A THREE-STAGE MODEL FOR THE DOMESTICATION OF *ORYZA SATIVA* AND THE EMERGENCE OF RICE AGRICULTURE IN CHINA, 12,000 – 7,000 BP

BY

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ABSTRACT

Domesticated rice (*Oryza sativa*), one of five major crops in the world, is the main dietary staple for over 30% of the world's population. However, the understanding of its origins remains poor due to a lack of a multidisciplinary synthesis within a comprehensive theoretical model. Although archaeological and archaeobotanical evidence indicate that rice agriculture appeared earliest in China, there are still debates concerning its center(s) of domestication. The purpose of this study is to offer a new synthesis of available data and a new theoretical model for key issues concerning the origins of rice agriculture: where, when, how and why this process occurred.

The principal methodology of this study has been to apply Western theories to the available archaeological, archaeobotanical, and paleoenvironmental data concerning the domestication of rice and the origins of rice agriculture. Various factors, including population growth, changing environment, and social competition, are considered in elucidating a mechanism for the emergence of this subsistence strategy. A theory of coevolutionary change, specifically one that outlines a three-stage model of incidental-, specialized-, and agricultural domestication, is used to understand the process that resulted in the fully matured practice of rice agriculture.

This dissertation suggests that rice agriculture emerged through a long-term process between 12,000 and 7,000 years ago. It identifies three independent centers for the origins of rice agriculture in China: the Middle Yangzi Valley, the Lower Yangzi Valley, and the Huai Valley. It proposes that: 1) incidental domestication resulting from the harvesting of wild rice had occurred in the first two centers by 12,000 BP; 2) specialized domestication resulting from increasing local population density had emerged in all the three centers by 9,000 BP; and 3) established rice agriculture resulting primarily from increasing social complexity and social competition had emerged in the Middle Yangzi Valley and the Lower Yangzi Valley by 7,000 BP.

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Finally, I want to thank my wife Jun for her endless love and unconditional support of my study, and dedicate this dissertation to my late father who always encouraged me to pursue my dream. I wish he could see my completion of dissertation and graduation from KU.

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<u>**Chapter 1**</u>

Introduction

Domesticated rice (*Oryza sativa*), one of five major grain crops in the world, is the main staple food for over 30% of the world's population, particularly for people living in China and other Asian countries. However, our understanding of the origins of rice domestication and rice agriculture is still poor. There has been less research into the origins of rice than other major cereal crops such as wheat, barley and maize. Although rice agriculture was an important economic basis for many ancient civilizations in Asian countries, both archaeological and archaeobotanic evidence to date indicate that rice domestication first appeared in China and spread to other places (Bellwood 2005). The purpose of this dissertation is to provide a theoretical model for key issues concerning the origins of rice agriculture. As a result, this dissertation focuses on the earliest rice agriculture in China. By introducing evolutionary and post-processual theories to the study of origins of rice agriculture, the proposed theoretical model refreshes our understanding and represents a new perspective on this subject.

1.1 The Importance of Rice Agriculture in Chinese Archaeology

Rice belongs to the genus *Oryza*, which contains two domesticated species: the Asian *O. sativa* and the West African *O. glaberrima*. *O. sativa* has two major subspecies: *indica* and *japonica* (See chapter 3.3 for details). In Chinese archaeology and archaeobotany, *indica* is also called *hsien* and japonica is called *keng*. Rice (Figure 1.1) is

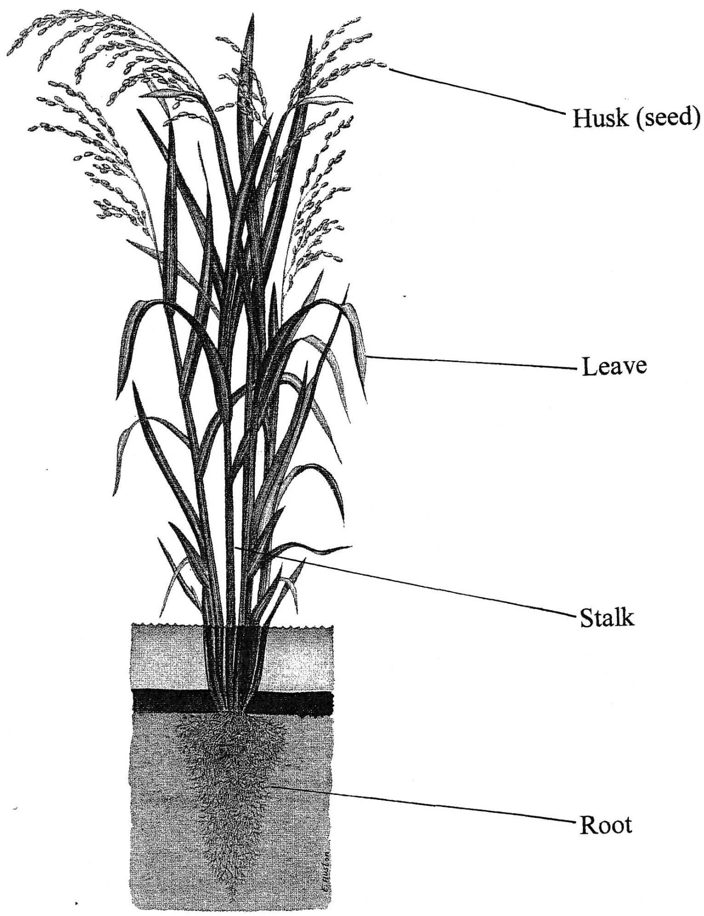


Figure 1.1 Rice (*Oryza sativa*)

an annual grass that shares many characteristics with wheat, barley, oats and rye. It has seed grains at the top of the grass stalk and fibrous roots buried in field. Each seed is covered by a husk (glum) and connected to the stalk by a stem (rachis). Husks are most commonly found in archaeological sites. But in some water-logged conditions, stalks and grains can also be preserved. The size and surface characteristics of the husk are often used to identify whether rice remains are from domesticated plants.

In Chinese archaeology, the origin of rice agriculture is closely related to the invention of pottery and the emergence of civilization (Yan 2002). The oldest pottery and the earliest rice remains have been found in the same archaeological assemblage from the Yuchanyan site in the Yangzi River Valley (Yuan 1996). As will be demonstrated in Chapter 5, the origins of rice agriculture allowed the development of the Neolithic cultures in the Middle and Lower Yangzi Valleys. At 5,000 BP, the interaction of the Neolithic cultures in the Yangzi Valley and those in the Yellow Valley formed the foundation of the first Chinese civilizations: the Three Dynasties (Chang 1986). Therefore, the understanding of origins of rice agriculture is critical to the study of Chinese prehistoric archaeology.

As a student of archaeology interested in the transition from the Paleolithic to the Neolithic, my initial exploration of the origins of rice agriculture was made during my experience as a researcher in Shanghai, a major city in the Yangzi Valley of China. On one hand, I was encouraged by the latest discoveries of early rice remains in the Yangzi Valley, which indicated great promise for the study of the origins of rice agriculture in that region. On the other hand, I was frustrated by the fact that the focus of most of the studies was the center of origins of rice agriculture. There were few studies that attempted to explain the origins of rice agriculture. Explaining this process is equally important to knowing where it originated and it provides a more complete understanding of the subject. It is the increasing database of the earliest rice agricultural remains and the lack of good explanatory theory to understand the subject that led me to study the theories of origins of agriculture from Western archaeology and apply them to the study of origins of rice agriculture.

1.2 Research Significance

This dissertation is the first comprehensive study of the origins of rice agriculture that combines the understanding and application of major theoretical achievements made in the study of the origins of agriculture in Western archaeology with the reconstruction of a detailed and updated context on both paleoenvironment and human cultures. By introducing processual, post-processual and evolutionary models into the study of origins of rice agriculture, this dissertation provides the first theoretical model that gives answers to all key questions of this subject: where, when, how and why did the transition occur? Therefore, the contribution of this study lies in three aspects.

First, it refreshes our understanding of the origins of rice agriculture. By introducing the three coevolutionary processes of domestication (incidental, specialized and agricultural) proposed by Rindos (1984), it provides a clearly defined sequence of the evolution of rice domestication and the associated human cultures. Since incidental domestication (a symbiotic relationship between humans and plants that was controlled by evolutionary selection) only involves human harvesting of wild plants, we can understand why rice remains with very primitive trace of domestication could be found in archaeological assemblages without clear evidence of farming tools. The theory that rice domestication began in three independent centers in China and the general development sequence from specialized domestication (an intensified human-plant relationship in which humans become obligatory agents of plants) to full agriculture (in which plants are completely domesticated and the systems of agricultural production become established) clearly addresses the question of the exact location of the center of the origins. The explanations of the appearance of each of the three coevolutionary processes provide the most plausible answers to the question of why the origins of rice agriculture happened.

Second, it makes the origins of rice agriculture a more accessible subject to the archaeological world community. On the one hand, the environmental and archaeological database of this dissertation gives non-Chinese readers the relevant materials to evaluate the current research level and to make their own exploration of the subject. On the other hand, the study demonstrates the strength and potential of processual, post-processual and evolutionary approaches on the research of agricultural origins. Although traditional approaches such as historic narrative and processual analysis are powerful in recognizing the patterns directly represented by archaeological assemblages, the post-processual approaches pinpoint the direction for us to find those buried far beneath the technological level in every human society and culture.

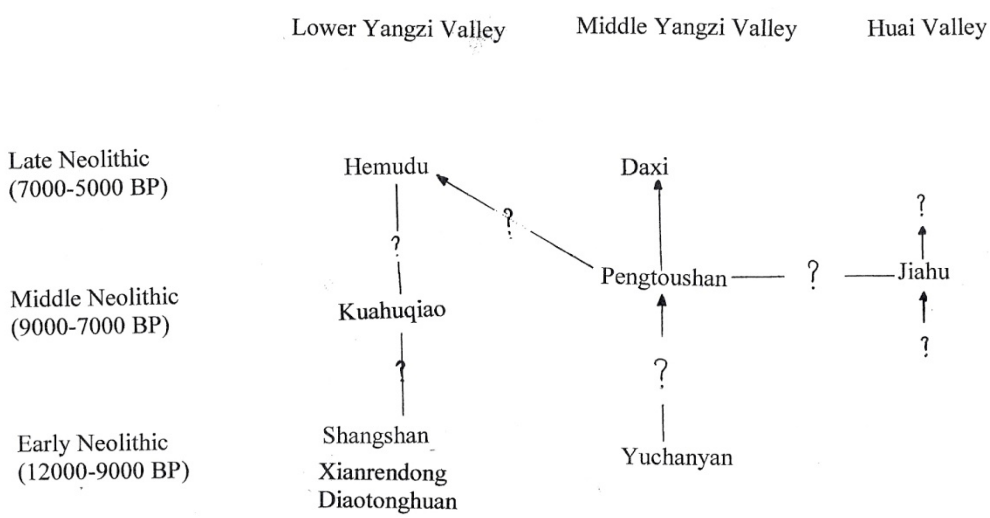


Table 1.1 The Relationships of Sites/Cultures mentioned in Chapter 1

Third, it points out the direction for further research on this subject (Table 1.1). In terms of archaeological fieldwork, three aspects are worthy of particular attention: the lack of knowledge about the cultural precursor of the Pengtoushan Culture and its relationship to the Yuchanyan assemblage; the cultural precursor and successor of the Jiahu assemblage and its relationship to the Pengtoushan Culture; and the cultural precursor of the Hemudu Culture and its relationship with Shangshan, Kuahuqiao sites and the Pengtoushan Culture (Figure 1.2, the details of these assemblages/cultures are in Chapter 5 and the discussions of their relationships are in chapter 7). From the perspective of theoretical exploration, the analyses of population growth during the millennium before the appearance of specialized domestication and the development of cultural complexity during the period of specialized domestication require more evidence and arguments.

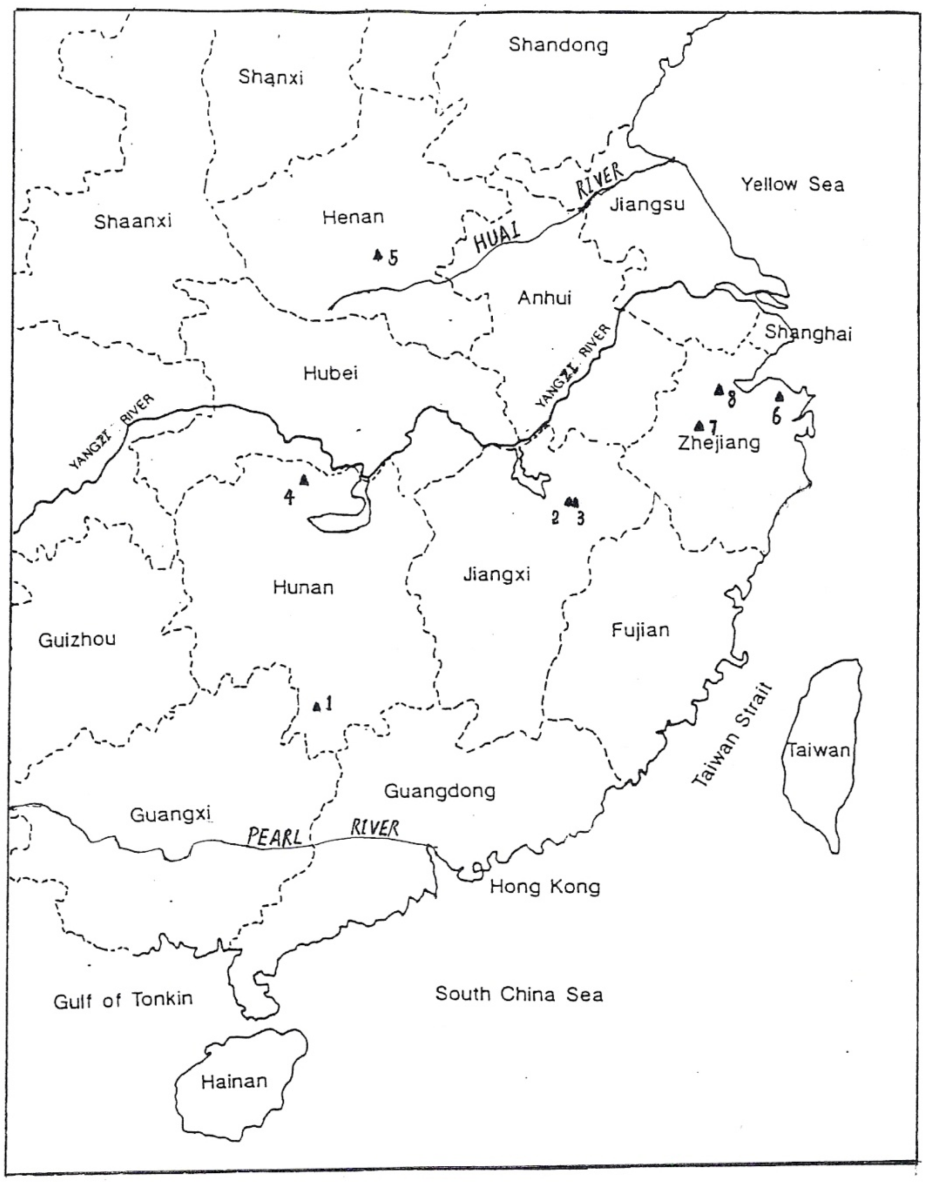


Figure 1.2 Archaeological sites mentioned in Chapter 1

1 Yuchanyan 2 Diaotonghuan 3 Xianrendong 4 Pengtoushan
5 Jiahu 6 Hemudu 7 Shangshan 8 Kuahuqiao

1.3 Research Problem

The earliest literature on the emergence of rice domestication was dominated by the work of botanists and agronomists whose main interest was to define the homeland of domesticated rice. The first such theory was proposed by Vavilov (1926), who considered India the hearth of rice domestication based on the comparison of genetic diversity among current wild progenitor of domesticated rice. Although the genetic diversity principle has been adopted by later botanists, improving methods of measuring genetic diversity shifted their attention to Southeast Asia. Among the famous Southeast Asia hearth theories are Watabe's Assam – Yunnan hearth (1984) and T. T. Chang's Mainland Southeast Asian broad belt hearth theories (1976). Another botanical viewpoint, proposed by Chinese agronomist Ding (1957), favored a South China hearth theory. All these theories were introduced before a series of early rice remains found in the Yangzi Valley of China, and none of them are substantiated by current archaeological evidence.

Evidence pinpoints central China to be the center of the earliest rice domestication, but the specific location is still unknown. The most popular viewpoint is Yan's Middle and Lower Yangzi Valleys hearth theory (1997, 1998), which is based on evidence from archaeology, ancient agricultural history and the distribution of wild rice. Other viewpoints include the Lower Yangzi Valley hearth theory (e.g., Min 1979), the Middle Yangzi Valley hearth theory (e.g., Zhao 1996) and the Huai Valley hearth theory (e.g., Zhang and Wang 1998). Although all the theories are based on the oldest rice remains found in that region, they differ on the status of the rice remains found in the related area and the understanding of cultures associated with the rice remains. Yan believes that rice remains from Yuchanyan, Xianrendong and Diaotonghuan represent the beginning of rice domestication, and Hemudu is an established agricultural society with a local precursor. So the whole Middle and Lower Yangzi Valleys should be viewed as a center of the origins. On the other hand, the Middle Yangzi Valley has a rich and continuous sequence from the earliest domesticated rice to the developed rice agriculture, which strongly supports its hearth claim. The Huai Valley hearth theory is backed by the discovery of the Jiahu rice remains, which are almost as old as the clearly domesticated rice remains in the Middle Yangzi Valley, and represent the appearance of *japonica* rice that is the typical domesticated rice in China. It is notable that the domesticated rice during the Neolithic Period in the Yangzi Valley was mainly *indica* type. Therefore, a thorough analysis of the status of the early rice remains and their associated cultures as well as the relationships of the rice domestication and related cultures in the three debated areas is necessary before we can make an acceptable conclusion on the center(s) of the origins of rice domestication and rice agriculture.

Compared to the research on the hearth of rice domestication, the study on the reason of the origins has a very short history. Within the past decade or so, as the Yangzi hearth theory has gained popularity, scholars have begun exploring the impetus of the origins of rice agriculture. Most of the theories focus on a demographic or environmental explanation. Yan (1997, 1998) considered the Yangzi Valley as the marginal zone of the growth of rice and the strong regional seasonality affected the availability of natural food resources. As population increased at the end of the Pleistocene led to food crisis, people in the Yangzi Valley had to utilize wild rice, develop the mutual dependence between human and rice, and gradually domesticate rice. On the other hand, Higham (1995), Zhao (1996) and Yashuda (2002) all favor an environmental explanation. Both Higham and Zhao see environmental deterioration as the trigger of the emergence of rice domestication, but they differ on the exact environmental event related to the origins: Higham considers the importance of the Younger Dryas episode, where as Zhao prefers a short deterioration period after 9,000 BP. Yashuda, on the contrary, argues a scenario of the post – Late Glacial Maximum (LGM) environmental amelioration that encouraged the utilization and later domestication of rice. As will be demonstrated in Chapter 3, all of these viewpoints are based on a relatively coarse reconstruction of paleoenvironmental changes and are not well connected to the archaeological evidence. An in-depth analysis of both environmental data and archaeological evidence relate to the origins of rice agriculture is necessary before we can make a sound argument on the mechanism of the origins.

To date, the understanding of the origins of rice agriculture is relatively poor: there are still no convincing arguments on the center(s) and the explanation of the origins of rice agriculture and the related time and process of the origins are largely unanswered. This situation is not compatible with the increasing body of archaeological discoveries of early rice domestication and agriculture in China and could affect further research of the subject in both field excavations and theoretical exploration. It is important to build a theoretical model that can offer supported hypotheses to those key questions of the origins of rice agriculture. The model should be the most plausible and well argued on the basis of current theories and evidence, and should be testable and amendable by others and by future discoveries.

1.4 Research Methodology

Although the increasing body of evidence related to the earliest rice agricultural remains found in China show great potential for aiding explanations of the origins of rice agriculture, there are still no satisfactory answers to the key questions of the subject: where, when, how and why did it originate? One of the main problems is the lack of a multidisciplinary synthesis within a comprehensive theoretical framework. The methodology of this dissertation is to apply Western archaeological theories of origins of agriculture to the analysis of the earliest evidence of rice domestication and agriculture.

To conduct a comprehensive study of the origins of rice agriculture, this dissertation will analyze all available evidence related to this subject. The data for this analysis are based on published materials of archaeological cultures and environmental background. Although the existing evidence of the earliest rice agriculture is relatively abundant in terms of the number of sites and the materials from each site, there is still no systematic study to organize these scattered discoveries into a well-defined framework, which is necessary for a comprehensive analysis. This problem has often resulted in the emphasis on individual discoveries of early rice remains in many studies, which partially led to the debate of the center of origins of rice agriculture.

Although the data used in analysis here comes from existing publications, the comprehensive framework of archaeological and environmental settings (in Chapters 4 and 5) reflects some of the original contributions of this dissertation to the study of origins of rice agriculture. This is the first database that includes all existing materials related to the origins of rice agriculture. Although many sites have been found with early rice remains, the reports of the discoveries are often problematic for further research. For example, the publication is often very simple and incomplete, and is issued locally and unavailable to general readers. In some cases, it is necessary to collate different publications from an individual site to find required and reliable information. Secondly, the database organizes information of each site by following the same sequence, so the information from these sites is well-defined and comparable. Thirdly, most of the discoveries were only reported in Chinese. This database makes many important discoveries of the earliest rice agriculture accessible to English readers.

Despite the strengths of the database, it also contains some deficiencies related to the limitations of the published data. The most common problem is the incomplete information provided in some reports. Absolute dating is missing in some reports, because stratigraphy and seriation are still used by many Chinese researchers to build the chronology of sites. Many brief reports lack detailed descriptions, statistics and illustrations of the artifacts. Two approaches are adopted in this study to overcome the inherited deficiencies of the published data. First of all, whenever available, I use multiple sources. In doing so, I can verify the reliability of the data and obtain more information. In addition, I visited some important collections and sites considered in this study during my field trips in the summer of 2004 and 2005. My attention was focused on the key assemblages of the earliest rice agriculture: the Yuchanyan, Pengtoushan and Bashidang sites of the Middle Yangzi Valley, the Hemudu, Luojiajiao, Xianrendong and Diaotonghuan sites of the Lower Yangzi Valley. For most of the assemblages, I examined both stratigraphy and museum collections and verified the published data as well as gaining a first-hand understanding of the site. In very few sites, like Yuchanyan, where excavation was on going, I was provided some unpublished information from the site, which completed the published data. These two approaches make the database for this study more reliable and informative than just using published data alone.

In the database, the absolute dating is presented in two forms: BP and bp. BP represents calibrated absolute dates before present; bp refers to uncalibrated radiocarbon dates and other absolute dates based on stratigraphy, seriation or other means. The available radiocarbon dates of archaeological remains of the earliest rice agriculture are presented chronologically in a table in Appendix I. Those obtained by AMS dating method are marked as such in the table. The calibration completed for this work was done using the program CALIB 3.0 (Stuiver and Reimer 1993) with a half-life of 5568. Calibrations are rounded to the nearest 10 years. In the description of the database, the dated assemblage is given a chronological range based on the available dates.

One final note about the database concerns the English translation of the names of the assemblages. All Chinese names in this database are translated according to modern Chinese *pinyin* (pronunciation) system. A glossary of Chinese names is included in Appendix I. Since the current English translation of Chinese characters is different from the system used in the past (e.g. Chang 1986). This difference in Chinese names is also noted in the chart (Appendix II).

The analytical methodology of the database is comprehensive and comparative. The analysis is conducted at two levels. The first level concerns the technological development associated with the transition to rice domestication. The methodology includes lithic, pottery and settlement analysis, and the evolution of rice morphology. The second level is about the economic and social development of the early rice agricultural cultures. The analysis is based on the technological development of the related cultures. The purpose of the two-level analysis is to build a basis for the construction a theoretical model to understand the origins of rice agriculture. In the analysis, studies of the origins of agriculture in the Near East are used as references because they represent the most in depth studies of the origins of agriculture and have been used as an archaeological basis for many predominant theories in Western archaeology.

1.5 Research Goal

Although the fundamental purpose of this study is to propose a theoretical model to understand the origins of rice agriculture, the research goal consists of two parts: the preliminary goal is to reconstruct the environmental and cultural development during the period related to the origins of rice agriculture, and the ultimate goal is to build a theoretical model to answer the key questions of the origins by bringing together disparate information in the context of a critical evaluation.

The preliminary goal serves two purposes. First of all, the archaeological evidence of the late Paleolithic and early Neolithic in the Yangzi Valley were mainly found within the past three decades and most of them were very recent discoveries. As a result, the general development framework of cultures during this period has not been well built. This situation seriously impedes the understanding of related cultural evolution including the origins of rice agriculture, and partially contributes to the problems of those current models on the origins. The amount of archaeological and environmental data currently available is sufficient to allow reconstructing of human cultures and their environments. I acknowledge that this reconstruction is tentative due to the restriction of the available data. However, the cultural and environmental settings are critical for us to build the theoretical model of the origins of rice agriculture. Using the two related settings as reference, those individual sites and assemblages can be compared and connected, those explanative factors can be argued and substantiated, and the developmental process from the last hunter–gatherers to the first rice agriculturalists can be outlined and understood. Meanwhile, since the theoretical model is built upon the concrete cultural and environmental background, it can be evaluated and revised according to further examination of the data and further discoveries of relevant evidence.

