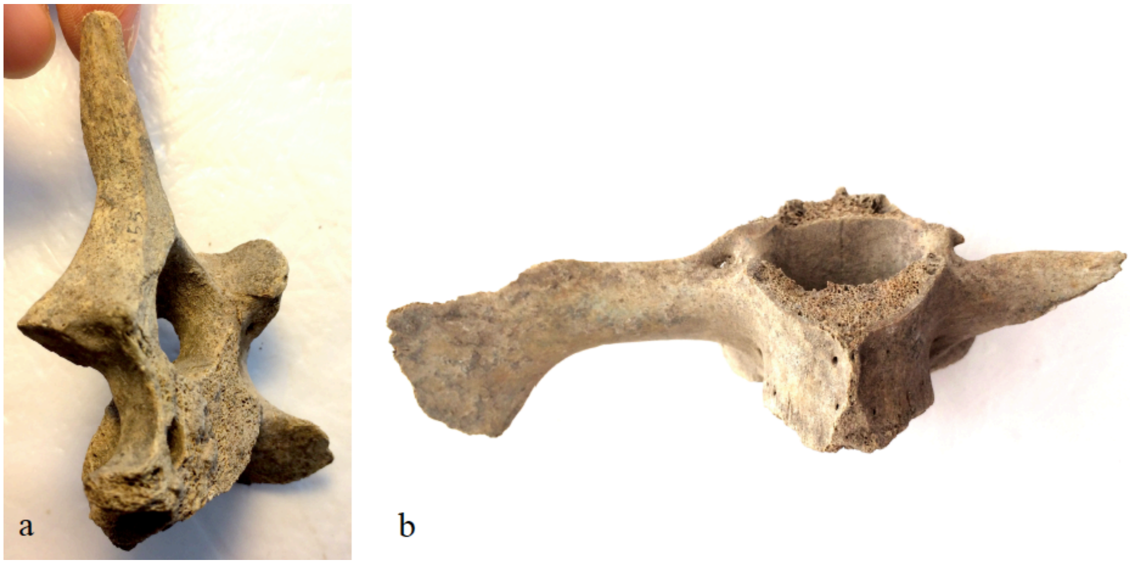
a. 03AXST2911H573-L4(124): left half of an occipital;
b. 04AXST3107H493-L2(87): right half of a frontal-parietal-occipital fragment;
c. 03AXST2911H573-L4(240): left half of a frontal-lacrimal-zygomatic fragment.

Figure XI–10 Xiaomintun: examples of pig's cranial fragments



a. 03AXST2306H252-L3(129): a lumbar vertebra, with both the transverse processes and the spinous process sheared off;
b. 03AXST2306H252-L3(141): a thoracic vertebra, with both the transverse processes and a portion of the spinous process sheared off;
c. 03AXST2003H226-L1(15): an axis fragment, with a sheared fracture surface;
d. 03AXST2306H252-L2(53): a cervical vertebra, with chop marks and a sheared fracture surface;
e. 03AXST2003H226-L1(16): right half of an atlas, with a chop mark and a sheared fracture surface.

Figure XI–11 Xiaomintun: examples of cattle's vertebral fragments



a. 03AXST2410H413-L7(55): a cervical vertebra;
b. 03AXST2410H413-L7(47): a lumbar vertebra

Figure XI–12 Xiaomintun: examples of pig's vertebral fragments

03AXST2413H496-L7(21): a rib fragment (flat blade)
Note: red arrowed point to chop marks and anthropogenic fracture surface.

Figure XI–13 Xiaomintun: an example of cattle's rib fragment

03AXST2410H413-L7(20): distal half of a scapula, with a straight fracture outline.

Figure XI–14 Xiaomintun: an example of pig's scapula fragment

a. 03AXST2911H573-L4(136): medial view of an ilium;
b. 03AXST2306H252-L3(232): lateral view of an acetabulum fragment (connected to the ilium);
c. 04AXST2911H687(7): medial view of an acetabulum fragment (connected to the ischium);
d. 03AXST2306H252-L3(84): lateral view of an ilium shaft fragment.
Note: red arrows point to the sheared fracture outlines.