The other purpose of this goal is to make the related data accessible to a wide range of readers. As I noted, a lot of them are very recent discoveries, and most were published in Chinese. This made them inaccessible to scholars who can not read Chinese. In addition, for readers who are not archaeology experts, it is very useful to have a cultural and environmental reference to help them understand the process and evaluate the theoretical model on the origins of rice agriculture.

The ultimate goal of this study is the application of those long-standing theories of agricultural origins developed in Western archaeology to the study of the transition from the hunter-gatherer societies to the early rice agricultural societies. For various reasons, the theoretical development in Chinese archaeology is far behind that in Western archaeology. The trend of applying Western archaeological theory is reflected in some recent publications (e.g., Xu and Zhang 1999). In fact, some of the theoretical attempts specifically on or related to the origins of rice agriculture were conducted by Chinese students who learned archaeological theories and methods in Western countries (e.g., Zhao 1996, Lu 1998, and Chen 2004). However, there has been no systematic theoretical exploration of origins of rice agriculture in Chinese archaeology. Part of the reason for this is the lack of the understanding concerning major theories of agricultural origins. These theories are used as reference to guide the analysis of environmental and cultural evidence and assist in building the theoretical model. As the model is based on specific theoretical applications and detailed cultural and environmental evidence, it can contribute to the current understanding of the origins of rice agriculture and serve as a data source and the theoretical basis for further exploration of this subject.

1.6 Summary of Chapter Contents

In Chapter 2, I will take a critical look at the major theories of agricultural origins which have been developed in Western archaeology. I try to understand what makes these hypotheses testable or mere suggestions. Finally, a series of factors will be concluded as the reference to guide the analysis of environmental and cultural evidence and assist in building a theoretical model.

In Chapter 3, I will analyze the current research situation of origins of rice agriculture. What are the focuses of the studies on this subject? What achievements these studies have made and what problems are still unresolved? The previous achievements will be the basis of our further research whereas the existing problems will point out the direction our research should take.

In Chapter 4, I use evidence from paleogeology, zooarchaeology, archeobotany, pollen analysis and phytolith analysis to reconstruct a general process of environmental changes from the LGM to the Middle Holocene when the environment became stable. In addition, I analyze the effects the environment had on humans in terms of vegetation, fauna, climate and sea level. All these aspects will be useful in the analysis of environmental influence on individual archaeological sites.

In Chapter 5, I will present the archaeological cultures from the earliest Paleolithic assemblages to the established rice agricultural societies. To facilitate the presentation, I build a tentative chronological framework. The Paleolithic period is divided by the LGM when human cultures became related to the emergence of rice domestication. The Neolithic chronology is based on those proposed by Yan (1998) and Chang (1986), and divided to the Early, Middle, Late and Epi Periods. The presentation in Chapter 5 mainly serves as the database for an in-depth analysis in Chapter 6.

The analysis in Chapter 6 is comparative and focuses on the following aspects: the status of the rice remains, the human subsistence strategies, the technology, the technology, the settlement pattern and the level of social development. This analysis provides arguments and evidence to support the building of theoretical model in the next chapter.

In Chapter 7, I propose a new theoretical model to answer major issues of the origins of rice agriculture. The theoretical references are adopted from those reviewed in Chapter 2, the research basis is the current research achievements on this subject as presented in Chapter 3, the database comes from those in Chapters 4 and 5, and part of the arguments are from Chapter 6.

Chapter 2

The Research History of the Origins of Rice Agriculture

As mentioned in previous chapter, the lack of theoretical model to understand the origins of rice agriculture led me to study the theories of origins of agriculture in Western archaeology and apply them to the database of the earliest rice agricultural remains. My first impression of Western theories of origins of agriculture came from one of very few Chinese articles mentioning the mechanism of origins of rice agriculture (Yan 1998). Yan adopted Binford's (1968) "marginal zone theory" to explain the reason of the origins, but he was reluctant to accept the pure theoretical postulation of Binford's theory. This situation encouraged me to systematically study the relevant theories in Western archaeology and examine their applicability and reliability in Chinese archaeology. In this dissertation study, I recognize the great potential of the application of the Western theories. Because historic narrative and processual theories have been applied to the study of origins of rice agriculture (e.g., Zhao 1996, Lu 1998, Chen 2004) and the results are not satisfactory (see Chapter 3.4 for the critical discussion), I intend to add the post-processual and evolutionary theories to my theoretical analysis of the subject.

Therefore, before I discuss the origins of rice agriculture, it is helpful to review the history of research on origins of agriculture. There are three reasons for this. First, rice agriculture is part of a general study on the origins of agriculture and has been mentioned in many of these studies (e.g., De Candolle 1884, Vavilov 1926, Sauer 1953, Harlan 1971). Second, the development of theories on the origins of agriculture can help us better understand changes in the history of the understanding rice agriculture that will be discussed in the following chapter. Third, a critical review of major theories on the origins of agriculture can help improve a new theoretical construction of origins of rice agriculture.

A literature search of the history of origins of agriculture shows a continuous development of theories during the past 120 years (e.g., De Candolle 1884; Kennett and Winterhalder 2006). In reviewing these theories, seven types of approaches can be identified. The first type of academic attempt to explain the origins of agriculture focused on the issue of where agriculture initially originated and developed the theory of "centers of agricultural origins" (De Candolle 1884, Vavilov 1926, Sauer 1952, Harlan 1971). The second type started using environmental factors to explain the origins of agriculture (Childe 1926, Braidwood 1953, Wright 1977). The third type emphasized demographic factors as the primary mechanism of agricultural origins (Boserup 1965, Smith and Young 1972, Cohen 1977). The fourth type considered an interaction of population growth and climate change as the driving force of agricultural origins (Binford 1968, Flannery 1968, Bar-Yosef and Meadow 1995). The fifth type used various social-economic factors to explain the origins of agriculture (Bender 1978, Hodder 1990, Cauvin 2000, Hayden 1995). The last two types are evolutionary theories: Darwinian evolution (Rindos 1984) and behavioral ecology (Kennett and Winterhalder 2006).

2.1 Theories of Centers of Origins of Agriculture

2.1.1 De Candolle

The earliest academic efforts on the origins of agriculture were made by botanists whose major interests are the locations where various plants were initially cultivated. By utilizing data from a variety of scientific fields, De Candolle (1884) formulated a series of preconditions for the initial cultivation of plants:

1) the plants must be productive and easy to grow.
2) the climate must not be too rigorous.
3) there must be some duration of drought in hot countries.
4) there must be some degree of security and settlement.
5) there must be a pressing necessity arising from insufficient resources from hunting, fishing, or the gathering of wild plants.

Combining evidence from botany, archaeology, paleontology, history and philology, he discussed the origins of 245 cultivated plants. For example, he suggested that wheat (excluding einkorn) was domesticated in Mesoamerica, and barleys in the area bounded by the Red Sea, the Caspian Sea, and the Caucasus. Because the valid archaeological data at the time were not sufficient to support these theories, they are often seen as “more a mental exercise than a practical means” (Smith 1969: 2). Nevertheless, De Candolle’s work encouraged the study of the centers of the origins of agriculture.

2.1.2 Vavilov

Russian botanist Vavilov (1926) is considered the founder of “the centers of the origins of agriculture” theory, mainly because his theory dominated the study of this subject for decades and is still influential. Through systematic collection of wild ancestors of modern cultigens and determination of regularities in their geographical distributions, he identified at least five major independent centers of the origins of cultivated plants: south-western Asia, south-eastern Asia, the Mediterranean, the Sudanic-Abyssinian area, and a New World center focusing on the Mexican-Peruvian region. The identification procedure, as Smith (1969: 2) summarized, includes the following:

1) establishment of areas with the greatest varietal diversity of species;
2) elucidation of the system of varietal diversity of species;
3) delineation of the differential geography of the wild relatives of a cultivated plant;
4) recognition of varietal endemism in a crop species;
5) determination of absence of inter-specific hybridization;
6) location of centers of genetically dominant characteristics;
7) use of archaeological, historical and linguistic data.

Vavilov also predicted that the homelands of cultivated plants and primitive agriculture are to be found in mountainous regions. He argued that the observed concentration of varietal diversity in mountainous regions was not just the result of the variety of environmental conditions; human involvement also played a significant role.

Vavilov's theory of "centers", offered at a time when diffusionism was a predominant theory in archaeology, had a pervasive effect on the study of agricultural origins. From the 1960s on, however, this theory was challenged by some botanists. Helbaek argues that "varietal multiplicity in a species has, fundamentally, no dependence on a very long factor of time" (1960: 102). Zohary (1970) observes that diversity is frequently found in area which combines a wide range of ecological niches with partial isolation and that these do not necessarily include mountainous regions.

2.1.3 Sauer

American cultural geographer Carl Sauer's study of agricultural origins was influenced by Vavilov's theory. Sauer (1952) proposed six necessary conditions to locate the centers of agricultural origins:

1) Agriculture was not invented to solve food shortages. The society concerned must already have a flourishing economic base because people under the pressure of starvation do not have the leisure time to experiment with improving food plants.

2) The “hearths of domestication” must be found in areas of a wide variety of plants and animals. The areas are characterized by both diversified terrain and a variable climate.
3) Agriculture did not emerge in large river valleys, because these areas are subject to flood and require drainage and irrigation.
4) Agriculture should start in wooded lands, for grass sod is too tough for primitive tools.
5) The earliest farmers had already subsisted more on food gathering than on hunting, and acquired special skills that predisposed them to agriculture.
6) These earliest agriculturists were already sedentary, for growing crops cannot be left unattended.

Sauer identified mainland Southeast Asia as the cradle of agriculture in the Old World. Agriculture was diffused to five secondary centers: North China, West India, Ethiopia, West Africa, and Southwest Asia. Sauer’s New World centers are poorly defined. They include the Caribbean area, northern South America, Andean highlands, and middle Central America.

Most of Sauer’s six preconditions are contradicted by the increasing empirical evidence. Marginal societies have been found to have plenty of leisure (Lee 1968). In the southern highlands of Mexico, agriculture originated in non-secondary societies and non-grassland environments (Bender 1975). In addition, Sauer’s hypothesis that mainland southeastern Asia was the single cradle of earliest agriculture in the Old World is no longer borne out. Increasing archaeological and biological evidence suggests that there are at least two primary centers in the Old World, namely, southwestern Asia and China, and southeastern Asia is only a secondary center.

2.1.4 Harlan

American agronomist Jack Harlan was one of the followers of Vavilov's theory. Although he was a very keen student of Vavilov's work, he found in his own fieldwork that the centers of crop origins described by Vavilov were actually centers of diversity and centers of long-standing agricultural activity that may or may not represent centers of crop evolution or domestication (Harlan 1970). Harlan revised the methodology for locating the geographic regions in which specific crops originated. He agued that Vavilov's "differential phyto-geography" method is questionable, because the information from living crops and their spontaneous relatives is far from adequate. He suggested that the evidence from many related fields, such as palynology, paleobotany, ethnography, archaeology, history, etc. could provide useful information. By synthesizing all available evidence from these fields, Harlan (1971) proposed that agriculture started in three comparatively independent regional systems. Each of these had a center of agricultural origin and a noncenter to which agriculture was diffused from the center. The three regional systems he proposed were: 1) a Near East center with a noncenter in Africa, 2) a North Chinese center with a noncenter in Southeast Asia and the South Pacific, and 3) a Mesoamerican center with a South American noncenter. His extensive research in the Near East and Africa allowed him to formulate a sound system that stands the test of time well. However, Harlan's two other systems have been challenged by later studies that indicate the Andes is also a center in the New World, and South China instead of North China is the center in the Far East (MacNeish 1991).

Harlan also conducted microanalysis of the process of plant domestication. Plant domestication, as an evolutionary process, may involve a variety of human activities: gathering, harvesting, storage, planting, sowing, weeding, land clearance, soil tillage, etc. Some suggested that domestication began with gathering (Rindos 1984). Others are more concerned with harvesting (Hillman and Davies 1990). Harlan (1967) conducted an experiment of harvesting grain by himself in south-central Anatolia, where wild wheat grows densely. Harlan demonstrated that a family could have harvested in three weeks sufficient food for a whole year. The food value of this wild grain proved to be superior to most of the grain cultivated today. Using his observation of living farmers, he argued that planting is the key operation in the process of plant domestication. "It is the seeds that escape the harvester that produce the next generation, and if there is any selection pressure at all it would be in favor of such wild-type characters as shattering, intermediate growth with maturation over long period of time, seed dormancy, etc. As soon as man starts to plant what he has harvested, the situation changes drastically" (Harlan 1992: 117). Harlan's research refined the study of agricultural origins in terms of general theory as well as the specific evolutionary process.

2.2 Environmental Changes and Agricultural Origins

2.2.1 Childe

As botanists were interested in the centers of agricultural origins, archaeologists started looking for the explanations of the origins. The first well known theory of such explanation is “Oasis Hypothesis” proposed by V. Gordon Childe (1928). Childe’s study of agricultural origins was influenced by geologists Pumpelly (1908) and Brooks (1926) who hypothesized post-Pleistocene desiccation of climate in the Near East. This, along with Childe’s belief that the Near East was the birthplace of the Neolithic Revolution, led Childe to formulate a set of theories to explain the origins of agriculture.

At the center of the Oasis Hypothesis was the belief that the deterioration of climate adversely affected the area in the Near East where the earliest farming was invented. The retreat of glaciers around 12,000 bp dried up the Near East where had been fertile and well watered before. Many rivers stopped flowing; forests and grasslands were replaced by deserts. As a result, hunters and gatherers who had sparsely occupied these areas would have been forced to take refuge in the few remaining well watered places, such as the Nile, Tigris, and Euphrates valleys, or at oases that had not dried up. The concentration of human, animals and plants in these areas allowed people to observe the behavior and year-round cycles of those that were subsequently domesticated. Eventually, some early agriculturalists started to make channels for water to flow over a wider area and artificially sowed seeds to increase the density and distribution of the harvestable grains. It is possible that these early farmers were still seminomadic: they planted the seeds, went away, and then came back to harvest the grain later in the year.

Childe (1952) considered there was a period of cultivation before domestication. After the hunter-gatherers had become cultivators of grains, it became easier for them to domesticate some of the animals they had been hunting: the stubble of the cultivator's already harvested field provided the animal grazing which was especially rare elsewhere during the dry season. The proximity to the animals allowed the cultivators to study the habits of those animals, chase off predatory animals such as lions and wolves, and occasionally keep young animals as pets and feed them from their supply of stored grain. Gradually, some animals were tamed and they then attracted other herd animals to the settlement. In the end, the relationship between hunter-cultivator and the still-wild herd animals led to the animals no longer being able to survive on their own. The animals in turn benefited humans by fertilizing the harvested field with their manure, supplying milk, wool and meat, and more importantly, providing insurance for the primitive farmers against bad years when their crop yield were inadequate (Childe 1952).

Childe's Oasis Hypothesis was refuted in the 1950s when paleoclimatic data in the Near East suggested no desiccation happened in the region after the end of Pleistocene (Braidwood 1951a, 1951b, Wright 1968). As an environmental determinism model, the oasis hypothesis sees post-Pleistocene desiccation as the prime impetus towards agriculture. Therefore, the theory fell on the same environmental factor on which it stood. Childe's theory suffers from inconsistencies and fallacies. For instance, he believed that agriculture started where the potential plants and animals were available. He suggested the most suitable area is the Asiatic section of Afrasia. But he switched to the Nile Valley in the conclusion because he found the natural and cultural conditions of the Nile Valley are more compatible with his "oases" (Childe 1952). In addition, Childe didn't articulate the reason why animals migrated into oases when facing desiccation. More evidence and explanation are needed to support this claim.

Despite the drawbacks of Childe's Oasis Hypothesis, it is still a landmark in theoretical exploration of the origin of agriculture. It provided the first archaeologically testable model to explain the origin of agriculture. It outlined the cultural development towards agriculture that was based not only on the data of climate and wild species, but also on a careful analysis of archaeological cultures from Mesolithic to Early Neolithic (Childe 1952). As Flannery succinctly points out, Childe is "the man who made order out of archaeological chaos", and "produced a framework of successive revolutions and technological stages that have provided us with food for discussion for more than half a century" (Flannery 1994:109-110). Childe's study provided a theoretical basis for continuous investigation on the origins of agriculture.

2.2.2 Braidwood

Robert Braidwood, of the Oriental Institute of the University of Chicago, led the first multidisciplinary team to test the theories of agricultural origins and establishment of settlement in 1948 (Braidwood 1951a). The major theory tested by Braidwood is Childe's Oasis Hypothesis. Through his excavations of Jarmo site in Iraq, Braidwood found no evidence of desiccation in the Near East. A few C14 dates obtained from the site indicate that the earliest food production had probably not been in lowland oasis and riverine situation, as Childe suggested, but rather in the watered upland region. Therefore, Braidwood rejected the oasis theory and formulated his own theory about the origins of agriculture, known as the "nuclear zone" hypothesis (Braidwood 1960).

The basic idea of the "nuclear zone" hypothesis is that at the end of the last Ice Age, the hilly flanks of the Fertile Crescent, with a favorable environment in terms of rainfall and temperature, and proper plants and animals, provided the culturally prepared (see subsequent discussion for explanation) hunter-gatherers an optimum area to experiment with the cultivation of certain plants and domestication of certain animals which finally led to the origin of agriculture. Based on his interdisciplinary field projects at Jarmo and other sites, Braidwood concluded that there had not been a significant climatic change in the Near East since the end of the Last Ice Age. Therefore, the existing distribution of the appropriate wild plants and animals may provide a clue for the search of places where the domestication of those species started. Considering the available evidence from both natural science and archaeology, Braidwood found the piedmont hills and lower intermountain valleys of the Zagros and Taurus Mountains, the so-called “hilly flanks”, were the optimum area (Braidwood 1960).

After locating the optimum area for the origin of agriculture, Braidwood tried to explain the mechanisms for the transition. Since he did not think the environment was pertinent, Braidwood turned to human culture as the primary factor. Archaeological evidence indicates that by the end of the Upper Paleolithic, technology, subsistence, and settlement style of people in the Near East were all moving toward the beginning of agriculture. Microlithic tools were used to gather wild plants efficiently, and grinding stones enabled the people to utilize abundant wild cereal grains. Hunting techniques were also developed even though the supply of large game was diminishing. The improving technology also allowed the people to utilize a variety of food sources, including small mammals, snails, and aquatic species. This phenomenon is what Flannery (1969) later termed “broad spectrum” subsistence. All of these helped humans become “culturally ready” for the origins of agriculture. This development made it possible for them to become sedentary and live at certain places longer than they had previously. This settling-in process enabled the people to have a closer contact with the plants and animals, which encouraged the development of a mutually beneficial relationship between the people and certain species of wild plants and animals. They harvested wild plants on a regular basis. When the people hunted ungulate herds, they also tried to avoid killing too many females in order to maintain the herd’s ability to reproduce. As the logical outcome of the trend, the people gradually started to sow and cultivate grains of some wild plants. Sometimes they also captured and kept animals. This stage of experimentation with plants and animals is what Braidwood called “incipient agriculture”. He suggested this may eventually develop to a successful agricultural economy (Braidwood 1960).

Braidwood’s major contributions are found in three areas. He demonstrated the inadequacy of environmental determinism in explaining the origins of agriculture. The paleoenvironmental and paleoclimatic data from his interdisciplinary projects in the Near East showed no evidence of long-term, permanent post-Pleistocene desiccation in the region. In addition, he provided archaeological evidence to substantiate the hilly flanks of the Fertile Crescent as the nuclear area for the origin of food production in the Near East. Finally, he presented a testable model of agriculture origins and field methods capable of testing this model as well as others. Multi-disciplinary research such as Braidwood introduced, has become a standard. Whether his colleagues, students, or his critics, a generation of scholars directly benefited from Braidwood’s research. Despite all these merits, the “nuclear zone” hypothesis, as a model to explain the origins of agriculture, has suffered serious drawbacks and thus largely been rejected. The most serious problem of Braidwood’s model is the explanation of the mechanism of the origins. Although all archaeological evidence is consistent with Braidwood’s mode of cultural development toward agriculture, the impetus for this change, merely relying on the unexplained human incentive, is far from acceptable (Binford 1968, Bender 1975).

2.2.3 Wright

Hebert Wright, a geologist of Braidwood's team in the Near East, formulated his own model of agricultural origins (Wright 1968, 1976, 1993). The model, known as "neoclimatic change" (Redman 1978) or "optimization" (Rosen 2007) hypothesis, suggested the amelioration of climate in the Near East during the Terminal Pleistocene and Early Holocene as a major motivating factor of agricultural origins.

Wright (1968, 1976) initially suggested that the climate of the Zagros region became warmer and wetter at the end of the Pleistocene. This change allowed the wild progenitors of potentially domesticable wheat, barley and other plants, which existed in temperate refuges during the Ice Age, t spread rapidly in the region. The migration and the accompanying environmental stresses would have encouraged hybridization of some wild species that were later domesticated. The amelioration of weather also allowed people to move out of caves to live in open areas that were more convenient for collecting plants. It is in the sunlit trash areas of the open settlement that some discarded seeds sprouted. Open settlements also allowed hunters to keep animals as pets that were potential food sources when game animals were scarce. These favorable conditions finally led to the appearance of agriculture (Wright 1976).

Wright (1993) later revised his theory according to new climatic evidence. New evidence suggested that during the terminal Pleistocene and Early Holocene, the retreat of ice sheet caused a moister winter and a warmer but drier summer in the Near East. The markedly warm and dry weather created a strong seasonality that is typical in the Mediterranean. Ecologically, the phase of marked seasonality and human impact on the landscape led to the increase of the ecotonal zone and the spread of grassland environment in which cereals increased naturally. This marked seasonality provided the incentive to the origins of agriculture.

Wright's paleocliamtic studies supply evidence to reject Childe's claim of post Pleistocece climatic deterioration. Wright's theory provides an ecological explanation of agricultural origins in the Near East at the end of Pleistocene, but it did not give cultural reasons of the origins. The sole dependence on climatic data makes Wright's theory vulnerable as new climatic evidence emerges. Even today the nature of climatic change and its ecological effects are being discovered (Rosen 2007).

2.3 Demographic Factors and Agricultural Origins

Demographic factors were introduced into the study of agricultural origins by Danish economist Esther Boserup (1965). She argued that when population density is low enough to allow it, land tends to be used intermittently, with heavy reliance on fire to clear fields and fallowing to restore fertility. It is the pressure of growing populations that motivated farmers to develop new techniques for increasing agricultural productivity. The changes in agricultural technology and land use increased the production of food, but the potential energy of the extra food produced does not increase in proportion to the extra energy required for the production of that food. This suggests that the changes in food-gathering techniques and agricultural systems were not voluntary decisions to produce more food than was necessary to meet the need of the family or community, rather, resulted from the pressure of a growing population on the food supply. These changes often induce agricultural innovation but increase marginal labor cost to the farmer as well: the higher the rural population density, the more hours the farmer must work for the same amount of produce. Therefore workloads tend to rise while efficiency drops. This process of raising production at the cost of more work at lower efficiency is what Boserup termed as "agricultural intensification". Although Boserup did not directly apply her theory to the study of agricultural origins, the elements this population growth model have been adopted by researchers in formulating their hypotheses regarding the origins of agriculture (e. g., Smith and Young 1972, Cohen 1977).

2.3.1 Smith and Young

Smith and Young's (1972) hypothesis of agricultural origins was based on the archaeological and environmental evidence in the Near East. During the Late Pleistocene, the climatic amelioration in the Near East led to the growth of population to a point at which further intensification of food supply was necessary. Since the major method of food procurement – hunting – was no longer sufficient, people increased their reliance on plant resources. This allowed the population to continue to grow. In the meantime, people became more sedentary and the population grew rapidly. Infant mortality rates decreased with increased sedentism and more children and elderly survived. As the population increased even more food was required. One way to deal with this was to plant wild cereals to artificially increase the distribution and density of a grain that was already a staple food. The first step towards agriculture happened in or near areas where the plants grew naturally. With successful experimentation and the increase of food supply, population kept growing. Continuing population growth led to a further series of technological innovations to increase the productivity of agriculture, which in turn stimulated population growth. Although an intriguing theory of the subject at that time, this idea of Smith and Young, particularly its estimation of population and the development of subsistence systems, was based on fragmentary archaeological evidence and limited to the Zagros region.

2.3.2 Cohen

Mark Cohen's (1977) theory is probably the best known of population pressure models on the origins of agriculture. Unlike Smith and Young, Cohen tried to formulate a model of agricultural origins that can apply to various regions in the world. He noticed the fact that effective food producing appeared and was adopted almost simultaneously throughout the world between about 10,000 and 2,000 years ago. He argued that worldwide population growth was the primary reason (along with environmental changes and altered sociopolitical conditions) which explained why hunter-gatherers living in different ecological and cultural conditions independently turned to agriculture at the end of the Pleistocene. The premise of Cohen's Boserupian argument is that the adoption of agriculture is not the lifestyle any rationally minded hunter-gatherers would choose freely, for it increased the workload and reduced food diversity and sufficiency, and therefore lowered the quality of life.

As the human population at the end of the Pleistocene exceeded environmental carrying capacity, food shortages forced them to make a technological and economic adjustment, which ultimately led to the origins of agriculture. Despite the increased workload required in the new economy, its advantages were so significant that most of the world had been transformed from one dominated by hunter-gatherers to one where agriculture was the economic base within a relatively short period of time.

Cohen's suggestion of overpopulation has been criticized extensively. Many scholars have pointed out that archaeological evidence does not support his theory that the human population had saturated all attainable environments at the end of the Pleistocene (Bronson 1977, Rindos 1984). Even in some primary centers of agricultural origins, the localized populations were relatively small (Piperno and Pearsall 1998). In addition, some scholars questioned the ability to measure population levels or the carrying capacity of certain environments in prehistory (Glassow 1978, Henry 1989).

2.3.3 Binford

As the demographic factor emerged as a popular explanation of agricultural origins, a different view of the role of population pressure in the transition was proposed by Lewis Binford (1968). The theory, known as "marginal zone hypothesis", combines population pressure and disequilibrium relative to the carrying capacity of the natural environment to explain the origins of agriculture. Although this theory appeared as a direct rejection of Braidwood's "nuclear zone hypothesis", its basic premise can be traced to the work of Leslie White. As a student of White's, Binford adopted White's new theory of cultural evolution and his study of archaeological theory was strongly influenced by it. White suggested that agriculture is not a "sudden idea" but a "new kind of relationship between man – or probably women – and plants" which "began when the old equilibrium of hunting and gathering was upset, and a new type of adjustment, a new kind of relationship to local flora, became requisite to survival" (White 1959: 284). Although White considers environmental factors caused the change, it is the result of the changing relationship between man and habitat – overpopulation and migration of people – that led to the origin of agriculture: "This migration increased the population, and consequently the pressure upon food supply, in areas which the migrants settled. The increased pressure upon food supply upset the equilibrium between need and supply, initiating attempts to control food supply through the use of new techniques – as well as, perhaps, the refinement or extension of old ones – to control the growth and reproduction of plants. This is agriculture" (White 1959: 286).

Based on the analysis of archaeological data in the Near East, Binford argues that the transition to agriculture is a response to cyclical demographic pressure on the margins of the optimal environmental zone for wild progenitors of domestic plants and animals. On the basis of ethnographic evidence, Binford rejects the earlier concept that human beings normally look for methods of increasing their food supply (Braidwood 1960) and regarded Late Pleistocene hunter-gatherers as participating in an equilibrium system. Along with the change of environment, people were able to maintain relatively stable and nutritious food sources while decreasing their seasonal movements. This “broad spectrum” economy enabled them to increase their populations and become semi-sedentary or even sedentary. Binford further infers that human populations in equilibrium systems homeostatically regulate their numbers, keeping them below the carrying capacity of the local food supply. This inference somewhat contradicts what Boserup (1965) suggested. Under this circumstance, why should people adapt to agriculture?

In response to this question, Binford introduced two types of population systems: open vs. closed. These population systems explain the mechanism of cyclical demographic pressure, which, under certain circumstances, leads to the origins of agriculture. In a closed population system, a steady state is maintained by internal mechanisms. The number of births is balanced by the number of people dying. An open population system is one in which size is maintained by the budding off of new groups or by the emigration of individual members: a community from which members migrate is a donor; communities to which they migrate are recipients. Some short distance moves by settlements could happen in regular patterns that were part of a single closed system. However, when part of a group deviated from its pattern and entered a new area, a donor-recipient relationship was created. The relationship tends to happen in the marginal zone: a tension developed between the successful sedentary intensive hunter-gatherers and the more nomadic hunter-gatherers. When colonies from the more sedentary hunter-gatherer group periodically disrupt the density equilibrium balances of the less sedentary one, strong selective pressure would arise to favor the development of more effective means of food production (Binford 1968).

The “marginal zone hypothesis” has the advantage of deductive reasoning: that is it was developed on the basis of archaeological data but is not restricted by the existing data. This hypothesis is important for several reasons. It focused attention on changes in demographic structure, on the equilibrium of local subsistence systems, and on local environmental factors. It proposed that population increased in the optimal zones prior to the origins of agriculture. In this hypothesis the earliest evidence for domesticates is not from the optimal zones, but from the margins of these zones. The material inventories of the earliest domesticators are stylistically similar to those of their neighbors within the optimal zone. A final pertinent aspect of the marginal zone hypothesis is that agriculture originated in a number of places rather than a single center. Since all these predictions can be tested by archaeological and environmental evidence, they provide the directions for further research.

Kent Flannery (1969), by applying Binford’s model in the study of agricultural origins in southwestern Asia, supported and refined the “marginal zone hypothesis”. He defined the intermediate elevations of the Zagros Mountains as an optimal habitat of the wild progenitors of barley, sheep, and goats. The low elevation belt of the mountains, like the Khuzistan piedmont where he conducted excavations, was considered as a marginal area. Starting about 20,000 years ago, the broad spectrum revolution, a procurement strategy that utilizes a broad range of local food resources, caused population growth in the optimal area. This increased sedentism in turn supported further population growth. Once the population growth exceeded the carrying capacity of the optimal area, some people started migrating to the marginal area with their barley, sheep and goats. When people in the marginal zone tried to maintain the richness of the optimal zone, the move towards agriculture became inevitable.

In spite of the merits of the marginal zone hypothesis, it has not yet been substantiated by available evidence. In fact, later archaeological surveys showed that Upper Paleolithic sites in what Flannery considered "marginal zone" had considerably higher density than areas of equivalent size within the "optimal zone" (Henry 1989). This undermined the basis of population expansion as suggested by Binford (1968) and Flannery (1969). Besides, the marginal zone hypothesis lacks details in explaining the process that took place.

Over three decades later, Binford (2001) refined his hypothesis concerning the origins of agriculture in his general theory building of the cultural evolution among prehistoric hunter-gatherers. Binford writes that in spite of the refinement of chronology and settlement patterns, the accumulation of archaeological data has failed to provide a new understanding of the origins of agriculture. Binford further argues that the adaptation to agriculture is a self-organizing process of intensification among hunter-gatherers. "Packing pressure", the increase in population density, is believed to be the ultimate cause of the transition to agriculture although the process and speed of the adaptation are varied with different conditions. He predicts that "indicators of intensification would appear earlier in 'optimal' habitats and later in other, less user-friendly settings", and packing related events "should appear later in settings that are less conducive to high rates of population growth and more quickly in geographic settings such as islands where there are physical constraints on population expansion" (Binford 2001: 439).

Binford's intensification and packing pressure theory provide a more detailed picture about the origins of agriculture in terms of the cause and the process. Compared with his earlier hypothesis, this revised theory is more comprehensive and can be applied to a variety of geographical locations. Since almost all possible factors, including population, environment, disease, and the relationship among them, are considered in the study; the theory is very dynamic and subject to any adjustment if needed. Although the understanding and application of Binford's new theory requires time and more archaeological data, the ongoing research on the origins of agriculture in China on the basis of the theory indicates it is potentially relevant (Chen 2004).

2.4 Post-Processual Perspectives of Agricultural Origins

2.4.1 Bender

Barbara Bender, an anthropologist at the University College London, is the pioneer in introducing social factors into the explanation of the origins of agriculture. She started working on this issue in 1968, the same year Binford (1968) proposed his "Marginal Zone Hypothesis". Her first publication on agriculture origins (Bender

1975) is a synthetic analysis of both data and theories on this issue. By realizing the limitation of the available evidence and the popular hypotheses on the origins of agriculture, she turned to a social perspective for another explanation (Bender 1978).

Before elaborating on her social theory, Bender redefined the term "agriculture". She rejected the assumption that food production equals agriculture and argued that "food production is a question of techniques; agriculture a question of commitment" (Bender 1978: 204). Food production should be considered one of many forms of intensification: some forms led to domestication while others do not. Since the long term consequences of the intensification are unpredictable, the question of "why domestication?" should be rephrased as "why intensification?"

To build a social model for the origins of agriculture, Bender started with the assumption that Late Paleolithic hunter-gatherer societies are similar to their contemporary counterparts, for it is the ethnographic studies of hunter-gatherer societies that provide both empirical and theoretical evidence for her social model. She argues that the possible leaps of human's mental capacity and physical dexterity occurred around 40,000 BP may lead to the development of more varied and more complex human societies. She also suggests that prehistoric social systems were more complex than contemporary ones, because present hunter-gatherer systems are "impoverished versions of earlier systems" (Bender 1978: 211).

Based on ethnographic studies, Bender analyzes hunter-gatherer societies in both the macro scale (the social system) and the micro scale (the individuals within the system), and presents a dynamic development process of the hunter-gatherer societies in which social inequality arises, production increases, and sedentism emerges. The social model of agricultural origins can be summarized as following. During Late Paleolithic, the social structures of human societies become more varied and complex than ever. In general, hunter-gatherers survive via reciprocal exchange and alliance systems, these systems may create demand for increased production. The social competitions within the societies, as indicated by the rise of leaders, generated and channeled the increased production. The production of surplus leads to sedentism, which in turn enhances the increase in production and social inequality. The evolution of the social structure promotes the increase of population and the development of technology. Under this scenario, in areas where potential domesticates are available, intensification may lead to agriculture (Bender 1978).

The pioneering contribution of Bender's social model lies in two aspects. It calls for attention to social factors and provides the basis for later Post-Processual theories on the study of agricultural origins. Following Bender's work, many scholars pay attention to the role of internal factors of hunter-gatherers in the transition to agriculture and have even uncovered a set of archaeological data reflecting the social and cognitive evolution in their own research and by reexamining previous studies. Additionally, Bender's social model provides a sound explanation for the emergence of sedentism. As Bender points out, there are a variety of problems associated with sedentism, it is neither an easy nor a natural choice of hunter-gatherers as they adapt to changing technology and environment. Only when social competition leads to surplus production and delayed return do hunter-gatherers have the incentive and ability to become sedentary. The existence of leadership both permits and promotes this trend, which in turn enhances both increased production and the role of the leader. Following this trajectory, agriculture, which is the commitment to increase food production, emerges in those areas where potential domesticates are available.

Despite the influential contribution of Bender's social model, it suffers some theoretical and empirical drawbacks, which make the model vulnerable. On one hand, the whole theory is based on ethnographic evidence and theories, and has not been well substantiated by archaeological data. On the other hand, Bender's model does not specify the relation between the incentives to increase food production and the economic factors that affect the transition to agriculture. Bender asserts that technology is the product of social structure, but she does not explain how social structure works on the technology, nor does she give any ethnographic evidence to substantiate this point.

2.4.2 Hayden

Brian Hayden, a Canadian archaeologist at Simon Fraser University, is one of the few advocates of social theories of agricultural origins in America. His studies focus on the mechanism of the transition to agriculture. Hayden (1995) rejects any natural pressure factors, such as climate or resources, because all these pressures could occur during the whole Paleolithic period and they didn't result in food production until about 10,000 bp. He also considers that population pressure factor is too problematic to be accepted. Hayden (1990) introduces a competitive feasting model that suggests the competitive and feasting aspects of economic rivalry among complex hunter-gatherers as the driving force behind food production.

Hayden's model is based upon the understanding of two types of hunter-gatherers: generalized vs. complex. According to Hayden (1986), generalized hunter-gatherers are highly mobile and low populated. They depend on scarce and unpredictably fluctuating resources and opportunistic foraging strategies. Their tool kits are generalized, with little inter-assemblage variability. Complex hunter-gatherers, on the contrary, are semi-sedentary, with higher population densities. They adopt specialized foraging strategies (characterized by storing food for lean season of the year and organizing food-procurement parties logistically) and use more abundant and more reliable resources. Their tool kits become specialized to accommodate intensive resource harvesting and storage. The technological distinction between generalized and complex hunter-gatherers is similar to Binford's foragers and collectors system (Binford 1980). The technological development "may have led to a certain degree of complexity", but it "is not known to have led to domestication anywhere" (Hayden 1990:33). To find the driving force for the emergence of domestication, Hayden turns to social aspects of the hunter-gatherer societies.

Hayden (1990) believes that the social characteristics of the two types of hunter-gatherers are conditioned by their technological bases. To accommodate the scarce and fluctuating resources, generalized hunter-gatherers are egalitarian and sharing, because the nature of their resources and technologies would make human competition over those resources destructive of the resources and maladaptive of hunter-gatherers themselves. To specialized hunter-gatherers, however, the conditions of both resources and technologies allow individuals of the society to compete with each other to exploit the resources without overexploiting them. As a result, the rigid egalitarianism and sharing ethic are replaced by the economic competition. This change “is possibly the single most important development in cultural evolution in the last 2 million years” (Hayden 1990:33).

Once the competition occurs in the hunter-gatherer cultures, competing individuals (accumulators) would emerge to accumulate desirable foods, goods and services. They also channel these resources and dispense them as rewards to those who will support them. In doing so, these accumulators are able to maximize their power and influence, because gifts among hunter-gatherers create debts, which make up the power and prestige of these accumulators. The most effective scenario to create debts and distribute desirable commodities, according to ethnographic evidence, is the competitive feast. During the feasts, accumulators try to present highly desirable, rare, valuable, and often labor-intensive foods or delicacies to boast their wealth and power and increase the magnitude of the debts incurred by the guests. Hayden considers the accumulators and competitive feasts as the necessary stage from egalitarian to stratified societies. As the accumulators are motivated to get more people involved in producing more and better goods, social inequality, based on the competitive control of economic resources and services, emerges. The competitive nature of the accumulators inevitably pushes the production of certain most valuable resources to their limits. Under favorable conditions, species with high domestication potential are domesticated and the complex hunter-gatherers become the earliest agriculturalists.

Although Hayden's competitive feasting model is mainly derived from ethnographic studies, he suggests that his model is amenable to testing against archaeological evidence. According to the model, the following expectations can be found in archaeological data. First, domestication should originate in rich environment with abundant resources for hunter-gatherers. Second, the earliest domesticates should be considered as desirable for feasting; the species include intoxicants, delicacies, dietarily deficient types of food, or items conferring prestige. Third, the evidence for the development of status inequalities should be prior to or concomitant with the origins of agriculture. Fourth, under optimal conditions, the evidence for feasting can be reflected in the advent of trade in prestige items or feasting gift-items, feasting debris and structures.

Hayden finds the support of his model in the Near East, the Jomon in Japan, the Archaic Eastern United States, and Mesoamerica where the concurrence of abundant resources, specialized hunter-gatherer technologies and the appearance and proliferation of status goods and distinctions is evident in archaeological records.

Hayden's competitive feasting model is the development of Bender's social theory of the origins of agriculture. It continues Bender's social perspective, suggesting that social factors, such as status inequality and economic competition, are the incentive for surplus food production, which leads to the emergence of domestication and agriculture. Hayden combines ethnographic studies with archaeological data in building and substantiating the feasting model. This makes the model amenable to empirical testing and applicable to archaeological research. Despite Hayden's effort to make the competitive feasting model archaeologically applicable and plausible, the fundamental issue of this model – the evidence of accumulators and the social implication of competitive feasts – is still largely unsubstantiated by archaeological data.

2.4.3 Cauvin

Admittedly, the social theories, including Bender's and Hayden's, present in a large scale the social evolution of hunter-gatherer societies, which is consistent with the development of archaeological cultures. When it comes to the specific incentive for the origins of agriculture, the social theories only draw support from ethnographic studies or make unsupported claims. The biggest challenge of social theories on the origins of agriculture has been how to identify human's internal incentive to adopt the new strategy of subsistence archaeologically. On this issue, French archaeologist Jacques Cauvin's study in the Near East provides an answer.

Cauvin has worked on the origins of the Neolithic in the Near East for over twenty years. He has excavated sites important to the origins of agriculture and developed new theories on the transition from hunter-gatherers to farming society in the Near East. His studies enhance our understanding of the cultural, social and economic changes involved in this significant transition in the world. On the origins of agriculture, Cauvin (2000) challenged the ecological and materialist theories and argued for a cultural origin of agriculture: agricultural origins are driven by the transformation of the mind of hunter-gatherers that is reflected in archaeology as a symbolic revolution. Cauvin's interpretation of the origins of agriculture in the Near East is based on his understanding of the archaeological cultures during the transitional process from hunter-gatherers to farming societies. In analyzing these cultures, Cauvin found that in addition to the development of technology, there is an ideological evolution represented by the symbolic revolution among these cultures. After examining all major factors that might cause the transition to farming, Cauvin believed that human's cultural readiness and ideological willingness, driven by the transformation of their mind, caused this change.

Cauvin's (2000) hypothesis of the cultural origin of agriculture is based on evidence from his excavations in the Near East, cognitive archaeology, ethnography and cultural anthropology. He first outlined the developmental process of human technology and symbolic art between 14,500 and 11,000 bp. Human societies became sedentary in the Levant since the Natufian period. A cultural and social blossoming occurred among the Sultanian, the Aswadian and the Mureybetian in the "Levantian corridor" where the first farming economy emerged. A revolution of symbols, as represented by art works such as figurines, happened during the Khiamian period, which is right before the dawn of the first farming economy. By analyzing and rejecting all external factors that might cause the origins of agriculture, Cauvin introduces his cultural origin of agriculture. The Mother-Goddess and the Bull-God, two most dominant religious and symbolic figures in the Near East throughout the

Neolithic and Bronze Age, emerged during the symbolic revolution. The appearance of the divinities led to human's mental disequilibrium of the nature and themselves for the first time in the cognitive level. The transformation of the mind drove humans to change the world and themselves in order to regain the equilibrium which in their mind is crucial to human's survival. Therefore, Cauvin suggests that agriculture was the first event in the process of cultural evolution that was driven by human's desire to maintain their mental harmony between the natural world and themselves.

Cauvin's theory of cultural origin of agriculture is original and intriguing. It reminds us that the goal of archaeology is to reconstruct human history as whole, not only its economic and social practices. However, he did not make a solid connection between the symbolic revolution and the economic and social revolution, including agricultural origins. According to Cauvin's argument, it is clear that the change of human's mentality and their social-economy both happened around the Khiamian period. Although Cauvin rejected other factors that might cause agricultural origins, the causal logic between the symbolic revolution and the agricultural origins is not clear. More examples of the coexistence of the two changes would be helpful. But, unfortunately, as Cauvin acknowledged, the evidence from both archaeology and ethnography are rare. Because of this, Cauvin himself says this hypothesis "only deserves the value of a simple 'model' (Cauvin 2000: 69).

2.4.4 Hodder

Ian Hodder, a British archaeologist now teaching at Stanford University, has been considered the most influential post-processual archaeologist. His post-processual theory on the origins of agriculture is described in his book – *The Domestication of Europe* (1990). He adopted social theories of the agricultural origins from other scholars, and developed a symbolic structure theory to systematically explain the mechanism and process of the origins of agriculture. Hodder tends to see the development process of prehistory as a long-term duration of structures. He notices that a real, objective structure is often separated from a symbolic, subjective structure in many theories on social changes. He argues that "the very fabric of society, the relations of production, the dominance hierarchy, the systems of exchange can all be conceived as networks of symbols/powers" (Hodder 1990: 281).

Hodder (1992) considers the origins of agriculture as a dual transformation of both economic and symbolic. On the one hand, social competitions among hunter-gatherers caused sedentism and intensification of production. As people were caught in a delayed return system that ensured them benefits of social dominance, better goods and prestige but constrained them in social structure, they finally were led to a more intensive production – agriculture. On the other hand, as people became sedentary, the tendency of symbolic structure to maintain social prestige, shifts the locus to the house where a conflict of the symbols between the wild and the "domus" was created. To maintain security and stability, people had to tame the wild and as such, accept the social constraint and become "domesticated". "The long-term symbolic and economic structures were manipulated within social competition for within- and between- group control and domination, production, exchange, feasting, and settlement formation. A particular conjunction between the structured process and climatic and environmental events at the end of the Pleistocene produce the origins of agriculture." (Hodder 1990: 293)

Hodder's theory of agricultural origins is the best representation of post-processual archaeology on this critical issue in the evolution of human prehistory. By analyzing a variety of symbols in human societies, Hodder looks into the rationality of human societies involved in this great revolution and gives social meaning to this seemingly economic change. He incorporates all the social elements into a long-term symbolic/conceptual structure which, as he argues, reflects the interrelationship between events in real world, such as technological and economical changes, and the symbolic network that constitute power and prestige throughout human history. In Hodder's theory, we can find the basic social elements suggested by Bender, Cauvin and even Hayden. In this sense, Hodder's theory represents the culmination of post-processual contribution to the study of agricultural origins. Yet, just like all other post-processual theories on the origins of agriculture, Hodder's theory is still in its experimental stage. More solid archaeological evidence is needed to support a symbolic system during the transition from hunter-gatherers to farming societies. The proposed model should also be tested against archaeological contexts beyond Europe and the Near East before it can be applied as a universal theory.

2.5 Evolutionary Perspectives on Agricultural Origins

There are two different types of evolutionary approaches in archaeology: cultural selectionism (Rindos 1984, O'Brien 1996) and behavioral ecology (Smith and Winterhalder 1992, Kennett and Winterhalder 2007). Both approaches derive from the same theoretical framework – Darwinism, but reach different views of the explanation and description of archaeological records.

2.5.1 Rindos and Coevolutionary Theory

With regard to agricultural origins, cultural selectionists, represented by David Rindos (1984), introduced the concept of "coevolution" that is defined as "an evolutionary process in which the establishment of a symbiotic relationship between organisms, increasing the fitness of all involved, brings about changes in the traits of the organisms" (Rindos 1984: 99). The core of Rindos's theory is strictly Darwinian "natural selection" and the "naturalness" of human-plant relationship. Agriculture is "environmental manipulations within the context of the human coevolutionary relationship with plants" (Rindos 1984:100). There is a distinction between the origins of agriculture and domestication: agricultural origins are about the emergence of certain human behavior; domestication is evolution of the plants used in agricultural systems. According to Rindos (1984), there are three types of domestication in the coevolutionary process towards the origins of agriculture: ***incidental***, ***specialized***, and ***agricultural domestication***.

Incidental Domestication

The first type is *incidental domestication*, which refers to the relationship between a nonagricultural society and some of the plants upon which it depends. This is “the simplest and most common type of domestication relationship” (Rindos 1984: 154). One which does not involve specialized behaviors in which there is consciousness of the desired outcome of the behavior itself. It is instead a process in which evolutionary selection results in a symbiotic relationship between two species and the environment in which they interact. Animals (including humans) incidentally domesticate plants by harvesting the reproductive or vegetative propagules of the plant and dispersing them. The animals act as an opportunistic but not necessary agent for the dispersal of the plant. Rindos emphasizes that this relationship, unlike other types of domestication behavior, exists only within the nonagricultural environment. The amount of niche space for any incidental domesticate is environmentally (not culturally) predetermined. Therefore, neither the size of the plant nor its total yield is directly under human control. However, Rindos acknowledges that human activities may have some indirect effects (i.e., Harlan *et al*. 1976). Nevertheless, this relationship is, in general, independent of the subsistence strategy used by the society. The yield obtainable from the environment places a limit on the carrying capacity and on human population. In addition to the ecological effects, Rindos indicates three evolutionary processes that act on incidental domestication:

1) The spotty spatial distribution of incidental domesticates reduces the speed with which human selection can affect the evolution of the domesticates.
2) The plant is adapted to a nonagricultural environment, and thus many of its adaptive mechanisms may be lost to the specialized.
3) Incidental domesticates are likely involved in coevolutionary interactions with nonhuman agents.

For all these factors, the rate of change caused by incidental domesticates tends to be very low. There are two basic types of incidental domesticates that can be recognized to understand the coevolution of human and plants. The first type refers to wild plants whose distribution is partially determined by human behaviors. The second one includes those cultivated plants whose distribution and dispersal is mostly incidentally determined.

Specialized Domestication

Rindos' second type of domestication is *specialized domestication*. This involves both an intensification of incidental domesticates and new behavior which affect the evolution of domesticates. A very distinctive aspect in this relationship is that humans are no longer the opportunistic but the obligatory agents of plants. This behavioral change is specifically directed towards enhancing the success of the plants. The survival of humans becomes dependent upon domesticates and vice versa. Now the plants depend on humans for most of their dispersal. Within this type of relationship, people not only modify their agricultural environment, but also pay attention to storing and planting behaviors. By means of firing grasslands, disturbing the ground cover, cutting trees, etc., humans modify the local environment and thus increase the size of the potentially agricultural habitat. A significant consequence of these behaviors is that neither humans nor plants are restricted by intrinsic environmental parameters. The extent of environmental modification in specialized domestication is closely related to the degree of sedentism. Although much has been written about planting in this context, storing has not been addressed as thoroughly. Storing, as Rindos points out, helps the dispersal of plants and increases their size, which makes them less bound by temporal constraints. Planting and storing are closely related and often indistinguishable. Planting, according to Rindos, has two different forms. The first one is replacement planting, which invokes maintenance of the plant species in a preexisting niche. It basically does not affect the evolution, but encourages the development of agroecology. In contrast, the second type, agricultural planting, is featured by colonization of the plant into new areas created by human disturbance. It helps initiate the agroecology and the development of agricultural systems. Agroecology, a unique ecological niche created in the process of specialized domestication, makes it unnecessary for humans to affect the plant's evolution directly. Instead, the increasing meditative forces of the agroecology operate on the evolution of the plant.

Agricultural Domestication

Agricultural domestication is the third type in Rindos' taxonomy of domestication. It fits the notion of domestication used in most literature of agricultural origins. The evolution of domesticates becomes the establishment and refinement of the systems of agricultural production and can only take place within the agroecology. It is controlled by strictly agricultural behaviors such as harvesting, storage of selection of seed, weeding, and tillage. All stages of the plant's life cycle are under the control of these human behaviors. The increasingly obligate relationships of the populations of humans and plants created in specialized domestication culminate by being completely obligate in the process of agricultural domestication. One very significant tendency of this process is the development of systems of selection that create intentionally greater productivity.