Figure XI–15 Xiaomintun: examples of cattle's pelvis fragments

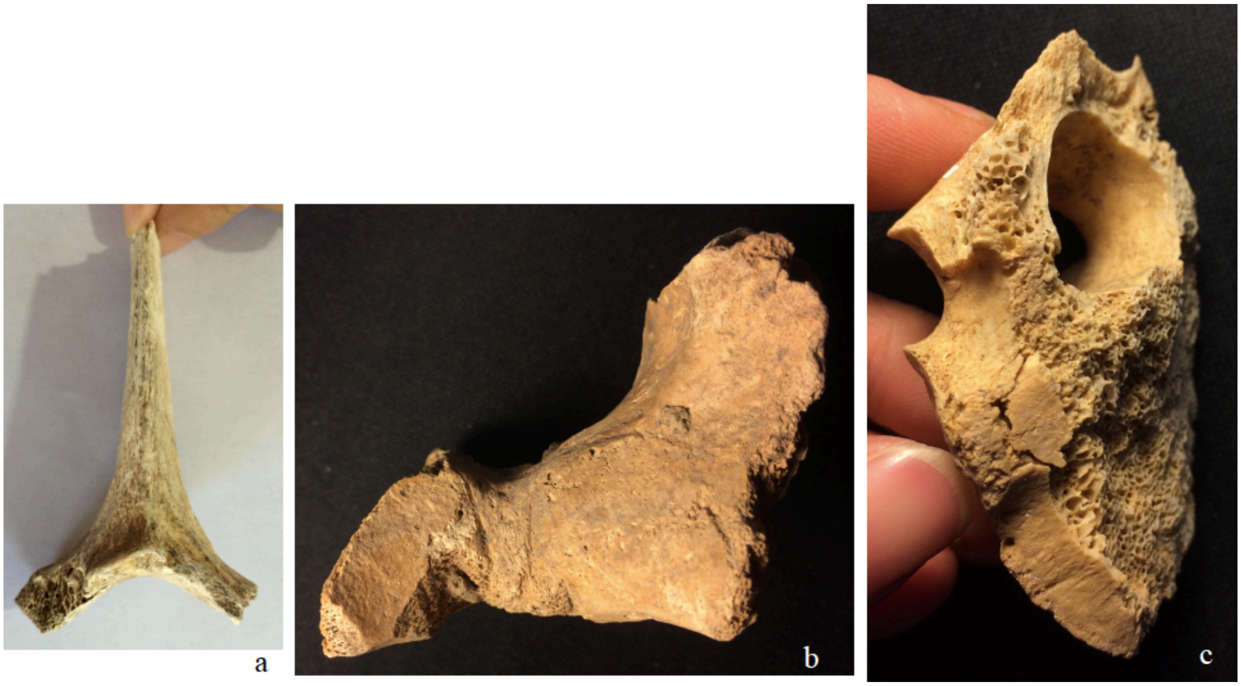
a. 03AXST2003H226-L6(165): lateral view of an acetabulum;
b. 03AXST2003H226-L6(170): medial view of an ilium, with a straight fracture outline (red arrow).

Figure XI–16 Xiaomintun: examples of pig's pelvis fragments

3. Zhougongmiao


06QFIIIA2H37-2(38-13)
a back view of a metacarpal (including a portion of the end-shaft)

Figure XI–17 Zhougongmiao: an example of cattle metacarpal



a. 09QZH6-6(17): spinous process of a thoracic vertebra
b. 04QZT9-6(16): ventral-lateral portion of an atlas
c. 06QFIIIA2H25-19(1): cranial portion of a thoracic vertebra

Figure XI–18 Zhougongmiao: examples of cattle vertebrae

09QZH6-1(21)

Figure XI–19 Zhougongmiao: an example of a cattle rib with flat shear edges

a. 06QFIIIA2H25-28(40): a whole acetabulum
b. 06QFIIIA2H107-2(45-1): a portion of the shaft, with sheared surfaces
c. 09QZH6-6(102): a portion of an acetabulum

Figure XI–20 Zhougongmiao: examples of cattle pelves

APPENDIX XII: A Comparison of Dimensions of Pig and Cattle Bone Fragments

In order to document the degree of cattle bone fragmentation in terms of the dimension of bone fragments in the Guandimiao, Xiaomintun and Zhougongmiao assemblages, I have made several measures, drawn several box plots, and performed Kruskal-Wallis tests.