Rindos' coevolutionary model of agricultural origins is by far the most controversial theory on the subject. The main reason is its notion of naturalness of human-plant relationship analogous to ant-acacia relationship (Rindos 1984). As Flannery (1986) pointed out, it is human selection after the initial cultivation of phenotypic wild plants, rather than natural selection in general, that caused the crucial genetic changes of those precursors of domesticates. In spite of the controversy, this model is useful to specify the means, mechanism and processes of the evolution towards agriculture. As Yarnell suggested, this model is more useful in explaining the evolution of domestication than explaining how agricultural practices originated. The latter, as an anthropological issue, should be addressed from a variety of perspectives (Yarnell 1985).

2.5.2 Behavioral Ecology

The behavioral ecological perspective on the origins of agriculture is represented by "optimal foraging theory" (Winterhalder and Smith 1981, Winterhalder and Goland 1993). It is derived from formal economics, with an emphasis on microeconomics or microecology. From this perspective, humans are seen as rational actors in environments in which they faced the pressure caused by limited resources and the continual needs for their survival. It is assumed that humans have the ability to recognize outcomes and make the best choice under any given conditions, and that they will learn from different foraging strategies and copy or repeat those that are most successful (Smith and Winterhalder 1992, Hawkes and O'Connell 1992). According to this theory, human's subsistence choices can be predicted and are based largely on the relative return rates of available resources in the given environment. Energy (or calories), which is highly correlated with the fitness of humans, is used to measure the rate of subsistence returns per unit time. All conditions being equal, natural selection should have favored more efficient strategies at the expense of less efficient strategies. The justification of this assumption is that the more efficient strategies, with more food and less exposure to risks through short foraging time, allow more time spent on other activities, such as caring for children, and thus increase f the fitness (Kaplan and Hill 1992).

Based on optimal foraging theory, a "diet breadth model" is proposed to specify the process towards agricultural origins (Kaplan and Hill 1992, Hawkes and O'Connell 1992, Winterhalder and Goland 1997). In this model, food resources are ranked by their postencounter profitability (meaning expected net return per unit handling time) that is independent of their own abundance or encounter rate. The four possible categories of plant resources are ranked from high to low: profitable/abundant, profitable/scarce, unprofitable/abundant, and unprofitable/scarce. As this model suggests, the “microecological” perspective of optimal foraging theory can be used to explain how lower ranked plant resources could have been exploited by foragers, initiating the coevolutionary relationships that led to domestication. According to this model, foragers tend to choose food according to the abundance of higher ranked resources. When the abundance of higher ranked resources decreases because of localized depletion, climate or habitat change, human population growth, or for any other reason, foragers will spend more time in procuring lower ranked resources. This results in a broader diet (which includes all exploitable higher ranked and lower ranked resources) for a higher return rate. More time has been saved from searching for food and thus allows greater investments in storage and food processing. These activities extend the use life of vegetative food and increase the nutritional quality of what is eaten. Broader diet and less search time will also reduce foraging range and probably increase residential stability. The long-term result of this process will be massive ecological change: the coevolution of some lower ranked (unprofitable but abundant) plants and humans who exploit them will lead to human population growth, and those plants becoming more profitable, abundant, and eventually domesticated.

In spite of the merits claimed by its proponents (e.g., Winterhalder and Goland 1997, Boone and Smith 1998, Piperno and Pearsall 1998, Kennett and

Winterhalder 2007), evolutionary ecological perspective on agricultural origins suffers a serious deficiency in its argument. The core of evolutionary ecology, the claim that many organisms (including humans) have developed efficient behavioral systems that allow them act optimally and adaptively with no effective role for natural selection in their operation and persistence, is empirically and essentially a teleological causation that features the non-Darwinian cultural evolution paradigm. Rather than substantiating such an empirical claim, evolutionary ecology merely assumes it as axiomatic.

A recent viewpoint on the origins of domestication, proposed by Terrell et al. (2003), suggests that the origins of domestication should be understood from the perspective of human subsistence behavior. I tentatively place this viewpoint under the school of evolutionary theories, mainly because it inherited the basic ideas of both evolutionary theories: the naturalness of domestication and the importance of ecology to human subsistence behavior.

Terrell et al. emphasize the role of domesticated species and related environment (ecology) in the origins of domestication (ibid). They argue that species to be domesticated and their environments conditioned skills and tactics used in the process of domestication (ibid). Instead of looking for evidences that distinguish foragers and farmers, such as domesticated species, domesticating technologies, and related human cultures, Terrell et al. suggest that we should understand the origins of domestication, as a change in human subsistence behavior, in an interactive matrix of species to be domesticated and tactics used to domesticate these species (ibid). A model proposed by Terrell et al. to understand the origins of domestication is based on a provisions spreadsheet which includes variables of different characteristics of species, environment and human behavior (ibid).

Terrell et al.' viewpoint represents a new theoretical exploration of the origins of domestication. Although the basic ideas used to formulate their model come from evolutionary theories, Terrell et al. (2003) recognize the insufficiency in archaeological record to understand important human behavioral changes such as the origins of domestication. Because of the deficiency of archaeological record, it is difficult to understand human behavioral changes merely from the perspective of humans themselves. The study of species and related environment provides a different perspective to understand the origins of domestication. However, as a common problem of all evolutionary theories, the lack of archaeological evidence could impede the application of this viewpoint.

2.6 Toward a Synthetic Approach: a Summary

After the efforts made by generations of scholars, we now have a better understanding of key issues related to the origins of agriculture. These issues include where and when it originated and how and why the transition happened. Before a summary the theories concerning those key issues of agricultural origins, a discussion of the definition of agriculture itself maybe helpful. For a long time, scholars of agricultural origins neglected the difference between domestication and agriculture and sometimes saw them as the same (e.g., Vavilov 1926, Childe 1952, Braidwood 1960, Harlan 1971). In recent decades, however, scholars (e.g., Flannery 1986) called for an examination of these concepts and reached general consensus on the difference between domestication and agriculture (Price and Gebauer 1995).

Following Rindos' (1984) evolutionary perspective, domestication is considered as a biological process in which plants and animals go through genotypic and physical changes and become dependent on human for reproductive success. This process is often unintentional; resulting from continued interaction between humans and the progenitors of domesticates (Price and Gebauer 1995). The concept of agriculture, on the other hand, is influenced by social anthropologists like Bender (1978). It is defined as a commitment to the human-plants/animals relationship. The changes caused by agriculture include not only the human use of the earth, but also the structure and organization of human society: the use of ceramics, the clearing of forests, the cultivation of cereals that can be stored for a long time, the invention of new farming technologies, increased sedentism and population, and finally increased social and political complexity (Price and Gebauer 1995). It is suggested that it might take thousands of years to develop from initial domestication to full agriculture (Bray 1976, Flannery 1986).

By considering these definitions, the origins of agriculture can be viewed as a two-step process: domestication first; then, the transition to agriculture. As the earliest step to understanding the origins of agriculture, the proponents of the centers of agricultural origins (Vavilov 1926, Sauer 1952, Harlan 1971) focused on the issue of where domestication started. Mainly based on biological evidence, the theories of centers of domestication origins have been revised according to later archaeological discoveries (MacNeish 1991). To date, six primary centers have been established to answer the question of where agriculture originated: the Near East, Africa, East Asia, North America, Mesoamerica, and South America. Although it is generally agreed that the transition to agriculture began at the end of the Pleistocene, the exact date of the initial domestication and the establishment of agriculture in each center varies and is subject to the progress of archaeological discoveries and dating methods. Considering the definitions of domestication and agriculture, I use the appearance of species genetically changed to be domesticated to define the beginning of domestication, and use the appearance of basic characteristics of agriculture to define the establishment of agriculture.

Most of the theories on the origins were introduced to explain why and how agriculture originated. The environmental and demographic theories focus on why and how people began domesticating plants and animals. In spite of the differences between the two theoretical schools and among the proponents of each group, these theories all see stress, caused by either environmental changes or population growth, as the impetus to the beginning of domestication. However, the uncertainty of environmental changes and the difficulty of measuring prehistoric population density always constrain our evaluation of these factors in regions where data are limited. The social models of agricultural origins provide clues to understand the appearance of agricultural societies. Under these models, hunter-gatherers were active participants in the transition to agriculture through social competition and symbolic revolution. Although social factors are difficult to be substantiated in archaeology, they should be considered as an important aspect when we explore the origins of agriculture in a specific region. The coevolutionary model, despite the strong criticism of its emphasis of strict natural selection and its rejection of human intention in the transition to agriculture, is useful to deal with how domestication and agriculture originated. The three stages of domestication in this model explain the process from initial domestication to agriculture and can be evaluated in archaeological context.

Through a review of major theories of agricultural origins, I recognize that not one factor can provide satisfactory answers to the key issues of the origins. Indeed, it is acknowledged by increasing numbers of scholars that multiple factors should be considered in our attempt to understand the origins agriculture (e.g, Bar-Yosef and Meadow 1995, Pearsall 1995). Following this trend, when exploring the origins of rice agriculture, I will adopt a synthetic approach that considers all the factors mentioned above. The discoveries of initially domesticated rice will be used to identify the center and the time of initial domestication. Environmental, demographic and social factors will be evaluated according to available data. The three stages of domestication put forth in the coevolutionary model will be tested against the archaeological record.

By using the synthetic approach, this dissertation intends to build a comprehensive model that can answer the ‘where’, ‘when’, ‘how’ and ‘why’ questions of the origins of rice agriculture. The basic ideas of this model benefit from the Western theories summarized in this chapter. The three coevolutionary domestications are critical to the proposed model, because they describe the development process from initial domestication to established agriculture that not only fits current consensus on the origins of agriculture but also can best explain the complicated data of the earliest rice agriculture in China. Environmental and demographic factors are still important to explain why rice agriculture originated. However, as discussed in previous sections and demonstrated in some studies of origins of rice agriculture (e.g., Zhao 1996, Chen 2004), just these two factors can not provide satisfactory answers to the 'why' question. In the development toward established rice agriculture, human cultural evolution was not only represented by technological improvement and population growth but also reflected by increasing social complexity and cognitive capability. For this reason, social factors have to be emphasized to understand why rice agriculture was developed.

As the proposed model adopts the essence of the previously discussed theories, it inevitably inherits their limitations. The common problem of these theories is insufficient archaeological evidence to support the hypotheses. Environmental and demographic theories are often weakened by the uncertainty of relevant data; whereas social models often lack of supportive evidence. To overcome these shortcomings, I intend to build my model on the most complete and updated data and a careful and comprehensive analysis.

<u>**Chapter 3**</u>

A Review of the Studies on the Origins of Rice Agriculture

There are a series of questions that need to be answered in order to understand the origins of rice agriculture: When and where did rice agriculture originate? Was it invented once or independently at several places? Why and how did it start? Did it happen suddenly or take a long period of time? Since the study of origins of rice agriculture has a long history, most of the issues have been discussed although many remain unsatisfactorily answered. This historical review can help us discover the focuses of past studies and inform our current knowledge on the subject. These issues include the hearth of the origins, the evolution and differentiation of domesticated rice and the explanations of the transition. Through the examination of different viewpoints regarding these issues, I will be able to build a solid basis to make further explorations.

3.1 A Brief Research History of the Origins of Rice Agriculture

Like studies on the origins of domestication and agriculture in other regions of the world, the research on origins of rice agriculture has a long history that goes back to the 1920s. In 1921, the impressions of rice husks were found on a potsherd of the Yangshao Culture dated to 5,000 BP at the Yangshao village of Henan Province in

China (Andersson 1934). This discovery might have been the oldest rice remains at that time, but it did not attract the attention of scholars of agricultural origins. The popular viewpoint at that time was that rice was first domesticated in India and then spread to other areas. Although this idea was first proposed by de Candolle (1884), it had become widely accepted after the study of Vavilov (1926), whose work marks the beginning of the research history of origins of rice agriculture.

The study of origins of rice agriculture can be divided into three periods. The first period is from the 1920s to the middle 1970s. Botanists dominated the study of the origins of rice domestication during this period. Their main focus was definition of the hearth of rice domestication based upon the distribution of wild rice and its genetic diversity.

Vavilov's theory of an Indian hearth was followed by many scholars (e.g., Chatterjee 1947, Ramiah and Ghosh 1951). Later, the location of the hearth in India was revised due to the progress on the research of genetic diversity and the investigation of wild rice distribution. Many scholars proposed the area that included northeast India and northwest Southeast Asia as the homeland of rice domestication, although they did not agree on the exact location of the hearth. Some suggested the zone from Assam, India to Yunnan, China (e.g., Nakagahra et al. 1975, Watabe 1977); others pointed to the broad belt extending from the Himalayan foothills to the northern extent of Southeast Asia (Chang 1976) or the area from northeastern India to southeastern China (White 1972). Chinese agronomist Ding held the view that subtropical China is the hearth of rice domestication (1957). Another focus of this period was the *indica-japonica* differentiation. *Indica* and *japonica* are two major sub-species of Asian domesticated rice. The debates were over the differentiation process and place of origins. Some suggested that *japonica* was differentiated from *indica* (Ding 1957, Chang 1976); others suggested that these two sub-species each had their own distinct wild progenitors (Oka 1974).

The second period of debates spans the late 1970s to the early 1990s. This period is characterized by the introduction of the ideas that China, particularly the Yangzi Valley, is the hearth of rice agriculture. In 1978, archaeologists published the discovery of large quantities of 7,000 years old rice remains at the Hemudu site in Zhejiang Province, China (Zhejiang Provincial Museum 1978a). This discovery finally shifted attention to China as a possible hearth for rice domestication, despite the fact that many Neolithic sites in China with rice remains had been known since the 1950s. Chinese scholars, particularly Chinese archaeologists, joined the debates over the homeland of rice domestication. Some scholars still advocated a Yunnan hearth (Liu 1975, Li 1984, You 1985) or the subtropical South China homeland theories (Tong 1984, Li 1985), but most considered the Lower Yangzi Valley as the area where rice domestication originated (Yan 1982, 1989). Another factor in the emergence of a Chinese hearth theory during was the detailed documentation of current distribution of wild rice in China. A national survey of wild rice was conducted in more than 10 provinces from 1978 to 1982 (National Wild Rice Resource Survey Group 1984). The result of this survey indicates that the wild rice in Yunnan Province today may not be the wild progenitor of domesticated rice, raising questions about a hearth in southern China. More importantly, the discovery of wild rice in the southern part of the Yangzi Valley challenged the traditional view that wild rice was restricted to subtropical South China.

The third period is from the middle 1990s to present. The progress of the past decade or so is represented by the establishment of the Middle and Lower Yangzi Valleys hearth theory and the explorations of the reason of origins of rice agriculture. Yan's hypothesis of Lower Yangzi Valley origins has been revised in light of the discovery of more than 10,000 year-old rice remains at the sites of Xianrendong and Diaotonghuan of Jiangxi Province and Yuchanyan of Hunan Province. Yan subsequently suggested a hearth in the area that includes the Middle and Lower Yangzi Valley (Yan 1997). This theory has gradually been accepted by Chinese and Western scholars (e.g., Bellwood 2005). These discoveries and hypotheses also encouraged scholars outside of China to participate in academic debate of the origins as well as archaeological excavations of some promising sites. In 1997, scholars from China, Europe, United States, Australia and Japan attended the 2nd international academic conference on origins and spread of rice agriculture in Nanchang, China (Crawford and Shen 1998). During the middle 1990s and middle 2000s, two Sino-American joint teams excavated the sites of the oldest domesticated rice remains in the Yangzi Valley (MacNeish and Libby eds 1995). Explanations of why rice agriculture originated during this period included the "marginal zone hypothesis" (Yan 1997), environmental pressure (Higham 1995, Lu 1998), and Binford's "packing pressure" (Chen 2004).

This brief review of the research history shows that studies of origins of rice agriculture focus on three major topics: the hearth of rice domestication, the origin and differentiation of *indica* and *japonica* domesticated rice, and the explanations of the origins of rice agriculture.

3.2 The Hearth of Rice Domestication

Until recently, a debate over the hearth of rice domestication has been the primary concern of scholars studying this topic. The homeland of rice domestication has been progressively revised from India to subtropical Southeast Asia to China in response to new information garnered from botanical studies and new archaeological discoveries.

3.2.1 The India Hearth Theory

Although de Candolle was the first scholar to postulate a hearth of rice domestication in India (1884), it was through Vavilov's work (1926) that this theory gained wide acceptance. Vavilov's model was based on his principle of center of genetic diversity: A center is characterized by an accumulation of various dominant genes where genetic variability is greatest. This was the place where the species arouse and from which it subsequently spread elsewhere. Specifically, the following four reasons led Vavilov to believe that India is the native home of rice:

1) There are a number of wild rice species and common rice that grows wild and can self-sow;
2) There are intermediate forms connecting wild and cultivated rice;
3) Indian cultivated rice has the richest genetic diversity in the world;
4) India is particular for the prevalence of dominant genes in its rice varieties.

According to Vavilov (1926), the exact area of the "India" hearth includes Myanmar (Burma) and Assam, India but excludes Northwest India and Pakistan.

Although Vavilov's theory was popular until the 1970s and had many followers (e.g., Chatterjee 1947, Ramiah and Ghosh 1951), it relied primarily on botanical evidence and lacked archaeological and historical support. The oldest reliably dated rice remains in India are dated to about 4,000 bp (Glover and Higham 1996). This is significantly younger than many well-documented Neolithic sites in China that have abundant evidence for the use of domesticated rice. Therefore, scholars abandoned the India hearth theory as genetic studies contributed additional relevant data in the 1970s.

3.2.2 Subtropical Southeast Asia Hearth Theories

In the 1970s, botanists started measuring genetic diversity of domesticated rice by investigating variations of isozyme zymograms in native rice cultivars. Nakagahra measured esterase isozymes to determine genetic diversity of domesticated rice and found that wide variations of genotypes without being dominated by any particular type in esterase isozymes were found in Assam, India

North Myanmar, part of Laos, and Yunnan, China (Nakagahra et al. 1975, Nakagahra 1978). Based on Vavilov's genetic diversity principle, these areas should be considered as the homeland of rice domestication. Nakagahra's study was confirmed by genetic evidence of Yunnan domesticated rice (Zhu 1982, Zhu et al. 1985, Xiong et al. 1988). This theory was also supported by Watabe, who suggested that old rice grains found in many parts of Asia are identical in form to those from China and Assam, India (1984).

So far, the most famous viewpoint of the subtropical Southeast Asia hearth is the one proposed by T. T. Chang (1976, 1985, 1989), who argued that rice domestication could originate independently and concurrently at many places within a broad belt between 20º and 23º N that extends mainly on the southern borders of the Himalayas and to a lesser extent its associated mountain ranges in mainland Southeast Asia and part of Southwest China (mainly Yunnan Province). This argument is based on the continuous distribution of common wild rice and its weedy forms, the great diversity of domesticated rice, and evidence from paleoclimatology, philology, and ethnology (Chang 1976). To support this hearth theory, Chang also outlined the possible routes of the dispersal of rice domestication on the basis of varietal diversity and genetic affinity. For example, *japonica* rice was evolved from *indica* rice in the hearth and diffused from the Nepal-Assam-Myanmar-Yunnan area via the Middle Yangzi Valley to the Yellow Valley, and also from Indochina (probably Vietnam) via a coastal route into the Lower Yangzi Valley (Figure 3.1). Watabe (1984) also proposed similar diffusion route but disagreed with Chang on the definition of rice subspecies (Figure 3.2, a detailed discussion of which appears in section 3.3 of this chapter).

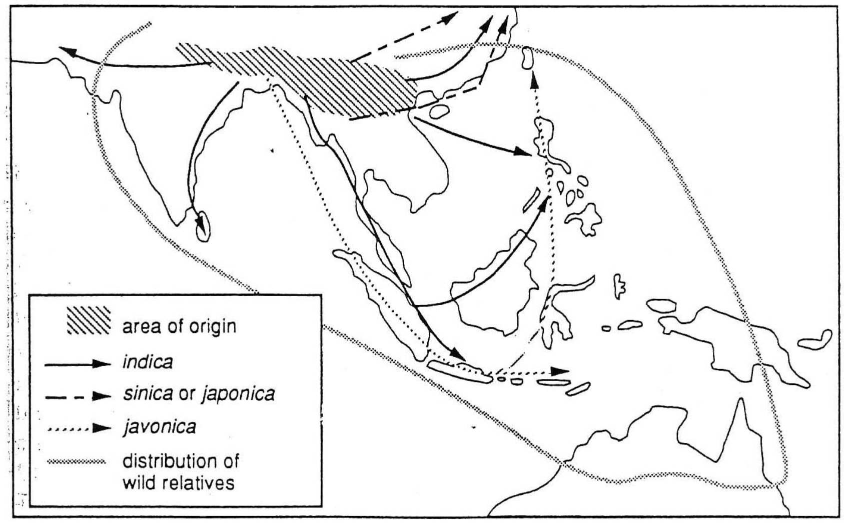


Figure 3.1 The hearth and spread of Asian domesticated rice by Chang (1976)

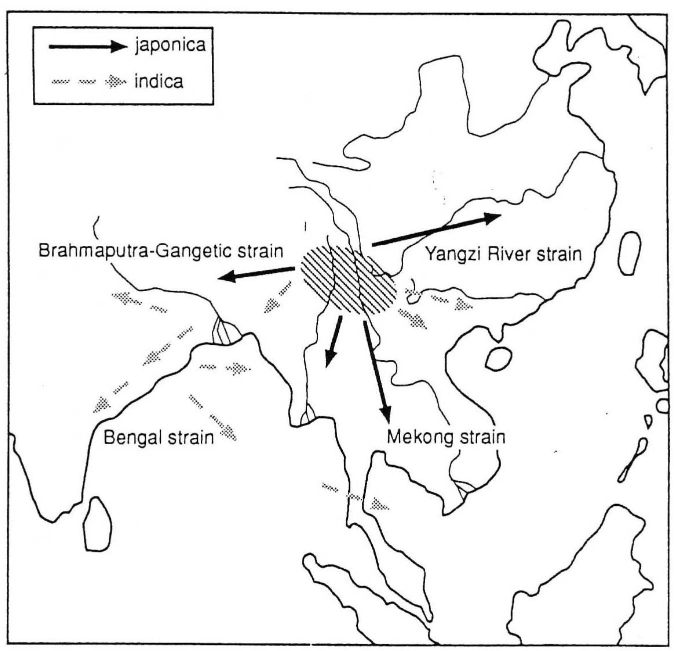


Figure 3.2 The hearth and spread of Asian domesticated rice by Watabe (1984)

The subtropical Southeast Asia hearth theory was criticized by Oka (1988) for the following reasons:

1) Genetic diversity is not sufficient to pinpoint the place of the origins of incipient cultivars.
2) Archaeological evidence does not support such a theory since many older rice remains have been found in the Yangzi Valley.
3) The distribution of wild progenitors is concentrated in Yunnan, China and Assam, India with lesser representation in the Himalayan foothills.

With the development of archaeological discoveries and the studies of wild rice distribution nowadays as well as in prehistory, China gradually becomes the focus of the search for the homeland of rice domestication.

3.2.3 South China, Yunnan and Lower Yellow River Valley Hearth Theories

As noted above, various parts of China have been proposed as possible hearths of rice domestication (Figure 3.3). In addition to the currently popular Yangzi Valley hearth theories (that will be discussed in next section), South China, Yunnan and the Lower Yellow Valley have also argued as the hearths of rice domestication.

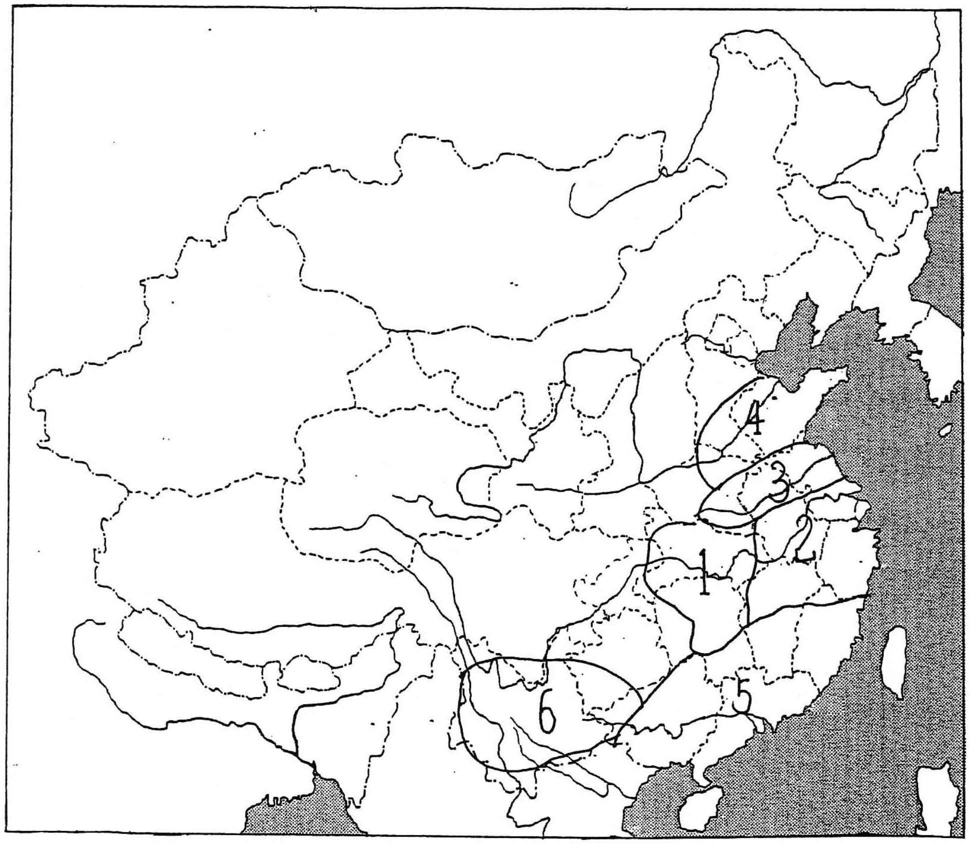


Figure 3.3 Various parts of China proposed as hearth of rice domestication
1. The Middle Yangzi Valley 2. The Lower Yangzi Valley 3. The Huai Valley
4. The Lower Yellow Valley 5. South China 6. Yunnan

Ding (1957) introduced the South China hearth theory on the basis of the extensive distribution of wild rice in tropical China. Other evidence in his argument includes historical record, archaeological discoveries, and linguistic analysis of words of wild rice. This theory was supported by Tong (1984) who argued that a number of early Neolithic sites were found in this area and some artifacts from the sites could have been used as farming tools. He went on to suggest the existence of sedentary life and the cultivation of vegetable crops at those sites. A similar viewpoint was put forth by Li (1985), who used both the distribution of wild progenitor of domesticated rice and the concentration of Early Neolithic sites older than Hemudu (the oldest rice site in 1985) in South China to support this theory.