Several measurements, especially means and medians, are simple and intuitive, suggesting cattle bone fragments from Zhougongmiao in general are smaller than those from Guandimiao and Xiaomintun.

Table XII–1 Measures of cattle bone dimensions (mm)

Limbs[1]	**N**	**Mean**	**SD**	**Median**	**Maximum**	**Minimum**
GDM	96	**138.67**	39.628	**140**	245	40
XMT	54	**129.35**	38.913	**130**	265	70
ZGM	48	**116.31**	38.725	**108.5**	185	30
vertebrae						
GDM	61	**89.18**	34.043	**90**	175	30
XMT	123	**89.76**	22.008	**85**	175	55
ZGM	59	**67.42**	26.326	**65**	144	20
pelvis						
GDM	17	**114.53**	75.254	**70**	280	55
XMT	42	**131.07**	71.359	**110**	380	50
ZGM	23	**94.78**	32.139	**90**	160	45
ribs						
GDM	52	**117.4**	89.057	**92.5**	450	30
XMT	106	**124.39**	66.18	**105**	460	50
ZGM	59	**98.71**	37.388	**95**	270	40

[1] Limbs includes humerus, femur, radius, and tibia. Metapodials are smaller than the four limb bones and their fragments should be small in general which may bias the whole distribution if included in the calculation. Since it is a measurement of dimensions of bone fragments, wholly preserved long bones[147] were not included.

[147] In my database, there are only whole long bones seen in the Guandimiao assemblage, and there are none in the Zhougongmiao sample, while the preservation of whole elements in Xiaomintun is unclear since some specimens may have been moved out in advance (see Chapter 8 for more information).

The box plots directly present the statistical distribution, especially the concentration of fragment dimensions. Roughly, fragments (whole elements are excluded) from Xiaomintun and Zhougonmgiao are more densely concentrated in a smaller range than those of Guandimiao (also indicated by the standard deviations), which indicates bone fragmentation was more standardized in urban settlements (Xiaomintun and Zhougongmiao) than in Guandimiao. Moreover, there are more large fragments in Guandimiao and Xiaomintun (not to mention some whole limb bone in Guandimiao), while almost all the selected specimens of Zhougongmiao are smaller than 200 mm.

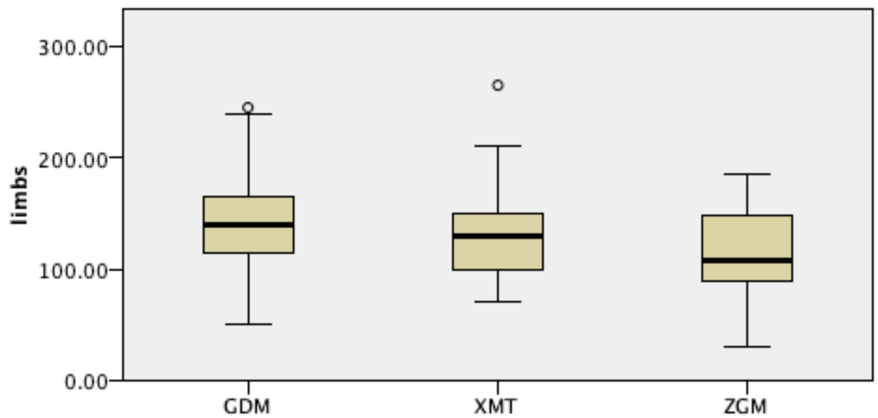


Chart XII–1 Distribution of limb bone fragment dimensions (mm) of cattle (humerus, femur, radius, and tibia)