The South China hearth theory no longer stands, because both botanic and archaeological evidence demonstrate that wild rice, the oldest domesticated rice, as well as the earliest archaeological cultures related to rice domestication are all found in the Middle and Lower Yangzi Valleys. Based on current evidence, Zhao (2006) argued that rice agriculture in South China was spread from the Yangzi Valley after 6,500 bp.

The Yunnan hearth theory is influenced by the theories of Chang (1976) and Watabe (1984). The supporters of this theory include agronomists Zimin Liu (1975) and Xiulin You (1978), as well as archaeologists Ninsheng Wang (1977) and Kunsheng Li (1981). Based on the distribution of modern wild rice and historic record of wild rice distribution, Liu (1975) argued that rice was first domesticated in Yunnan and spread via Peral River, Yangzi River and other rivers to the valleys and plains related to these rivers. According to his studies genetic diversity of modern and ancient rice samples, You believed Yangzi Valley is not the hearth of rice domestication. Genetic, archaeological and botanic evidence all supported the Yunnan hearth theory (You 1978). Archaeolgists Wang (1977) and Li (1981) also supported this theory, but their arguments did not come from archaeological evidence.

Instead, they only used genetic diversity of modern rice in Yunnan and its suitable environment for the growth of wild and domesticated rice to support this theory.

The Yunnan hearth theory was proposed from the late 1970s the early 1980s when the Southeast Asia hearth theory by Chang (1976) and Watabe (1984) dominated the research field. Both theories suffered the same deficiencies: the insufficient support from genetic evidence and the lack of archaeological evidence. The theory was further undermined when the survey of the distribution of modern wild rice revealed that most wild rice in Yunnan was not common rice, the wild progenitor of domesticated rice (National Wild Rice Resource Survey Group 1984).

The Lower Yellow Valley hearth theory, proposed by historian Jiangze Li (1986), is the least influential theory on the hearth of rice domestication. His study was merely based on an interpretation of the oldest Chinese historic literature *Shiji*. He argued that a legendary figure, *Dafei*, lived in the Lower Yellow Valley during the period of approximately 8,000 – 7,500 bp in Chinese myth. The name of *Dafei*, according to Li's interpretation, represents wild rice. He further inferred that *Dafei* and his ancestors were the earliest people to domesticate wild rice (Li 1986). Because Li's interpretation of the historic literature, particularly whether *Dafei* represents wild rice, is questionable, and his theory lacks evidence from archaeology and rice ecology, very few scholars accept this theory.

3.2.4 Yangzi Valley Hearth Theories

As more early Neolithic sites with rice remains have been found in the Yangzi Valley, the Yangzi Valley hearth theory, first formulated in the 1980s, has gained greater attention. Based on archaeological discoveries of the oldest rice remains, some favored the Lower Yangzi Valley, where Hemudu and other Neolithic sites with rich rice remains were found (Yin 1979). Others suggested the Middle Yangzi Valley where the earliest rice remains were found (Xiang 1993, Higham 1995). Among the different interpretations of the hearth of rice domestication in China, Yan's Middle and Lower Yangzi Valley hearth theory (1982, 1989, and 1997) has the most support.

Yan's Middle and Lower Yangzi Valleys hearth theory is based on archaeology, ancient agricultural history, and the distribution of wild rice. It has emerged gradually, and has been revised according to new evidence.

Yan initially favored the Lower Yangzi Valley, mainly because of the evidence from Hemudu and other sites. These yielded rich evidence for the oldest domesticated rice remains as well as the oldest known farming tools at the time when the theory was formulated (Yan 1982, 1989). The Lower Yangzi Valley was considered by Yan as the hearth of rice domestication for the following reasons:

1) Domesticated rice remains were the oldest one at that time. The remains from the lower level of the Hemudu site were radiocarbon dated to 7,000 – 6,600 BP, which were the oldest domesticated rice remains at the time of their discovery.

2) Prehistoric sites with rice remains were the most concentrated in the region. Of about 70 prehistoric sites with rice remains found through the 1980s, over 20 were located in the Lower Yangzi Valley.

3) The remains found at Hemudu were abundant and similar to modern domesticated rice. There were a number of farming tools and evidence of sedentary village unearthed from Hemudu.

All these indicate that Hemudu enjoyed developed rice agriculture almost 7,000 years ago and that rice domestication originated in the Lower Yangzi Valley before 7,000 BP, and gradually spread to other regions.

To define the hearth of rice domestication, it also necessary to demonstrate the existence of wild rice in the region with a probable genetic ancestry to the oldest domesticated rice. The distribution of wild rice was unclear when Yan (1982) first introduced his hearth theory, so he used historic documents to demonstrate the existence of wild rice in the Lower Yangzi Valley in history (1982). He found ten records of wild rice in historic documents, of which eight were located in the Lower Yangzi Valley. Their exact locations were almost identical to those of prehistoric sites with rice remains. Two years after Yan introduced his theory, a report of national survey of wild rice resource in China became available (National Wild Rice Resource Survey Group 1984). Although most wild rice was located in South China, this survey found the north edge of wild rice in China was on the south part of the Middle and Lower Yangzi Valley, specifically, in Jiangxi and Hunan provinces (Figure 3.4). Since paleoenvironmenal evidence indicated that early Holocene (before

7,000 BP) climate was wetter and warmer than today and there is a historic record of wild rice, it is reasonable to infer that the Middle and Lower Yangzi Valley had wild rice distribution before 7,000 BP (Yan 1989). This supported Yan's Lower Yangzi Valley hearth theory.

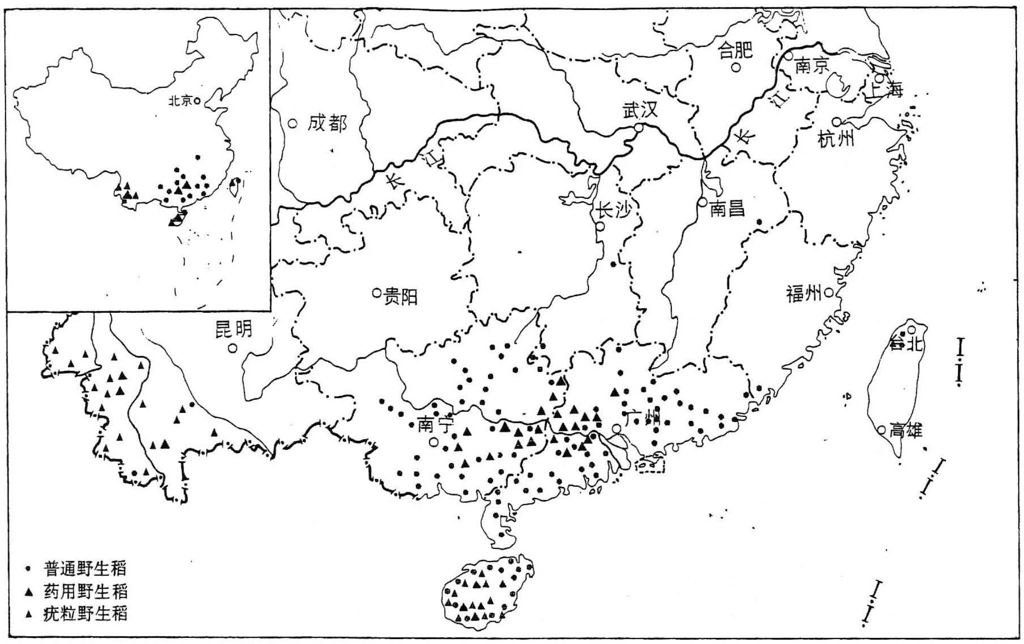


Figure 3.4 Current distribution of wild rice in China (after National Wild Rice Resource Survey Group 1984)

Since Yan introduced the Lower Yangzi Valley hearth theory, rice remains older than those of Hemudu were found at a number of sites in Hunan, Jiangxi provinces of Middle Yangzi Valley. Xiangrendong, Diaotonghuan and Yuchanyan sites yielded rice remains of more than 10,000 years old. Pengtoushan and Baishidang, dated to 9,000 BP, contained large number of domesticated rice remains and evidence of sedentary life. Based on the new evidence, Yan revised his theory and proposed the

Middle and Lower Yangzi Valley hearth theory (1997, 1998). He suggested five periods to illustrate the origins of rice agriculture:

1) Incipience Period (12,000 – 9,000 BP): The origins of rice domestication occurred in this period. So far, only three sites – Xiangrendong, Diaotonghuan and Yuchanyan – yield such evidence. Lower Yangzi Valley, particularly the area around Hemudu, is expected to have some evidence in the future. The hearth of rice domestication can be defined on the basis of this postulation.
2) Establishment Period (9,000 – 7,000 BP): Rice became an important part of human subsistence. Sedentary villages emerged. Rice remains were found in large quantities and its distribution reached 33˚ N, the south edge of the Yellow Valley.
3) Development Period (7,000 – 5,000 BP): Over 60 rice sites are reported, of which 50 or so are in the Middle and Lower Yangzi Valley, the remaining in the Lower Yellow Valley. Rice became the main staple in broad spectrum subsistence. Paddy rice field and irrigation facilities were found in some sites.
4) Prosperity Period (5,000 – 4,000 BP): Rice agriculture dispersed to South China and Sichuan Province. Rice farming system became mature, characterized by sophisticated farming tools and large scale permanent settlement.

Compared to other rice domestication hearth theories, Yan's Middle and Lower Yangzi Valleys hearth theory is the most reasonable one. It was built on solid archaeological evidence and the studies of modern and historic distributions of wild rice. However, this theory still has some problems. First of all, it is not sufficient to define the vast area of the hearth on the basis of three sites. Since the distance between the sites is far, their cultural connections to those established rice farming sites are unclear. Also, since there are no earlier rice remains found in Lower Yangzi Valley, some scholars preferred to locate the hearth in the Middle Yangzi Valley only (Xiang 1993, Zhao 1998).

3.2.5 Huai Valley Hearth Theory

The theory that the Huai Valley is one of the centers of rice domestication is based on the discovery of rice remains from Jiahua site (Zhang ed. 1998) in Huai Valley. According to the proponents of this theory (Zhang and Wang 1998), there are three arguments to support their theory.

First, the dating of the Jiahu domesticated rice is around 9,000 BP, which is almost contemporaneous with the domesticated rice from Pengtoushan site, which is thought as the earliest domesticated rice in the Middle Yangzi Valley.

Second, the Jiahu rice evolved toward the *japonica* type, whereas domesticated rice in the Middle Yangzi Valley such as the Pengtoushan rice differentiated mainly toward the *indica* type. Therefore, the Huai Valley is the hearth of *japonica.*

Third, the environment of Jiahu site during the time of occupation was subtropical ecotone, which allows the growth and evolution of domesticated rice.

The Huai Valley hearth theory is a relatively new theory on the center of the origins of rice domestication. Because it is only supported by the Jiahu site in the region and the cultural characteristics of Jiahu belong to North China Neolithic tradition whose subsistence was based on the domestication of millet, this theory is not well accepted. However, given the early dating of the Jiahu domesticated rice, it deserves further study to understand its role in the origins of rice agriculture. As will be suggested by my own analysis in Chapter 7, the Huai Valley, along with the Middle Yangzi Valley and the Lower Yangzi Valley, are three independent centers of the origins of rice domestication.

3.3 The Evolution and Differentiation of Domesticated Rice

Rice belongs to the genus *Oryza*, a semi-aquatic plant mainly distributed in the humid tropics. There are two domesticated species of rice: *Oryza sativa* and *Oryza glaberrima* that evolved separately from wild rice in Asia and Africa. They are genetically different: their hybrids are generally sterile; they have different isozyme patterns; and *Oryza sativa* is an annual whereas *Oryza glaberrima* a perennial (Chang 1976). African rice is being replaced by Asian rice and other crops (Grist 1986). Asian rice, which is the main staple in East, Southeast and South Asia, is the focus of this dissertation. To study the origins of rice domestication, an important and yet unsolved issue is the evolutionary relationships among modern wild rice, modern domesticated rice and archaic domesticated rice from archaeological sites. A series of questions are related to this issue: what is the wild ancestor of domesticated rice?

What is the evolutionary process of different modern domesticated rice subspecies? How do researchers identify rice remains from archaeological sites?

The taxonomy and nomenclature of the genus *Oryza* is complex and debated among botanists and geneticists (Ahn 1992). Of more than twenty species belonging to the genus *Oryza*, two species: the perennial *O. rufipogon* and the annual *O. nivara* are considered the closet relatives of domesticated rice *O. sativa* (Chang 1976). However, there are debates over which species is the direct ancestor of domesticated rice. One viewpoint, represented by Chang (1976), considered *O. nivara* as the direct progenitor of *O. sativa*. The basis of his argument is the genetical, morphological and ecological similarities between *O. nivara* and *O. sativa*. *O. sativa* is an annual plant with fibrous roots. It commonly grows in paddy fields and occasionally on uplands. *O. nivara* is an annual type with fibrous roots that grows in temporary swamps. *O. nivara* is sometimes indistinguishable from the weedy type *O. sativa var. spontanea*, which is genetically and morphologically similar to *O. sativa*. The evolutionary process suggested by this hypothesis is as follows: *O. rufipogon* → *O. nivara* → *O. sativa*. The other viewpoint, represented by Oka (1974), suggests *O. rufipogon* to be the direct ancestor of *O. sativa*. The main basis of this argument is perennials have greater within population genetic variation than annuals and hence have higher evolutionary potential. The parallel and independent evolutionary processes are as follows: *O. rufipogon* → *O. nivara*, *O. rufipogon* → *O. sativa*. A slightly different viewpoint of Oka’s argues that an intermediate type, derived from *O. rufipogon*, was the direct ancestor of *O. sativa* as well as *O. nivara* (Morishima 1984).

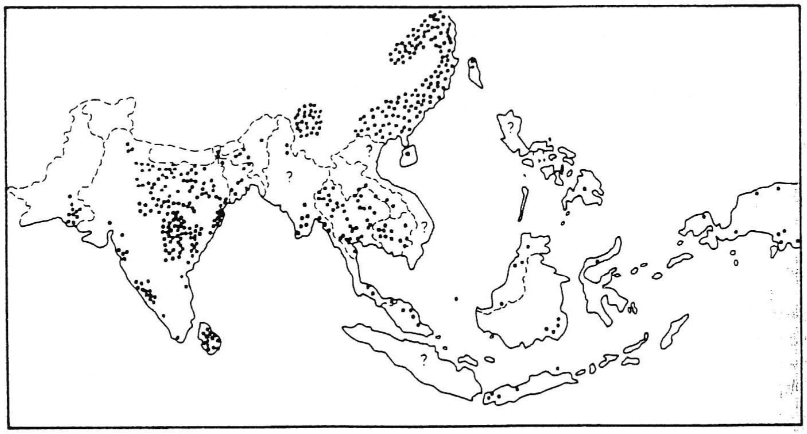


Figure 3.5 Current distribution of wild rice in Asia (based on Harlan 1975 and Ahn 1992)

In spite of the differences, it is generally believed that *O. sativa* originated directly or indirectly from the perennial *O. rufipogon* (also known as common wild rice) (Chang 1976, Second 1982, Oka 1988). The distribution of common wild rice (Figure 3.5) is in open swampy habitats at low altitudes in monsoon India, Thailand, Cambodia, South China, with smaller populations in western India, Malaysia, Indonesia and Philippines (Harlan 1992, Second and Ghesquiere 1985). In China, it is clear the distribution of wild rice is now known to have been broader than once thought (e.g., Chang 1976): it ranges between 100º47´E and 121º15´E and between 18º9´N and 28º14´N (National Wild Rice Resource Survey Group 1984). The distribution reaches Jiangxi and Hunan provinces, belonging to the Middle Yangzi Valley (Figure 3.4). Paleoclimatic and pollen evidence indicate that during the Neolithic period (12,000 – 5,000 BP) temperatures in the Middle and Lower Yangzi Valley were higher than today and annual precipitation was over 800 mm. Considering the historic records of rice distribution with environmental data, Tang et al. (1993) infer that the northern limit of wild rice in the Neolithic may have extended north to the Yangzi River and Lake Tai, which provided more evidence to support the Yangzi Valley hearth theories.

Because rice domestication has a long history in many Asian countries, there are numerous local variations that are adapted to local environment and cultural preference. *O. sativa* is often divided into two subspecies: *japonica* and *indica* (Kato et al. 1928). A third subspecies, *javanica*, is proposed by Chang (1976) (Table 3.1). *Javanica* shares many morphological characteristics with *japonica*, therefore Oka (1988) suggested that *javanica* cannot be elevated to the same status as *indica* and *japonica*, for there are no marked diagnostic differences between *japonica* and *javanica* comparable to the *indica*-*japonica* distinction. Following Harlan and de Wet (1971), Ahn (1992) suggests that *javanica* can be viewed as a tropical variation of *japonica*.

Characters	***Indica***	***Japonica***	***Javanica***
Grain			
Shape	Long and slender	Short and roundish	Long and broad
Awns	Usually absent	Present/absent	Usually present
Lemma/palea	Thin/short hairs	Dense/long hairs	Dense/long hairs
Plant status			
Leaf type	Broad to narrow	Narrow	Broad and stiff
Leaf color	Light green	Dark green	Light green
Tiller size	Large	Large	Small
Tiller habit	Spreading	Erect	Erect
Plant height	Tall	Short	Tall
Plant tissue	Hard	Soft	Hard

Table 3.1 Morphological difference of three types of O. sativa (based on Takahashi 1984 and Chang 1984)

In addition to morphological differences, the biogeographic distributions among these subspecies are different. According to Kato et al. (1928) and Chang (1985), their distributions are as follows. *Indica* is distributed throughout tropical Asia and some subtropical Asia, including South Asia, mainland Southeast Asia, and South China. *Japonica* is concentrated in subtropical and temperate parts of Asia, such as East and Northeast China, Korea, and Japan. *Javanica* is mainly found in the islands of Southeast Asia, like Indonesia, the Philippines, and Taiwan. In Yunnan of China, Ding (1957) found *indica* predominates up to 1750 meters whereas *japonica* is in areas above 2000 meters, and intermediate types are between 2000 and 1750 meters. Since only *japonica* and *indica* are distributed in China, I will focus on these two subspecies.

The differentiation of *indica* and *japonica* raised questions about their origins. Several hypotheses were proposed to explain the differentiation. One hypothesis suggests that *japonica* was differentiated from *indica* as an adaptation to temperate zones during the dispersal of rice domestication. The basis of this theory includes the similar distribution, the morphological and ecological resemblance between *indica* and wild rice, and the richness of variation of morphological and ecological characters in *indica* (Chang 1976, 1985). This theory was associated with the Southeast Asia and India hearth of rice domestication theories and is no longer favorable due to the evidence supporting the Yangzi Valley hearth theory. Another hypothesis, proposed by Oka (1988), suggests that the *indica*-*japonica* differentiation happened several times in different areas under selective pressure of domestication. This was based on his experiments of wild and domesticated rice (Oka and Chang 1962, Oka and Morishima 1982). This suggestion is questionable, because the rice strains chosen in the experiments were not representative (Ahn 1992).

To date the most popular hypothesis of *indica*-*japonica* differentiation is the independent domestication of *indica* and *japonica*. This theory was initially proposed by Chou (1948), who believed that *japonica* evolved from *japonica*-like wild rice in South China, and *indica* originated in India and was introduced to China later. This hypothesis is supported by isozyme analysis (Second 1982, 1986) and phenotypic traits studies (Morishima 1986). Based on distributions of wild rice and archaeological remains and studies of rice remains from archaeological sites, Tang et al. (1993) argue that *japonica* derived from *japonica*-like wild rice in the woodlands and marshlands in the Middle and Lower Yangzi Valley whereas *indica* evolved from progenitor with strong *indica* elements further south. Chinese geneticists also found evidence to suggest that *japonica* originated in China while *indica* evolved in both South Asia and China. Based on nuclear DNA, mtDNA and cpDNA analysis, Sun et al. (1998) classified current China common wild rice (CWR) into three types: proto type (P-CWR), *indica*-inclined CWR (J-CWR) and *japonica*-inclined CWR (I-CWR). According to the comparison of morphological, isozyme and DNA evidence between current CWR and ancient domesticated rice remains from Jiahu and Bashidang, they argued that Chinese proto CWR first evolved into J-CWR, I-CWR and P-CWR. J-CWR and some P-CWR evolved via Jiahu domesticated rice into modern *japonica*, while I-CWR and some P-CWR evolved via Bashidang domesticated rice into modern *indica* (Sun et al. 1998).

In recent years, DNA evidence has become an important means to study *indica-japonica* differentiation. Sato's (1996, 2002) DNA studies of modern wild and domesticated rice as well as ancient rice remains yield new evidence on the origins of domesticated rice. First, he found *indica-japonica* differentiation among the strains of wild rice in the sativa complex, which indicates that differentiation between *indica* and *japonica* took place before domestication. Second, he found no evidence for *indica* in rice remains from those Chinese sites he examined. This implies that initial rice cultivars in China were predominantly *japonica*. And third, his DNA evidence from rice found in archaeological sites shows the presence of tropical *japonica* in the Yangzi Valley. He infers that temperate *japonica* was born from tropical *japonica* by recurrent selections by human as well as the natural environment (Table 3.2).

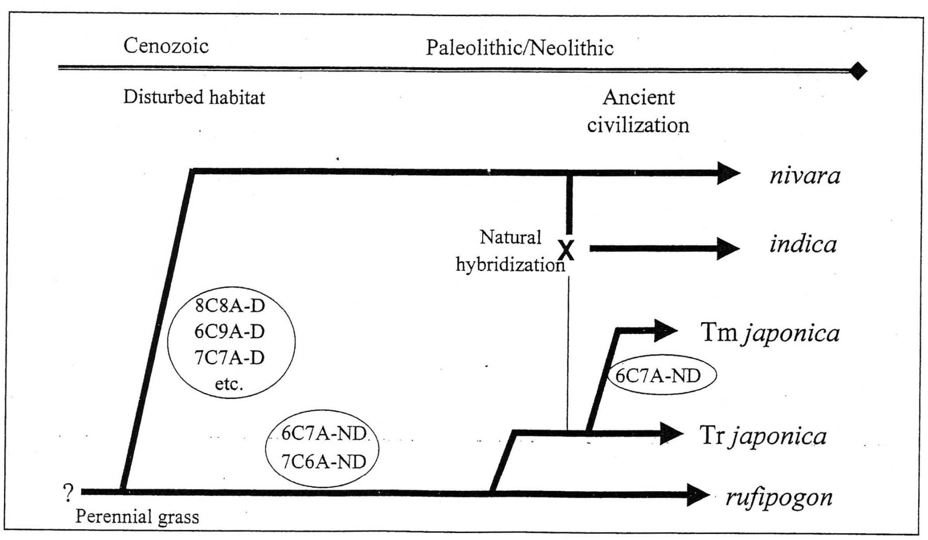


Table 3.2 Phylogenetic relationships among wild and domesticated strains of *sativa*-complex in relation to chloroplastDNA genotype (after Sato 2002)

Although DNA studies indicate that all early archaeological rice grain remains from China belong to *japonica* (Sato 2002), many reports on the status of rice remains were based on morphological criteria. Since rice remains from archaeological sites are mostly grains and husks that are preserved in charred states or as impressions in pottery and fired clay, it is difficult to identify their status of domestication. Although the best criterion to distinguish wild from domesticated rice is the presence or absence of the a brittle rachis, it is often not well preserved in archaeological context. Grain shape and size, as well as glume hair and awn are often used to identify archaeological specimens (Ding 1957). After examining other's research and conducting his own examinations, Ahn (1992) believed length-to-width (L/W) ratios of rice grains and their overall size can differentiate races of modern rice (with 20% error), and charring does not change the L/W ratios significantly. Zhang (1998) also observes the structure of bi-peak tubercles of lemma of rice to identify the status of rice remains. A new approach, by statistical measurement of rice phytoliths, has also been applied to determine domestication of rice remains (Zhao 1998).

It is clear that debates over those issues related to the evolution and differentiation of domesticated rice still exist among botanists and geneticists. With regard to the origins of rice domestication, however, some basic consensuses can be summarized here.

1) Domesticated rice originated from common wild rice (*O. rufipogon*), either directly or through *O. nivara*.

2) The distribution of wild rice reached the southern part of the Yangzi Valley, and probably extended north to the Yangzi Valley during the Neolithic Period.
3) *Japonica* evolved from *japonica*-like wild rice in the Yangzi Valley while *indica* evolved from *indica*-like wild rice in South Asia and South China as well.
4) Rice remains from archaeological sites in China are all *japonica*. This is supported by DNA studies and the majority of morphological identifications.

3.4 The Explanations of the Origins of Rice Agriculture

Compared to the studies on the hearth of rice domestication, exploration of the reason for the origins has a relatively short history. This is primarily because of the scarcity of archaeological data, but limited knowledge and understanding of contemporary theories on the origins of agriculture is another factor. Only a handful of articles and monographs, most published within the past decade, discuss the reasons for the origins of rice agriculture.

3.4.1 Yan’s Marginal Zone Theory

Yan (1989, 1998) was the first scholar to explore the impetus of the origins of rice agriculture. He adapted Binford’s (1968) “marginal zone theory” to formulate his own theory. He agreed with Binford as well as Harlan (1977) that agriculture originated on the margins of the optimal environmental zone for wild progenitors of domestic plants and animals, although he was somehow reluctant to adopt Binford's concept open/closed population systems. As presented in previous section, there was a concentration of wild rice in South China, with the northern limit probably extending to the Yangzi Valley during the Neolithic Period. Therefore, the Middle and Lower Yangzi Valley was considered the marginal zone of wild rice whereas South China was seen as the optimal or "nuclear" zone. Archaeological evidence supports this as well. Established rice farming cultures emerged earlier than 7,000 BP in the Yangzi Valley, but it did not appear in South China until 5,000 BP (Yan 1998).

Yan (1998) suggested two reasons why agriculture did not originate in South China. First of all, natural food resources were abundant and available year round. Neolithic people in South China often lived near rivers or coasts and enjoyed a broad spectrum subsistence of hunting, gathering and fishing. It was unnecessary for these people to cultivate wild rice, since wild rice was less tasty and more difficulty to cook compared to other food items. Wild rice was always available, making it a good "fulllock" food. On the other hand, the hilly landscape of South China restricted the development of prehistoric culture and the growth of population was slow. Therefore, there was no population pressure to force people to change their lifestyle and invest energy in a focus of rice collection (Yan 1998).

The ecological and cultural situations in the Yangzi Valley were different. Seasonality there was strong: natural resources were rich in summer and autumn but scarce in winter. Neolithic people were under the pressure to secure their food resources for winter. In addition, the wide and flat alluvial plains along the Yangzi

River allowed the development of prehistoric culture and hence the increase of population. This situation worsened the food crisis. As a result, people had to collect any available food items, including wild rice. In this process, people gradually recognized that wild rice could be stored for a long time. So, they started preserving and cultivating wild rice. Due to human's intentional preservation, common wild rice could be planted in areas of higher latitude and cooler temperatures where they were not able to survive before. This increased wild rice's dependence on humans. During this incipient period, through sowing, weeding, land clearance and soil tillage, human involvement changed some morphological and genetic characteristics of wild rice. In the end, wild rice became domesticated rice and rice agriculture emerged (Yan 1998).

Yan's demographic pressure theory is the first explanatory model of origins of rice agriculture. In his theory, the impetus of this transition is the increase of population that exceeds the carrying capacity of natural environment. Although Yan gave ecological reasons for the increase of population, and presented a logical postulation of the process leading to the emergence of rice agriculture, he did not provide archaeological and related evidence to substantiate the population pressure in the Yangzi Valley during the early Neolithic Period. In fact, the archaeological record from Late Paleolithic to Early Neolithic in the Middle and Lower Yangzi Valleys does not show the existence of population pressure (Lu 1998). Therefore, Yan's theory of why rice agriculture originated cannot be accepted as a plausible explanation.

3.4.2 Higham's Environmental Deterioration Theory

In 1995, Charles Higham, a New Zealand archaeologist specializing in early rice agriculture in Southeast Asia, suggested the impetus for rice agriculture had to be environmental factors. He (Higham 1995) agreed that the sites of Pengtoushan and Hemudu represent the earliest rice agriculture. The Yangzi Valley may well be the homeland of rice domestication. Based on his studies of the earliest rice agriculture in Southeast Asia, Higham (1995) saw sedentism and an ideology that favored farming as prerequisites for rice domestication. Although these factors were supported by ethnological and archaeological evidence in Southeast Asia, Higham found no clear evidence in the Yangzi Valley. He also argued that population growth should be considered as a consequence rather than the cause in the transition. Finally he concluded that only environmental factors became convincing elements of the causal explanation.

Considering the date of the earliest rice agricultural sites of Pengtoushan and Hemudu, Higham felt the period between 11,500 BP and 8,500 BP was critical to understand the event of the transition. The Younger Dryas was believed to play an important role in the transition. During the Younger Dryas period (11,500 – 10,000 BP), climate became increasingly cold and sea levels fell up to 7 meters. This was followed by a marked warming period from 10,000 to 8,500 BP. Higham believed there was possibly a certain level of sedentism in the Middle and Lower Yangzi Valley during a long warm period before the Younger Dryas. During the Younger Dryas period, the cold and dry weather provided a less favorable environment for humans and their natural food resources. To sustain stable communities under increasing environmental pressure, humans were forced to start domesticating rice (Higham 1995).

Because the available archaeological and paleoenvironmental data were limited when Higham initially introduced his theory, his environmental deterioration theory did not sound convincing and lacked details. He later refined his theory according to new evidence from archaeology and environmental studies. During the Last Glacial Maximum of the terminal Pleistocene, the cool and dry climate reduced the availability of fruits and nuts that were often collected by foragers of the Middle and Lower Yangzi Valleys. The dominance of herbs in local vegetation led people to exploit wild grass, including wild rice. This transition was accompanied by the move from seasonal or semi-sedentary occupancies of caves and river terraces to permanent villages. The invention of pottery and the use of stone, bone, wooden and bamboo implements may have also resulted from the extensive wild grass collection. The use of pottery and tools made of all kinds of materials might further facilitate the exploitation of wild grass, particularly their seeds. The increasing dependency on grass collection reduced the mobility of foragers, and hence increased their population and sedentisem. Once collection could no longer meet the demand, cultivation of wild plants like rice was triggered to increase the supply, which eventually led to the beginning of rice domestication (Higham and Lu 1998).

As an environmental pressure model of agricultural origins, Higham's theory considered the deteriorating climate and human ecology during the terminal

Pleistocene as the trigger of agricultural origins in the Yangzi Valley. Under this pressure, a series of factors, such as increasing sedentism, invention of pottery, extensive exploitation of wild grass and increased population, all combined to lead to the origins of domestication. Although Higham's model depends on many postulations that are unsubstantiated by archaeological evidence, as one of very few models to explain the reason of origins of rice agriculture, his theory was adopted and refined by many others (e.g., Lu 1998, Bellwood 2005).

One problem in Higham's model is that he did not explain why foragers chose wild rice to cultivate. There are two reasons that wild rice were chosen by foragers to cultivate. On the one hand, the seeds of wild rice, after being cooked, were a tasteful, nutritious and easily digested food. Once foragers knew the value of wild rice, they might have a desire to increase its availability by cultivation when it became scarce due to climatic deterioration (Lu 1998). On the other hand, wild rice only produces a limited number of seeds per year and has a lower survival rate in disturbed habitat (Oka 1975). These botanical characteristics required foragers to cultivate wild rice if they wanted to increase its production.

Since Higham, environmental factors have become a dominant explanation of the origins of rice agriculture (e.g., Zhao 1996, Lu 1998, Yashuda 2002, and Cohen 2002). Zhao's environmental pressure explanation was based on detailed analysis of archaeological data from the sites of Xianrendong and Diaotonghuan. While Yashuda favored an environmental amelioration model to understand the origins. These two studies are worthy of a brief review here.

3.4.3 Zhao's Environmental Deterioration Theory

Zhao's (1996, 1998) hypothesis was based on his own experience of archaeological excavation and phytolith analysis of Xianrendong and Diaotonghua (also known as Wangdong) sites. These two sites were located at Dayuan Basin of Jiangxi Province in the Middle Yangzi Valley. Human occupation of the sites was from around 12,000 BP through the whole Neolithic period.

Zhao suggested that the climate of the sites was in a long post-glacial warm trend that was punctuated by a short, cold period circa 11,000 – 10,000 BP. This environmental change led to a significant retraction of wild rice distribution in the region. As a result, local foragers who collected wild rice as part of their food resources before had to adopt a broad-spectrum hunting strategy. Sophisticated hunting tools and high ratio of animal bones of this period supported this conjecture. The return of warm climate after this cold interval not only came with the increase of wild rice but also resulted in a rapid rise of sea level. Zhao inferred that areas near Dayuan Basin, which is not far from the Yangzi River and Poyang Lake, may have suffered a reduction of land mass due to the expansion of fresh water habitats. This change reduced the mobility of local inhabitants and hence affected their broad-spectrum subsistence pattern. One consequence is that wild rice collection was increased to supplement the inadequate food supplies which resulted from the reduced foraging area. Cultural remains from the two sites provide a basis for Zhao (1996) to argue the case for population increase. He suggested that Xianrendong was not occupied until around 9,000 BP by the people from Diaotonghua where human occupation started at 12,000 BP. Although the two sites were explained as a hunting camp and a home base for the same group of people (Redding 1995), Zhao preferred to see both as home bases of local inhabitants. The extensive collection of wild rice may provide a more secure and reliable food resource which was able to support an increased population in the basin. Once the Diaotonghuan cave became too crowded, some residents might have moved into the Xianrendong cave to build a new home (Zhao 1996).

Soon after 9,000 BP, a very short cold period hit the Yangzi Valley including the Dayuan Basin (Xu 1992, Tang and Shen 1992). The effect of this climatic deterioration was not as dramatic as the Younger Dryas, but it was significant enough to reduce the distribution and yield of wild rice. Population growth combined with a decrease of wild rice forced people to find a way to increase their food supply. The knowledge of wild rice obtained during their long-term collection experience allowed local foragers to plant harvested wild rice grains in order to increase the yield. Human interference resulted in some permanent genetic changes in wild rice, which led to rice domestication (Zhao 1996).

Zhao's hypothesis was largely based on archaeological and other related data from two of the earliest sites with rice remains. Although some of his postulations, such as the hypothesized population growth and human experimentation with planting rice still need more supporting evidence, his case study did provide support for environmental pressure theory of the origins of rice agriculture. Another weakness of

Zhao's hypothesis is that the whole theory was built upon data from two sites within a small basin. A further consideration of other early sites related to early rice agriculture in the Yangzi Valley as well as other areas is necessary before we can make a sound and convincing argument about the reasons for the origins of rice agriculture.

3.4.4 Yashuda's Environmental Amelioration Theory

All the above environmental theories emphasize environmental stress as the impetus of the transition to rice agriculture. Japanese scholar Yashuda (2002), however, proposed a different view of the role of environmental change played in the transition. He argued that environmental amelioration around 15,000 BP triggered the beginning of rice domestication. Based on the analysis of pollen diagrams from Lake Suigetsu of Japan, he suggested that global warming beginning in 15,000 BP caused a sharp change of ecosystem from the Last-glacial type to the Post-glacial type in the Yangzi Valley during the next 500 years. The temperate deciduous broad-leaved forest with beech or deciduous oak returned, and wild rice grew in the region. Local inhabitants began to collect the ears of wild rice that grew near their residences. Since the rachis of wild rice is very brittle, their seeds are easily dispersed. Genetic changes in the process of human collection and dispersal led to the appearance of some wild rice with tough rachis, which were often chosen by foragers because they could survive in the long run. This unconscious selection eventually led to deliberate selection and cultivation which marked the beginning of rice domestication. The

Younger Dryas during the terminal Pleistocene, on the other hand, resulted in the expansion of rice domestication in the Yangzi Valley. Yashuda argued that the sudden occurrence of cold and dry climate during the Younger Dryas had a significant impact on rice domestication similar to the case of wheat domestication in the Near East. Facing environmental deterioration during the Younger Dryas, the people of the Yangzi Valley had to expand rice cultivation to solve the problem of food scarcity (Yashuda 2002).

Yashuda's model relied heavily on environmental data to explain the origins of rice domestication but failed to substantiate itself with archaeological data. Under both environmental amelioration and climatic deterioration, Yashuda only used the ambiguous and unsubstantiated claim of food scarcity to explain that people were force to start and expand rice cultivation. The deficiency of Yashuda's argument made his hypothesis less convincing and largely unaccepted.

3.4.5 Chen's Synthetic Theory

The last view of the explanation of origins of rice agriculture worthy of a discussion here is the one proposed by Chen (2004). A student of Binford, Chen adopted many of Binford's theories (e.g. 1968, 2001) in formulating his own viewpoint. To explain the transition to agriculture, Chen prefers mechanism (internal factor) and initial condition (external factor) to the traditional cause and effect explanation. The mechanism refers to the adaptive strategies under pressure in a given environment: either controlling population or increasing carrying capacity. The initial condition is the primary state of a cultural system before any significant change. It primarily means the condition of biotic and abiotic environments, but also includes human culture built upon past experience. The origins of agriculture are the outcome of the systematic selection of adaptive strategies under environmental pressure. Binford's (2001) minimalist terrestrial model was used to evaluate the constraints of the environment.

Chen did not specifically address the domestication of rice and suggested we do not yet know why and how rice domestication occurred due to limited data; however, he did imply that packing population pressure and the terminal Pleistocene environmental pressure could be responsible for the origins of rice domestication.

Chen tried to integrate Binford's "marginal zone hypothesis" (1968) and general framework of reference (2001) including minimalist terrestrial model and packing population pressure theories into the study of the origins of rice agriculture. He built a general system to analyze the transition through archaeology and presented some general thoughts on why the transition occurred, but he failed to provide any new insight on the subject. Chen (2004) believed that a series of factors, including environment, population, development of human culture (e.g., subsistence, social organization, ideology), all together contribute to the origins. Among them, environmental stress is the leading factor, but packing pressure resulted from the change of mobility is also required.

From a brief review of all major viewpoints explaining the origins of rice agriculture, we can see that most scholars believed environmental factors are the explanation of origins of rice agriculture, although some also emphasize the significance of population growth and changing mobility. It is clear, however, that despite all these viewpoints we have not answered the question completely and convincingly. There are two main weaknesses of these theories. First of all, most of the hypotheses were not built upon solid archaeological evidence, which made them vulnerable. Since the origins of rice agriculture are an important cultural event in human history, any understanding of it should begin with its cultural aspect, that is, archaeological evidence. The other problem is that the theoretical frameworks used to construct these theories were limited to environmentalism and demography. Many new theories of agricultural origins, as described in Chapter 2, should be considered in our exploration of the transition to rice agriculture. This is becoming necessary as we could not find satisfactory answers to those critical questions based merely on the traditional theories.

3.5 Summary

In this chapter, I described the research history of the origins of rice agriculture and reviewed three topics related to the origins: the hearth of rice domestication, the evolution and differentiation of domesticated rice and the explanations of the origins.

The research history on the origins of rice agriculture can be divided into three periods. The focuses of the first period (the 1920s to the middle 1970s) were the hearth of rice domestication and the *indica-japonica* differentiation. During the second period (the late 1970s to the early 1990s), China replaced India and Southeast Asia as the hearth of the origins of rice agriculture. The third period, from the middle 1990s to present, witnessed general agreement that the Lower and Middle Yangzi Valley is the hearth.

As to the studies on the hearth of rice domestication, India hearth theory dominated the field until the 1970s and it was replaced by the subtropical Southeast Asia hearth theory. To date, the most influential hearth theory of rice agriculture is the Middle and Lower Yangzi Valleys theory proposed by Yan. Considering some deficiencies of Yan's theory, as discussed earlier in this chapter, we ought to re-examine archaeological data as well as other related evidence in three areas where the earliest rice remains and associated cultures were found: the Lower Yangzi Valley, the Middle Yangzi Valle as well as the Huai Valley.

On the differentiation *indica* and *japonica,* it is generally agreed that perennial common wild rice, *O. rufipogon*, is the wild ancestor of domesticated rice. Biogeography, morphological and ecological characteristics and DNA evidence have been used to formulate different hypotheses of the *indica-japonica* differentiation. The most popular theory is the independent domestication of *indica* and *japonica*: *japonica* evolved from *japonica*-like wild rice in the Yangzi Valley while *indica* evolved from *indica*-like wild rice in South Asia and probably South China as well.

The explanations of the reason for the origins of rice agriculture are the most controversial and unresolved issue in the studies. Most viewpoints use environmental factors, population growth or the combination of the two aspects to explain why rice domestication and agriculture started in the Yangzi Valley. All those hypotheses fail to provide satisfactory answers to the question, mainly due to a lack of archaeological evidence. It is quite a challenge to construct a convincing explanation of the origins of rice agriculture based on scattered and often inadequate data in archaeology and other related aspects. However, one thing is clear from the review of current explanations: more theoretical frameworks than the traditional environmentalism and demography should be considered if we want to achieve any further understanding of this issue.

After a review of current research on the origins of rice agriculture, we can see that several critical issues of the origins are still unsettled. With regard to when and where rice agriculture originated, since it is still not certain if there is only one hearth of rice domestication and how long it took from the beginning of domestication to the emergence of rice agriculture, we have to take a careful examination of archaeological data containing both the earliest rice remains and the earliest rice agricultural societies. As to the reason of the origins, new theories concerning agricultural origins, such as those post-processual and evolutionary theories, should be considered in addition to traditional environmentalism and demography. But first, the environmental and ecological settings of the regions when the earliest rice domestication and agriculture started: the Middle Yangzi Valley, the Lower Yangzi Valley, and the Huai Valley should be examined.

Chapter 4

Environmental Background to the Origins of Rice Agriculture

The natural environment is always an important limiting, if not determining, factor in the origins of agriculture. Because the areas that have provided the earliest evidence for rice domestication and rice agriculture are part of China, I start with an overview of the geography and environment of China and then focus on the region related to the origins of rice agriculture. First, I will outline modern topography, climate, vegetation and fauna that form the basis for understanding the changes in the past. This is followed by a discussion of the paleoenvironment (including climate, floral and faunal resources, and sea level) from the late Pleistocene to the early Holocene, the period related to the origins of rice agriculture. Finally, the impacts of major environmental variables to humans will be presented.

4.1 China: An Overview

The information of current China, including those of the Yangzi Valley and Huai Valley, comes from three syntheses of modern Chinese geography, environment and natural resources (The Editing Committee of Chinese Physiography 1984, Zhao 1986, The Editing Committee of Agricultural Resources and Distributions in China 1987).

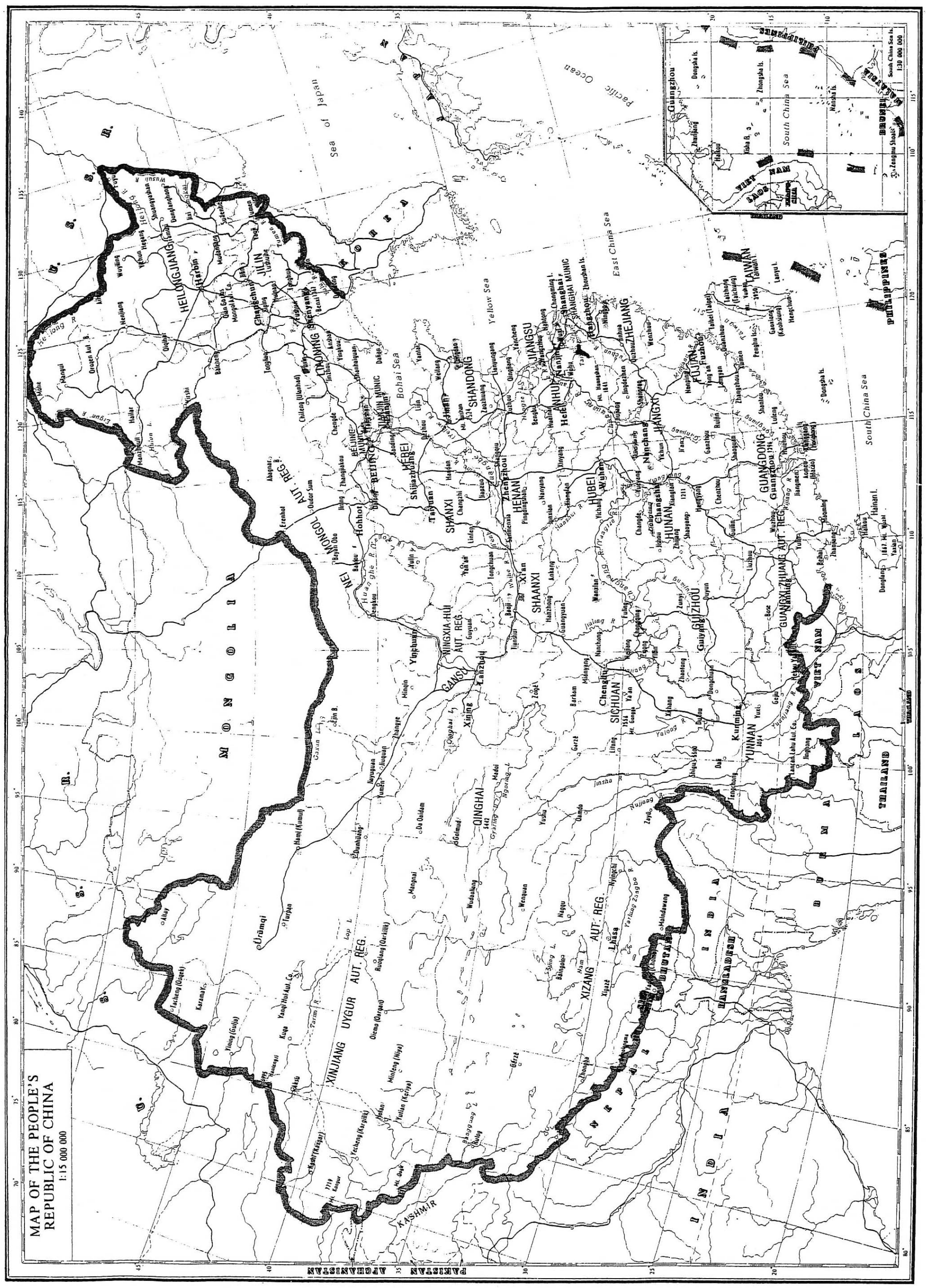


Figure 4.1 Administrative map of China

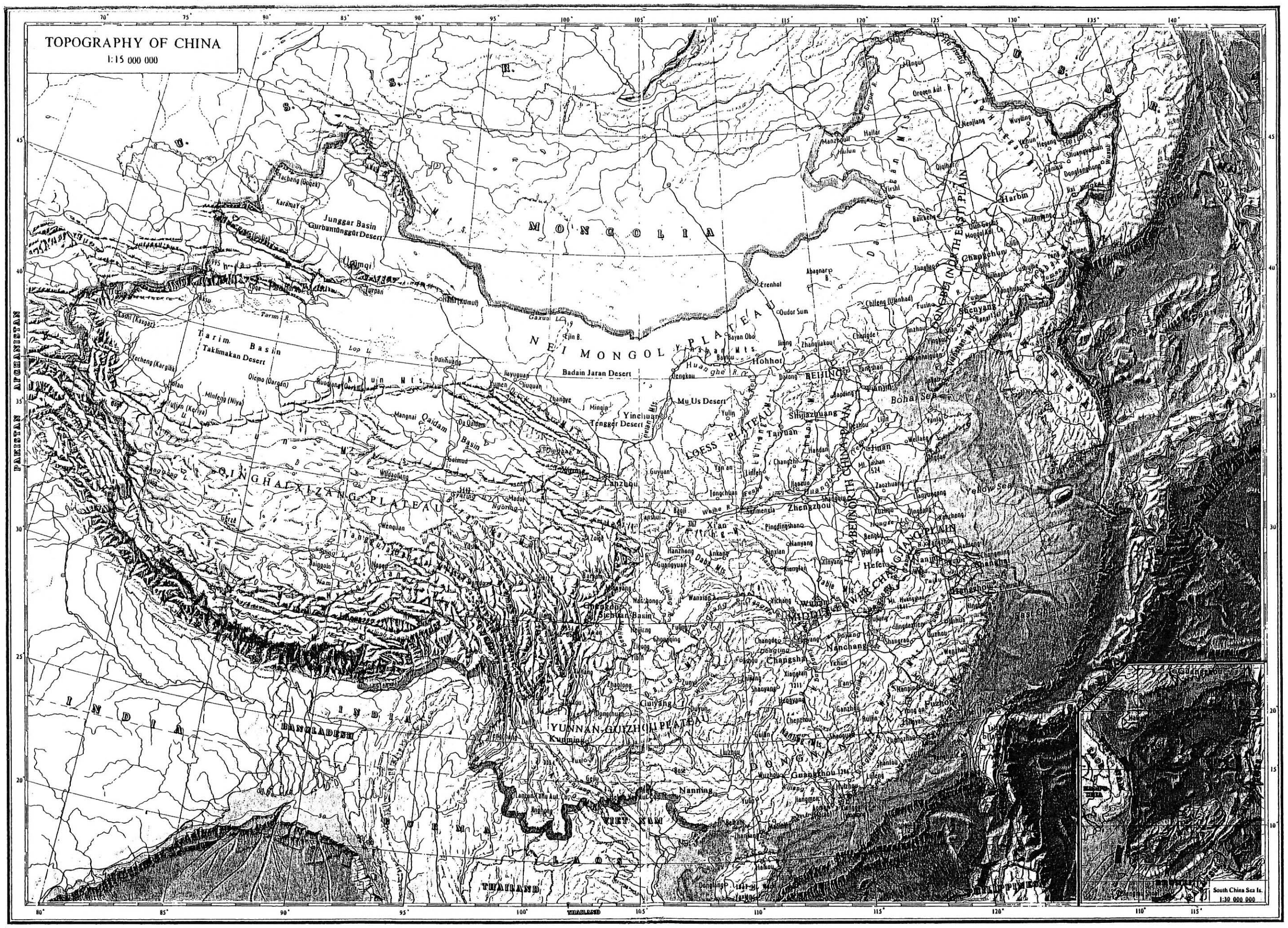


Figure 4.2 Topographic map of China

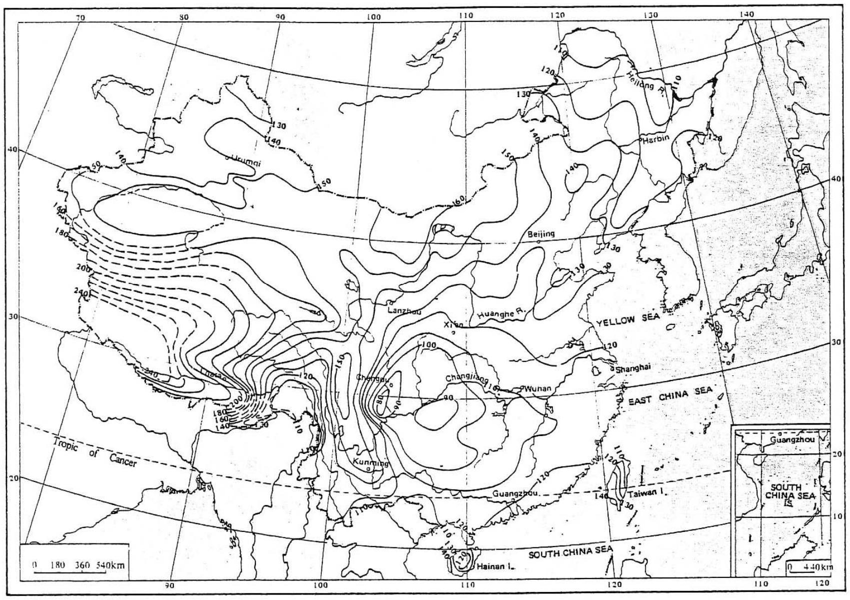


Figure 4.3 Distribution of annual total solar radiation in China (after Yang 1986)