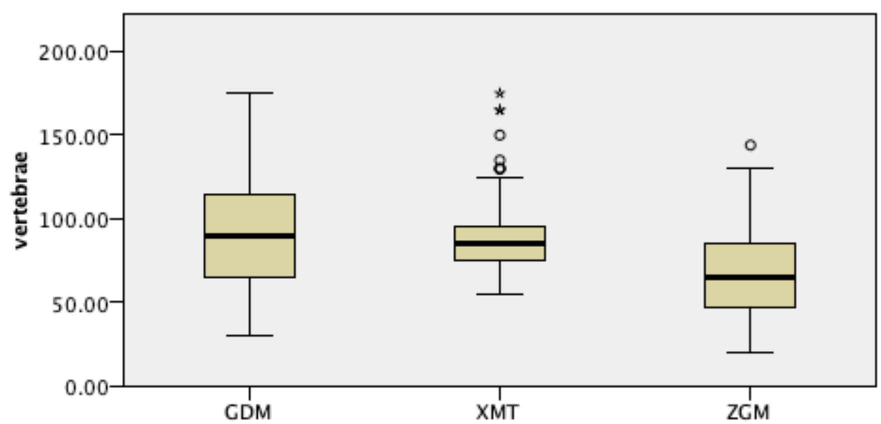


Chart XII–2 Distribution of vertebra fragment dimensions (mm) of cattle (humerus, femur, radius, and tibia)

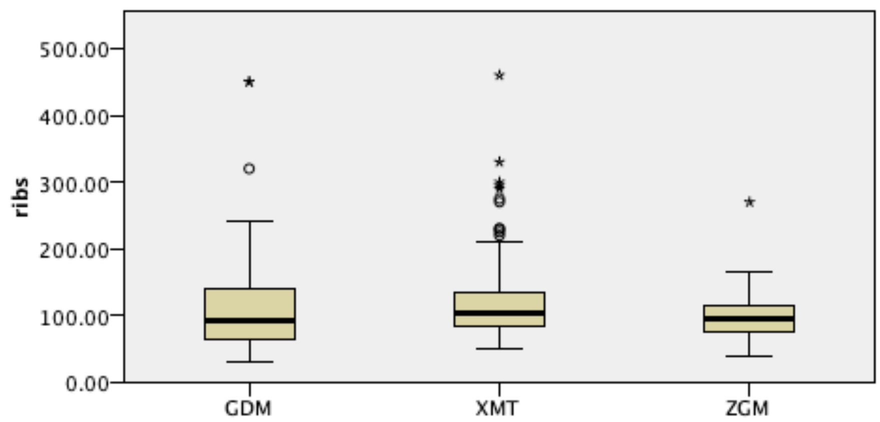


Chart XII–3 Distribution of rib fragment dimensions (mm) of cattle (humerus, femur, radius, and tibia)

To confirm whether the observed variations among the three sites are statistically meaningful, I have tried the Kruskal–Wallis test by ranks, since the dimensions of bone specimens are not in a normal distribution. After the result has proved to be significant, the following pairwise comparisons are made to identify the specific pair(s) with significant variations. Results show that the Zhougongmiao assemblage can indeed be distinguished from the Guandimiao and Xiaomintun assemblages in terms of fragment dimensions, although the comparison between Zhougongmiao and Guandimiao and that between Zhougongmiao and Xiaomintun may not be significant. At the same time, it shows that there is no statistical difference between the Guandimiao and Xiaomintun assemblages in terms of fragment size.

Table XII–2 Results of the Kruskal-Wallis test to dimensions of cattle bones

	Kruskal-Wallis test	Pairwise comparisons
limbs	$p = 0.006 < 0.05$	ZGM-GDM: $p = 0.005 < 0.05$
vertebrae	$p = 0.000 < 0.05$	ZGM-GDM: $p = 0.000 < 0.05$; ZGM-XMT: $p = 0.000 < 0.05$
pelvis	$p = 0.041 < 0.05$	-
ribs	$p = 0.025 < 0.05$	ZGM-XMT: $p = 0.045 < 0.05$

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