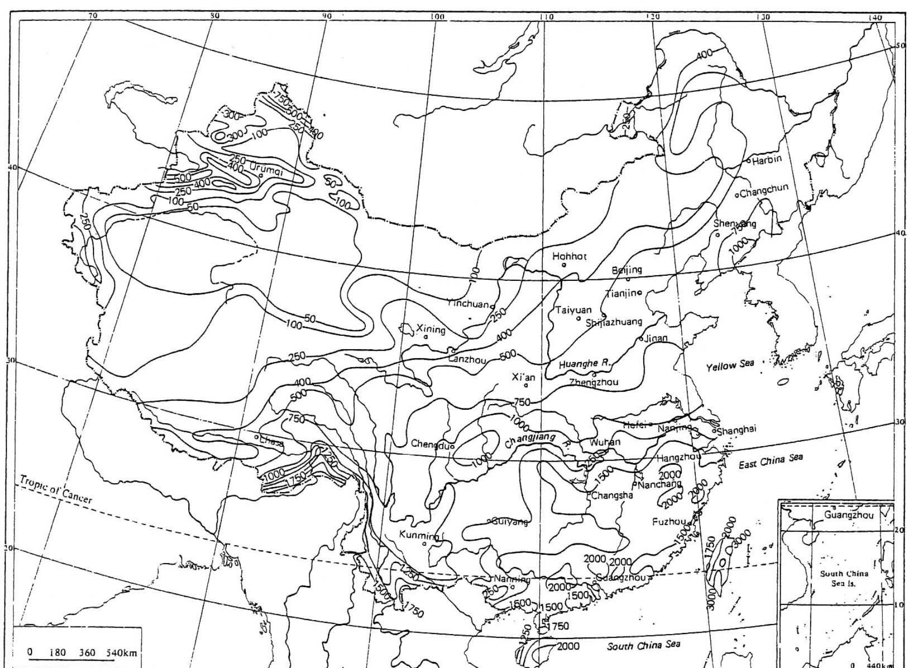


Figure 4.4 Distribution of annual precipitation in China (after Yang 1986)

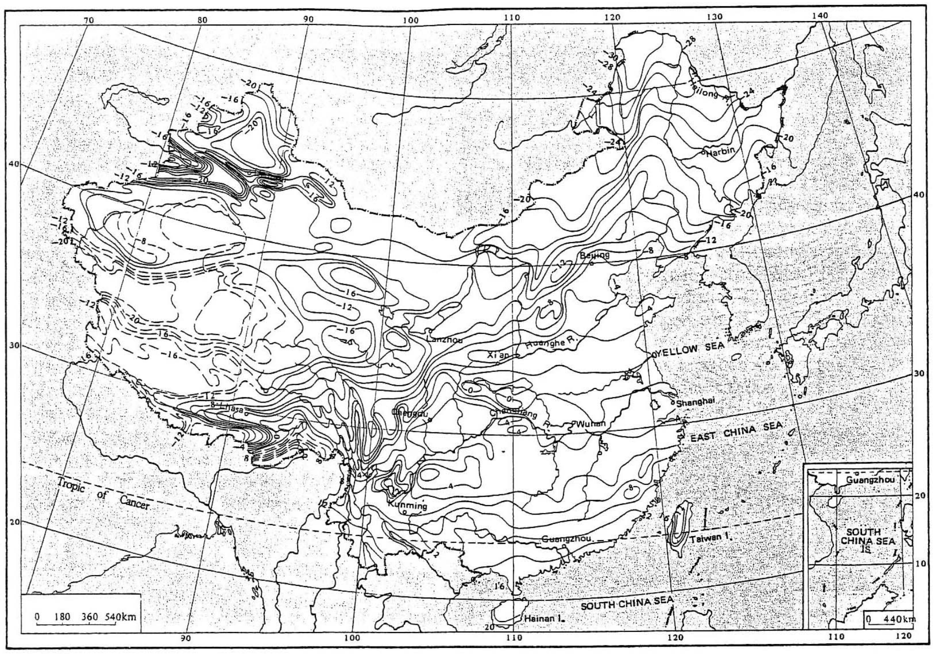


Figure 4.5 Distribution of mean January temperature in China (after Yang 1986)

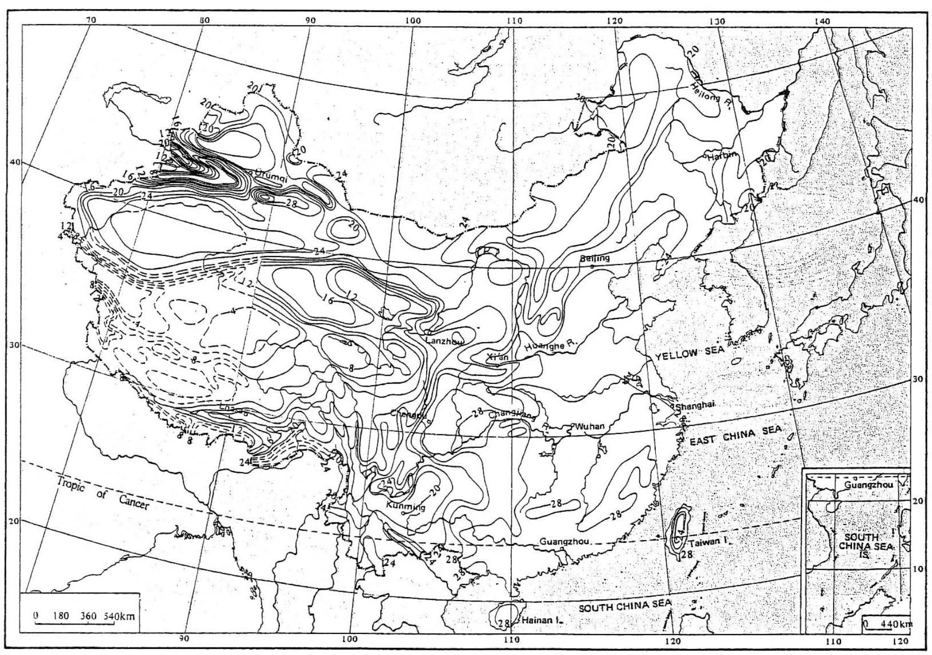


Figure 4.6 Distribution of mean July temperature in China (after Yang 1986)

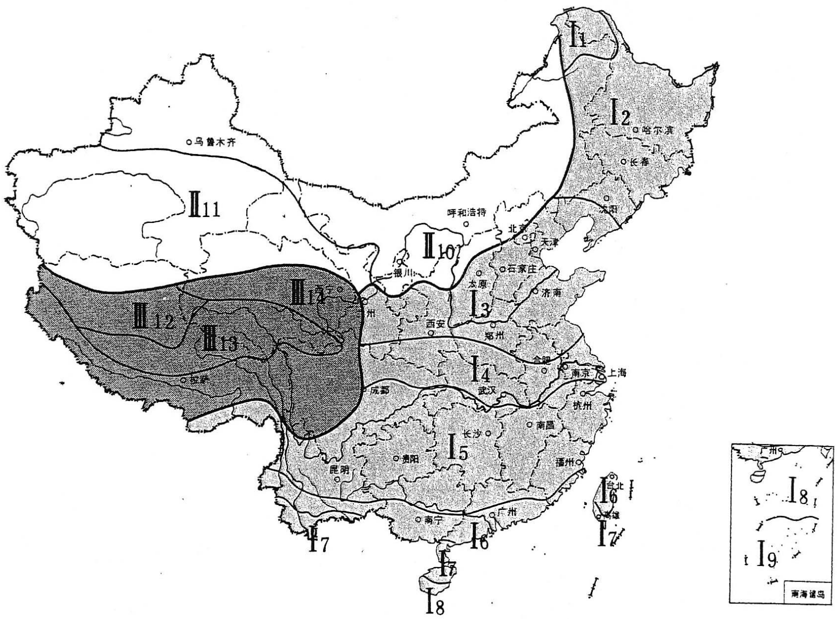


Figure 4.7 Distribution of major climatic regions in China
(after The Editing Committee of Agricultural Resources and Distributions in China 1987)

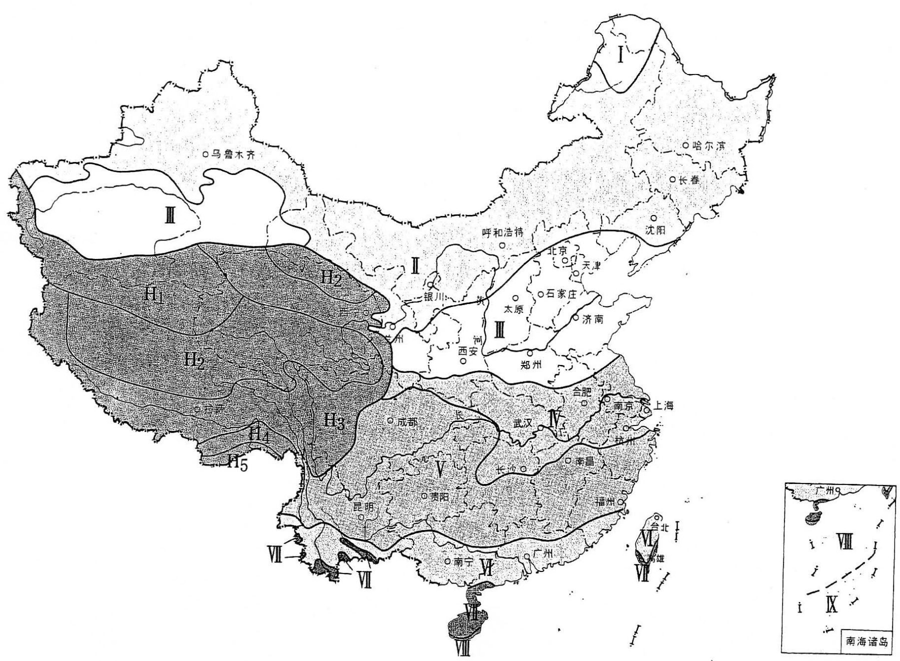


Figure 4.8 Distribution of temperature zones in China
(after The Editing Committee of Agricultural Resources and Distributions in China 1987)

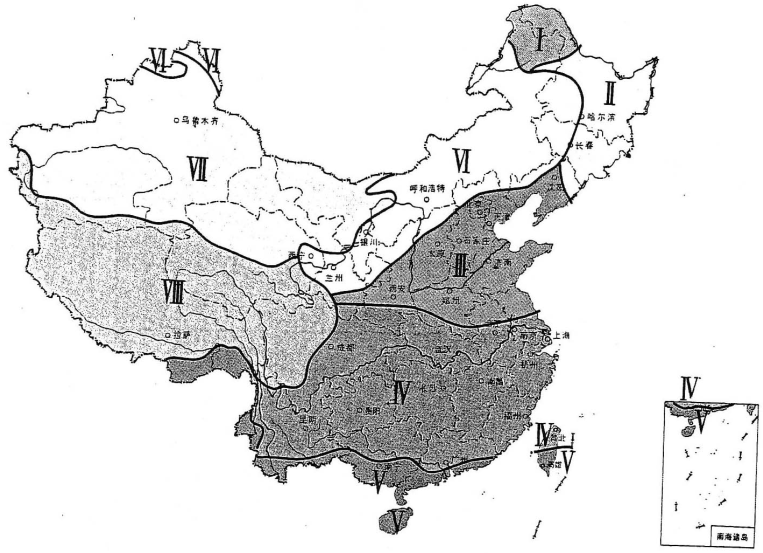


Figure 4.9 Distribution of vegetation zones in China
(after The Editing Committee of Agricultural Resources and Distributions in China 1987)

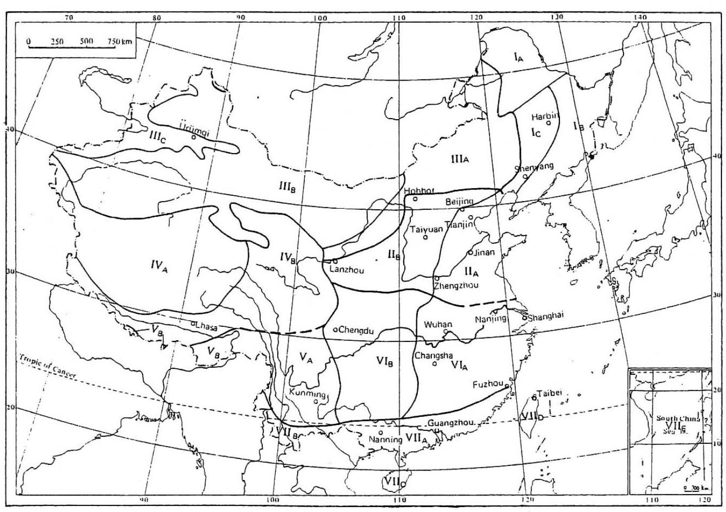


Figure 4.10 Zoogeographical regions in China (after Yang 1986)
I_A: Cool temperate forest fauna; I_B-II_B: Temperate forest, forest-steppe, and farmland fauna; III_A: Temperate steppe fauna; III_B: Temperate desert fauna; III_C-V_B: Highland forest steppe, meadow steppe, and alpine desert fauna; VI_A-VI_B: Subtropical forest, scrub, grassland fauna; VII_A-VII_E: Tropical forest, scrub, savanna, and farmland fauna

China is located on the eastern part of the Eurasia, facing the Pacific Ocean on the east. It consists of thirty three provincial level administrative units (Figure 4.1). The mainland of China spans from 54ºN to 20ºN and 74ºE to 135ºE. Its topography (Figure 4.2) can be divided to three regions: the Tibetan Plateau (also called Qinghai-Xizang Plateau) in the southwest, with mean elevation above 4,000 m; from the eastern margins of the Tibetan Plateau eastward to the Da Hinggan-Taihang-Wushan mountain chains, featured by plateaus, Gobi deserts, mountain chains and basins with elevations from 2,000 m to 1,000 m; the eastern part of China, including Northeast China Plain, North China Plain, the Middle-Lower Yangzi Plain, the Pearl Valley, and interspersed with hills below 500 m in elevation.

The three-region topography and some other important landmarks like the Qingling Mountain Chains-Huai River strongly affect the climate, and generally define major ecological zones. Based on such key climatic elements as solar radiation (Figure 4.3), precipitation (Figure 4.4), and winter and summer temperatures (Figures 4.5, 4.6), China can be divided into three great climatic regions (Figure 4.7): the Tibetan Frigid Plateau (III), Northwest Arid China (II), and Eastern Monsoon China (I). The two latter regions can be further divided to five temperature zones (Figure 4.8) from south to north: Tropical (VII and VIII), Subtropical (IV and V), Warm Temperate (III), Temperate (II), and Cool Temperate (I). East Monsoon China covers the eastern portion of the second region and the whole third region of topography. This area has been the home of the vast majority of Chinese since the beginning of human occupation. It is dominated by maritime monsoon from south and continental monsoon from north alternating in summer and winter. The temperature decreases from south to north, with sharper differences in winter. Precipitation is plentiful and concentrated in the high-sun growing season, which benefits agricultural production.

The biogeography of China is shaped by its climate and topography, and the zoogeography is associated with the vegetation. In terms of vegetation (Figure 4.9), East Monsoon China is covered by various forests from north to south: cool-temperate needle-leaved forest (I), temperate mixed needle- and broad- leaved forest (II), warm-temperate deciduous broad-leaved forest (III), subtropical evergreen broad-leaved forest (IV), and tropical monsoon and rain forest (V). Northwest Arid China and the Tibetan Frigid Plateau are primarily covered by grassland, dessert, steppe and tundra. China is home to more than 2,000 species of terrestrial vertebrates, which account for about 10 percent of the total terrestrial vertebrate species in the world. The distribution of fauna (Figure 4.10) is related to vegetation zones.

4.2 Modern Environment of the Middlle Yangzi Valley, Lower Yangzi Valley and Huai Valley

Given the locations of those sites with the earliest rice remains and rice agriculture, I will focus on the Middle Yangzi Valley, the Lower Yangzi Valley and the Huai Valley. In terms of administrative units, it consists of seven provinces: Henan, Anhui, Hubei, Hunan, Jiangxi, Jiangsu, Zhejiang and the city of Shanghai. The landscape is characterized by alluvial plains deposited by the Huai River, the

Yangzi River, their tributaries, and major lakes such as Poyang Lake, Dongting Lake, and Tai Lake. A series of small mountains disperse over the flat plains. Based on vegetation, the area can be divided along the Huai River to two parts: the northern warm-temperate deciduous broad-leaved forest zone, and the southern subtropical evergreen broad-leaved forest zone.

The area north of the Huai River consists of southern Henan, northern Anhui and northern Jiangsu. The landscape is flat, has low elevation and is watery. The climate is subhumid warm-temperate featuring a dry and windy spring, a warm and rainy summer, a fine and calm autumn, and a cold and dry winter. The hottest month is quite subtropical, with a mean temperature of 24 to 29 ºC. The mean temperature during the coldest month is from 0 to – 14ºC. Annual precipitation totals 500 to 800 mm. Rainfall is concentrated in summer, with a maximum daily precipitation of 100 to 200 mm. The vegetation is dominated by the warm-temperate deciduous broad-leaved forests, including a number of species of oaks and some deciduous hardwoods such as hackberry, ash, walnut, poplar, elm, beech, and maple. Since the area is mainly farmland, forests are small-scale and scattered. The fauna is dominated by all kinds of rats.

The area south of the Huai River includes most of Anhui and Jiangsu, and the whole Hubei, Hunan, Jiangxi, Zhejiang provinces and the city of Shanghai. The landscape is characterized by broad basins and valleys interwoven with mountains and hills. Chemical weathering and fluvial action are strong: red beds and karst topography are well developed. The landform consists of two parts: the Middle-

Lower Yangzi Plain and hills and basins south of the Yangzi River. In the latter part, hills are scattered with small basins and strips of flat plains along rivers or around lakes. The climate is humid subtropical monsoon. The winter temperature is generally lower than other parts of the world with similar latitudes. During the summer, maritime southeastern monsoon predominate, bringing in high temperatures and heavy rainfalls. The mean January temperature is between 2 and 8 ºC, but the absolute minimum temperature may drop below – 4 to – 14ºC. Summer is very hot, with absolute maximum temperature rise above 37 ºC. The climate features strong seasonality. Annual precipitation is abundant, generally above 1,000 mm. Over 70 percent of the total annual precipitation is concentrated in summer, but winter still has more than 10 percent of the precipitation. The vegetation is mostly subtropical evergreen broad-leaved forest. The trees are mainly evergreen oak, *Cataanopsis*, and *Pasania*, with over 150 species. The trees can be as high as 30 m. The fauna includes the *Euroscaptor* moles, some white-toothed shrews, various kinds of bats, snub-nosed Langurs, some macaques, the spotted Linsang, the coarse-haired hare, squirrels, bamboo rats, the feret badgers, crab-eating mongoose, and goat antelopes.

4.3 The Changing Environment from Late Pleistocene to Holocene

Evidence from a variety of fields including geology, paleontology, pollen analysis, and phytolith analysis contributes to our reconstruction of the changing environment related to the origins of rice agriculture. Since geological epochs have often been used alone or with absolute dating, we start with comparisons of geological chronology, absolute age, and archaeological sequence. As indicated by the dating of the earliest rice remains, the origins of rice domestication and rice agriculture happened during the Late Pleistocene and Holocene and define the transition from the Late Paleolithic to Early Neolithic. It is generally agreed that the Last Glacial Maximum (LGM), the peak of the Last-glacial period, is the beginning of a series of environmental changes that led to the origins of rice domestication and agriculture. Therefore, our reconstruction of paleoenvironmental changes starts with the LGM (about 21,000 BP) and ends at around 6,000 BP when the climate and landscape became stable. The process can be divided into four major time periods and will be discussed in the next section.

I. 21,000 – 15,000 BP

It was generally dry and cold during the LGM. The climate of the LGM included a very weak summer monsoon and a strong winter monsoon, which lead to a cold and dry environment (An et al. 1993). This was discovered by examining geological sediments and pollen assemblages. The loess sediment found in the Middle Yangzi Valley, dated between 21,000 and 13,000 BP, indicates the environment was comparable to the cold and dry environment (300 – 600 mm annual precipitation) of the modern Loess Plateau of Northern China. Floral pollen from the loess shows a vegetation of coniferous and a grassy steppe environment (Yang 1986). A series of pollen assemblages also indicate a steppe environment with coniferous and deciduous trees. In the Longquanhu pollen profile, the distribution of vegetation is herbs 60%, trees 30% and ferns 10%. Most herbs are Artemisa and Gramineae; fir, pine and birch are major components of trees. Based on the vegetation, the maximum average monthly temperature could be 10 – 15 ˚C with a precipitation of 500 mm (Liu 1991). The Wuhu pollen profiles show a slightly different picture. The environment between 21,000 and 18,000 BP is considered relatively mild, as trees (mainly oak) account for 56-78% of the pollen profile. It changed to a steppe environment from 18,000 to 15,000 BP as the quantity of vegetation decreased and the percentage of herbs increased (Xu et al. 1987). Similar results were also obtained in the study of Diaotonghuan pollen (Wang et al. 1995). In spite of the difference, it is clear that during this phase the arid steppe environment of North China expanded southward, and the mixed pine and deciduous broad-leaved forests retreated south of the Yangzi River. The sea level, which was affected by the dry and cold climate, may have been up to 180 meters lower than today (Huang 1998). As a result, the islands of Japan, Taiwan and Hainan might have connected to Mainland China, and the mouth of the Yangzi River may have been some 600 km southeast from its present location (Yasuda 1996).

II. 15,000 – 11,000 BP

This period is characterized by environmental amelioration with some fluctuations. In the Zhenjiang pollen profile, trees increased to almost 50% of the vegetation, with oak becoming the major component. Herbs account for about 40%, the remaining is ferns. This vegetation indicates the climate was humid and warmer than previous phase. The climate turned to cold and dry again, as the quantity and variety of the pollen declined substantially. The dominance of drought-resistant herbs in the vegetation suggests a steppe environment with sparse trees during the latter stage of this phase (Xu et al. 1987). The Diaotonghuan pollen shows a more fluctuated picture. The vegetation from 15,000 to 13,700 is a mixed coniferous and broad-leaved forest. The presence of some subtropical plants and the abundant pollen suggest this is a warm and humid environment similar to that of the present. Until 13,000 BP, the climate became cold and dry and the vegetation was coniferous forest and steppe. From 13,000 to about 12,000 BP, a mixed coniferous and broad-leaved forest and warm and humid environment returned. Until about 11,500 BP, the environment turned cold and dry again. To 11,000 BP, the environment became similar to that of the present again (Wang et al. 1995). A similar fluctuating pattern was reflected in sporadic data collected from the Lower Yangzi Valley (Xu 1992). The Qidong pollen profile of the Yangzi Delta also indicates that in the latter stage of this period the climate was similar to the present subtropical environment but slightly cooler (Liu et al. 1992). A total of six assemblages of fauna (see Table 4.1), three of the Middle Yangzi Valley and three of the Lower Yangzi Valley, also support the environmental amelioration claim. The existence of a substantial percentage of temperate to subtropical species in these faunal assemblages, such as macaque, giant tapir, Chinese rhinoceros, Sumatra gazelle, bamboo rat, masked palm civet, panda, monkey, Asiatic elephant, porcupine, Stegodon, etc., indicates the environment during this period was similar to that of the present, with a warm and humid climate.

Site	**Dating and Method**	**Species**	**English Name**	**Habitual Environment**
Zhangnaodong	13490±150 bp C14 uncalibrated	*Rodentia*		
		Meles leucurus	Badger	Forest and densely vegetative areas
		Ailuropoda melanoleuca	Giant panda	Bamboo forest
		Vulpes	Fox	Hilly/forest areas
		Stegodon orientalis	Stegodon	Forest and bush
		Dicerorhinus		Cool-temperate forest or forest edge
		Megatapirus augustus	Giant tapir	(Sub)tropical grassy plains
		Bubalus	Buffalo	Moist bush/forest
		Cervus	Deer	
		Nemorhaedus goral	Himalayan goral	Rugged, wooded mountains
		Kanjereus		(Sub)tropical bushy areas
Yanerdong	Late Paleolithic (estimated age)	*Macaca*	Macaque	Subtropical forest
		Macaca arctoides	Red-faced Macaque	Subtropical forest
		Hystrix		
		Rodentia		
		Lepus	Hare	
		Ursus arctos	Brown bear	Deciduous forest/bushy areas
		Cuon javanicus	Javanese dhole	Non-desert environment
		Stegodon orientalis	Stegodon	Forest and bush
		Megatapirus augustus	Giant tapir	(Sub)tropical grassy plains
		Rhinoceros sinensis	Chinese rhinoceros	(Sub)tropical forest/watered areas
		Bos	Ox	
		Cervus	Deer	
		Muntiacus muntjak	Muntjac	Forest/dense vegetated areas with water
		Ovis	Sheep	Upland/grassy mountains
		Gezella	Gazelle	Dry open or bushy lands
		Sus scrofa	Wild boar	Forest

Sanshandao	Late Paleolithic (estimated age)	*Macaca*	Macaque	Subtropical forest
		Rattus rattus	Black rat	Human commensal
		Hystrix		
		Nyctereutes procyonoides	Raccoon dog	River valley, forest and steppe
		Arctonyx collaris	Hog badger	Forest
		Ursus arctos	Brown bear	Deciduous forest/bushy areas
		Ursus thibetanus	Black bear	Moist deciduous forest
		Mustela	Polecat	Steppe
		Meles leucurus	Badger	Forest and densely vegetative areas
		Crocuta crocuta ultima	Hyena	Steppe
		Lynx lynx	European lynx	Forest, cold environment
		Panthera tigris	Tiger	Forest
		Bovinae		
		Cervus unicolor	Sambar	Wooded area
		Muntiacus reevesi	Small muntjac	Forest, dense vegetated areas with water
		Muntiacus muntjak	Muntjac	Forest/dense vegetated areas with water
		Ovis	Sheep	Upland/grassy mountains
		Sus scrofa	Wild boar	Forest
Shenxiandong	11200±1000 bp C14 uncalibrated	*Scaptochirus*	Short-faced mole	Dry steppe and sandy area
		Macaca	Macaque	Subtropical forest
		Cricetus	Ratlike hamster	Dry and cold steppe, border of desert
		Rattus rattus	Black rat	Human commensal
		Hystrix	Old world porcupine	Forest, mountain, steppe
		Leporide		Steppe, forest
		Nyctereutes procyonoides	Raccoon dog	River valley, forest and steppe
		Ursus arctos	Brown bear	Deciduous forest/bushy areas
		Mustela	Polecat	Steppe
		Meles leucurus	Badger	Forest and densely vegetative areas
		Paguma larvata	Masked palm civet	(Sub)tropical forest
		Crocuta crocuta ultima	Hyena	Steppe
		Felis teilhardi	Wild cat	Forest

		Bovinae		
		Cervus	Deer	
		Sus scrofa	Wild boar	Forest
Yuchanyan	12000-8000 bp AMS uncalibrated	*Macaca*	Macaque	Subtropical forest
		Hystrix	Old world porcupine	Forest, mountain, steppe
		Rodentia		
		Rhizomys	Bamboo rat	Subtropical bamboo forest
		Nyctereutes procyonoides	Raccoon dog	River valley, forest and steppe
		Arctonyx collaris	Hog badger	Forest
		Ursus arctos	Brown bear	Deciduous forest/bushy areas
		Mustela	Polecat	Steppe
		Meles leucurus	Badger	Forest and densely vegetative areas
		Paguma larvata	Masked palm civet	(Sub)tropical forest
		Felis teilhardi	Wild cat	Forest
		Viverra zibetha	Oriental civet	Forest, bush and meadow
		Viverricula indica	Rasse	Forest, bush and meadow
		Bovinae		
		Cervus nippon	Sika deer	Fores/grass
		Cervus unicolor	Sambar	Wooded area
		Sus scrofa	Wild boar	Forest
Xianrendong	10000-9000 bp C14 and pottery seriation crossdate	*Macaca cf. mulatta*	Rhesus monkey	Forest
		Lepus	Hare	
		Nyctereutes procyonoides	Raccoon dog	River valley, forest and steppe
		Mustela sibirica	Siberian weasel	Forest
		Arctonyx collaris	Hog badger	Forest
		Paguma larvata	Masked palm civet	(Sub)tropical forest
		Felis bengalensis	Leopard cat	Forest
		Felis	Small cat	
		Viverricula		
		Canis	Dog	
		Sus scrofa	Wild boar	Forest
		Cervus		Forest, glassland

		hortulorum		
		Cervus elaphus	Red deer	
		Elaphurus davidianus	David's deer	Swampy area
		Hydropotes inermis	Chinese water deer	Tall reeds, rushes
		Muntiacus muntjak	Muntjac	Forest/dense vegetated areas with water
		Ovis	Sheep	Upland/grassy mountains

Table 4.1 Upper Pleistocene Fauna in the Middle and Lower Yangzi Valleys

References: Zhangnaodong – Huang et al. 1987
Yanerdong – Hunan Provincial Institute of Archaeology and Shimen Museum 1994
Sanshandao – Zhang et al. 1987
Shenxiandong – Li and Lei 1980
Yuchanyan – Yuan 2000
Xianrendong – Jiangxi Cultural Relics Adminstration 1963, Jianxi Musem 1976
Lu 1999

III. 11,000 – 10,000 BP

The environment of this period was strongly affected by the Younger Dryas event. An et al. (1993) show abrupt climatic anomalies during this phase. The climate began with a sudden strengthening of the summer monsoon and a strong winter monsoon, indicating the sudden appearance of increased seasonal distinction, with summers warmer than today and winters cooler. It was followed by a weaker summer monsoon and stronger winter monsoon, with a cold and dry climate. This deterioration is also reflected in pollen profiles. In the Zhenjiang profile, the quantity of arboreal pollen fluctuated during this period. Trees decreased whereas ferns increased significantly (Xu et al. 1987). In the Taihu (Xu et al. 1996) and Qidong (Liu et al. 1992) profiles, a sudden increase of fir, spruce and drought-resistant herbs support the environmental deterioration claim. Affected by the deterioration of climate, sea level dropped sharply during this phase. During the first 100 years, the sea level dropped 5 meters, descending at a rate of 35 mm/year (Geng 1981).

IV. 10,000 – 6,000 BP

The Holocene climate generally trends toward becoming more humid and warmer. The winter monsoon weakens and a strong, warm and humid summer monsoon becomes dominant (An et al. 1993). At the Holocene thermal optimum, around 8,000 BP, the average temperature was 4 ˚C higher than that of the present. This was followed by both cold and warm temperature fluctuations. At 6,000 BP, the climate became stable and has stayed the same until now (Shi et al. 1993). During this period, loess deposition stopped and loam began to accumulate on top of it. Since loam is only formed in a temperate and humid environment, the deposit of loam indicates a climatic amelioration (Yang 1986). Pollen assemblages also reflect this trend. In the Longquanhu profile, the quantity of pollen increased. Trees increased in vegetation, and there was a decrease in herbs. The proportion of evergreen trees increased significantly while firs dropped substantially. All these indicate a warmer and wetter environment (Liu 1991). Similar phenomena were found in the Zhenjiang, Taihu and Qidong profiles, which show a significant increase of subtropical broad-leaved trees (Liu and Chang 1996). In the Qingfeng profile, the pollen shows the vegetation changed from warm temperate broad-leaved deciduous forests to subtropical mixed broad-leaved evergreen forests (Tang and Shen 1992).

Evidence from archaeological sites of this period provides more support of this amelioration. Three sites have been chosen to represent three parts of the area: Pengtoushan of the Middle Yangzi Valley, Hemudu of the Lower Yangzi Valley, and Jiahua of the Huai Valley.

The Pengtoushan site is dated to about 9,000 – 7,000 BP. The pollen of the first millennium was dominated by broad-leaved China fir, and other components are rice, herbs, and ferns. During the second millennium, trees accounted for over 80% of the pollen, and pine became dominant, followed by China fir. All these indicate a subtropical environment similar to that of today (Hunan Provincial Institute of Archaeology Pollen Lab 1990).

The two lower levels of Hemudu are dated to about 7,000 – 6,500 BP. Fauna found there includes monkeys, sheep, deer, elaphure, red deer, muntjak, water deer, rhinoceros, elephant, tiger, bear, alligator, turtle, tortoise, etc. Flora consists of seeds of rice, bottle gourd, acorns, water-caltrop, and leaves of a number of subtropical broad-leaved trees. Pollen grains show species of warmer and moister climate. These indicate a subtropical environment similar to the present, but the climate during the occupation seems to have been warmer and moister than today (Zhejiang Provincial Museum 1978b).

The Jiahu site, dated to around 9,000 – 8,000 BP, contains fauna, flora, and phytolith data on the paleoenvironment. The fauna consists of deer, marten, badger, boar, wildcat, hare, turtle, tortoise, alligator, and domesticated pig, sheep, buffalo, etc. The flora is mainly seeds and husks of wild and domesticated rice. Phytoliths are dominated by types found in warm and moist environments. The existence of typical subtropical species like alligator, buffalo and wild rice, along with phytolith evidence, indicate that the climate during the occupation was warmer and moister than that of today, probably similar to the present Yangzi region (Zhang 1998).

As the warming occurred, sea level rose and altered the coastline. During the first two thousand years, sea level rose at an average speed of 5.4 mm/year (Yang and Xie 1984). At the Holocene Marine Transgression (8,000 – 7,000 BP), sea level was 4 – 5 m above the current level (Huang 1998). As a result, low elevation basins and alluvial plains in the Lower Yangzi Valley were inundated, and ground water level in rivers and lakes also lifted. It is believed that the two major lakes of the Middle and Lower Valley – Dongting and Poyang – are the remains of a large water body called "Yunmong Ze" (Zhao 1986). Another major lake, Lake Tai, was a bay on the sea coast during this period. These findings are consistent with what is recorded in ancient Chinese texts (Chang 1986).

4.4 The Environmental Effects on Humans

Although the determinative role of environment on the origins of agriculture is still debated, its effects on human cultures, particularly on human subsistence, are clear. Humans have an active influence on their environment, but they are also conditioned by the environment. A series of variables: vegetation, fauna, climate, and sea level will be discussed to evaluate their effects on humans.

4.4.1 Vegetation

The change of vegetation from Upper Pleistocene to Holocene is foremost in our consideration of environment, because it not only affected the ecology of human beings but also determined the food resources available to them both before and after the initial domestication of rice.

As mentioned above, the area including the Middle-Lower Yangzi Valley was dominated by a cold and dry steppe environment from 21,000 to 15,000 BP. The landscape was covered by grassland with sparse coniferous trees such as pines. There is no reliable archaeological data for this period, therefore we do not know the kinds of plants collected by humans. We do know some species of pines can provide edible and nutritious nuts.

From 15,000 to 11,000 BP, the area witnessed back-and-forth fluctuations between a steppe environment and mixed coniferous and broad-leaved evergreen forests. This phenomenon indicates this area was a transitional zone between cool and dry temperate grasslands and warm and humid subtropical forests. The fluctuations in vegetation could have challenged the adaptations of hunter-gatherers. As subtropical vegetation zones moved northward into this area (due to climatic amelioration), the variety of plant foods available to them increased considerably.

In the Yuchanyan site, dated to about 12,000 BP, over 40 plant species were found and four of them are edible: Chinese gooseberry (*Actinidia chinensis*), hackberry (*Actinidia* sp.), wild grape (*Vitis* sp.), and plum (*Prunus mune*). The seeds of *Celtis* sp. are particularly abundant, including *C. biondii* and *C. julianae*. They have been found in many other Paleolithic sites in China and are believed to have been utilized by humans for a long time (Yuan 1999). More importantly, wild rice was not only found in the Yangzi Valley during this period, but there is also evidence it was consumed by humans and may have been in the earliest stage of domestication, as is evidenced by remains from Yuanchanyan (ibid). In the Diaotonghuan site, phytoliths of wild rice were found dating earlier than 12,000 BP (Zhao 1998). And in Xianrendong, isotopic analysis of human bone suggested possible human consumption of wild rice during this period (MacNeish et al. 1995). It is clear that by the end of this period, humans of this area were well adapted to the unstable but mild habitat. This prepared them to face a more severe change in their environment during the next millennium.

During the Younger Dryas, the vegetation saw the retreat of subtropical trees and the return of dry, cold steppe. In addition to the deterioration of the general ecology and the reduction of natural plant resources, the most significant effect related to the origins of rice domestication is the disappearance of wild rice in the Yangzi Valley. Phytolith data from the Diaotonghuan site (Zhao 1998) and the paleo-esturay of the Yangzi River at the mid-west margin of the Okinawa Trough (Lu et al. 2002) both indicate the absence of rice remains during the Younger Dryas. This situation likely had a profound influence on human subsistence. To offset the sharp decline of natural plant food resources, local inhabitants could have intensified their collection activities to increase the yield of the available edible plants. Although this behavioral change has not been seen in archaeological sites in China during this period, partially due to the extremely limited data, it has been observed in the Near East (Hillman 1996). The development of intensification is critical to the origins of rice domestication, for intensification leads to domestication.

The general amelioration of environment during the Holocene led to the return of the subtropical vegetation. During the early stage of the Holocene, subtropical vegetation could occupy the southern part of the current temperate zone where the Jiahu site is situated. Along with the return of subtropical broad-leaved evergreen trees, the range of wild rice extended north of the Yangzi River and probably reached the Huai Valley. The existence of wild rice made the following rice domestication possible. By the Hemudu period, around 7,000 BP, agricultural societies based on domesticated rice and other domesticated plant and animal species were established.

4.4.2 Fauna

Faunal resources are closely related to the vegetation and are affected by the changing climate. Like plants, animals represent an important food resource for hunter-gatherers and farmers. The variability in fauna influenced the activities of hunter-gatherers significantly. We know little about the fauna from 21,000 to 15,000 BP, because no faunal evidence is securely dated to this period. The dating of the eight faunas of Upper Pleistocene in the Middle and Lower Yangzi Valley can only allow us to place them to the terminal stage of the period: 15,000 – 10,000 BP. These faunal remains share some common characteristics.

First, the composition of these faunas shows a mix of North China (temperate zone) fauna and South China (subtropical zone) fauna, which is consistent with the fluctuating climate and vegetation between these ecological zones. Species belonging to the typical southern giant panda – Stegodon fauna, including giant panda, Stegodon, macaques, giant tapir, Asiatic elephant, Chinese rhinoceros, etc., as well as temperate species such as brown bear, European lynx, short faced mole, ratlike hamster, and so on may be found.

Second, the faunal resources of this period were relatively rich and stable in the Yangzi Valley when compared to those in North China. In spite of the fluctuating climate and vegetation, particularly the effect of the Younger Dryas, a considerable number of animal genera existed with some minor changes during the Upper Pleistocene (Han and Xu 1989). Most of the faunal groups in the area consist of around 20 identified species. This situation could result from the less severe climatic fluctuations in the area. In particular, the cold winter monsoon could have a weaker influence in areas with lower latitude, so the winter climate was less severe in the Middle and Lower Yangzi Valley compared to that in North China. As a result, some North China species moved southward when faced with the severe climate, whereas those local southern species could still survive in places where the climatic change was not too dramatic.

Third, there is clear evidence of human utilization of animals during this period. In those faunal remains found on archaeological sites, animal teeth and long bones were found. Many of them were burnt, and some bones have cutmarks. This probably reflects human consumptions of these animals (Huang et al. 1987, Yuan 1999). In one instance, researchers found most of the ungulate teeth were deciduous and inferred these ungulates were killed as young animals (Hunan Provincial Institute of Archaeology and Shimen Museum 1994). Because most of the faunal species at sites are ungulates and small carnivores that contain a lot of meat and move slowly, these animals may have attracted hunters and could have been easily caught (Lu 1998).

Entering the Holocene, the variety of fauna in the Middle and Lower Yangzi Valley remained relatively stable. Very few species became extinct. With continuous climatic amelioration, more and more subtropical species returned to the Yangzi Valley and some extended to north of the Huai River. This is supported by the over 60 subtropical species in the Hemudu fauna (Liu and Yao 1993) and the existence of some subtropical species in the Jiahua fauna (Zhang et al. 1991). Although wild animals existed in many early Holocene faunas, solid evidence of domesticated dog and pig in the Hemudu fauna indicates that, as late as 7,000 BP, domesticated animals became part of agricultural activities.

4.4.3 Climate

The monsoon is the most influential climatic variable when considering the changing environment from the Upper Pleistocene to the Holocene in China. The two monsoon systems that affected the Middle and Lower Yangzi Valley during this period are the northern Plateau Monsoon in winters and the Eastern Asian Monsoon in summers. Due to this particular climatic phenomenon, the region along thirty degrees of latitude in China, mainly the Yangzi Valley, is drastically different from most regions of the same latitude in the world in terms of its subtropical and temperate climate, abundant water and therefore a dense population. However, summer monsoon often brings abrupt and concentrated rains that erodes soil and causes floods. The monsoon system during Upper Pleistocene and early Holocene was characterized by high-frequency variability on a scale of 1000-years or less. This resulted in the changes of vegetation, the migrations of fauna that was associated with the vegetation, as well as seasonal floods. The effects of these phenomena on prehistoric people were profound: not only were their natural food resources conditioned by the environment, but their selection of settlement locations were also limited by it (An et al. 1993, 2000, An 2000).

As it relates to the origins of rice agriculture, the effects of monsoon during two particular periods are significant: the Younger Dryas (11,000 – 10,000 BP) and the Holocene Optimum (8,000 – 7,000 BP). As discussed above, the Younger Dryas brought the Middle and Lower Yangzi Valley a very cold and dry climate suddenly. The climate had colder winters and warmer summers when compared to those of the present. This strong seasonality may have had a critical impact on the adaptive strategy of local hunter-gatherers. Increased seasonality meant their food resources became accessible during a shortened period. To secure food supplies during the long cold seasons may have required humans to find ways to store some of food they obtained during the growing season. This adaptive change of hunter-gatherers could lead to the beginnings of domestication. It is difficult to present details of this change and its impact on human cultures in the Middle and Lower Yangzi Valley, because the data concerning seasonal changes in both faunal/floral remains and human cultures in this area are very limited. However, recent study in the Near East suggests that increased seasonality during the Younger Dryas played a crucial role in the origins of agriculture (Rosen 2007). The effect of the monsoon season in the Middle and Lower Yangzi Valley during the Holocene Optimum was a precipitation increase (An et al. 2000). An important consequence of this phenomenon is the marine transgression that happened around the same time, which will be discussed in the following section.

4.4.4 Sea Level

Since the LGM, sea level throughout the world has been a generally rising, except for a short period of drop during the Younger Dryas. The change of the sea level in East China since the LGM has been relatively rapid. It is estimated from 15,000 to 10,000 BP the sea level rose at a rate of 24 mm/year and the coastline moved westward at 100 m/year (Huang 1998). But the rate was variable and during the first 100 years of the Younger Dryas (around 11,000 – 10,900 BP) the sea level fell at a rate of 35 mm/year (Geng 1981). During the Holocene Marine Transgression, the sea level rose to 4-5 meters above the current sea level (Huang 1998). There are two effects of the changing sea level on humans.

First of all, there is a general loss of land since the LGM. The comparison of the areas of East China Sea during the LGM and at present shows an increase from about 350,000 to 770,000 km^2. The Yellow Sea, which did not exist during the LGM, is now 380,000 km^2 in area (Xie et al. 1996). Since these two seas are near the Huai Valley and the Yangzi Valley, we can infer a huge loss of coastal land in these areas. The inhabitants of the inundated land would have had to migrate westward. The movement often stopped in front of mountains, because animals and humans tended to stay in the same ecological zone they had occupied and the mountains often serve as the boundary of different ecological zones. This may have resulted in a concentration of population and increased the pressure on food resources in these locations.

The other important impact of the changing sea level is the distribution of ground water. The rise of sea level leads to a general increase of the depth of water related to the Yangzi River, which affects the water levels of related tributaries and lakes. It is believed that most of lakes of the Middle and Lower Yangzi Valley are very young, appearing after 5,000 BP. The ground water in the area was less complex and less developed during the Upper Pleistocene and early Holocene, particularly the Younger Dryas, compared to that of today. Additionally, affected by the seasonality of the area, some ground water may have disappeared during dry seasons whereas floods could expand the ground water in wet seasons. Therefore, the settlement locations for the last hunter-gatherers and the early farmers were relatively limited. This situation could have led to population concentration.

4.5 Summary

The focus of this chapter has been the changing environment and its impact on the origins of rice agriculture. I examined the environment from the LGM to the early part of the Holocene, roughly between 21,000 and 6,000 BP. The region studied includes three areas: the Middle Yangzi Valley, the Lower Yangzi Valley and the Huai Valley. Based on evidence from geology, paleontology, pollen analysis, and phytolith analysis, the paleoenvironment of the region studied, between 21,000 and 6,000 BP, can be divided to four periods.

The first period, from 21,000 to 15,000 BP, is characterized by a dry and cold climate following the LGM. The vegetation was steppe with some coniferous and deciduous forests. The second period (15,000 – 11,000 BP) featured by environmental amelioration with some fluctuations. The vegetation showed changes between temperate steppe with sparse coniferous forests and subtropical broad-leaved evergreen forests. The fauna consists of both temperate and subtropical species, reflecting the fluctuations of the two vegetation zones. The third period, between 11,000 and 10,000 BP, is dominated by the Younger Dryas. The climate suddenly turned to cold and dry with an increased seasonality. The vegetation returned to steppe. During the last period, from 10,000 to 6,000 BP, the climate was becoming warmer and moister. The Middle and Lower Yangzi Valley was a subtropical environment similar to that of the present. During these periods, the sea level showed a general rising trend, except for the second period when sea level dropped sharply.

The changing environment has profound impacts on human subsistence. To analyze the relationship between environmental changes and the origins of rice agriculture, I discussed the environmental impact from four aspects: vegetation, fauna, climate, and sea level.

Vegetation from 15,000 to 11,000 BP was fluctuated constantly between temperate grassland and subtropical forests. Rich plant resources could encourage plant collections to supplement unstable faunal food supply. Wild rice was not only found in the area, but also utilized by humans as food. Vegetation resources reduced sharply during the Younger Dryas, and wild rice disappeared from the area. This could lead to an intensified collection of available plant resources. During the first stage of the Holocene, the return of subtropical vegetation, including wild rice, made it possible for local inhabitants to intensify their collection of a variety of plants such as wild rice thus begin rice domestication.

Faunal resources during the last stage of the Pleistocene were relatively rich and stable in terms of numbers of species even during the Younger Dryas. Animals were hunted and eaten by humans, but they were unstable food resources due to strong seasonality of the area. This required humans to collect plant food to ensure their security. Subtropical fauna was stable and rich in the Holocene, and some animals were domesticated by human as early as 7,000 BP.

The monsoon dominated climate of this region studies showed strong seasonality, particularly during the Younger Dryas. Food resources, particularly animals, become sparse in winter seasons. Precipitation concentration in summer seasons often caused floods. Both of these circumstances could restrict humans' selection of settlement locations and their ways of obtaining food, and hence change their adaptive strategies.

Finally, the general rise of sea level since the LGM could have led to the loss of coastal land and the migrations of coastal residents westward. The ground water system in the region before the early stage of the Holocene was not as complex and abundant as that of today. This, along with the effect of constant summer floods, could have limited the locations of stable water supplies and restrict the choices of where human settled.

Combining the effects of all these four environmental variables on human adaptation in the Middle Yangzi Valley, the Lower Yangzi Valley and the Huai Valley during the transition from the Pleistocene to the Holocene, I can postulate the development of human adaptation. The post-LGM environmental amelioration and the seasonality initiated the first step of change toward domestication: hunter-gatherers started collecting plant food more intensively (including wild rice) to supplement an unstable animal food supply in winter seasons. The severe environment during the Younger Dryas intensified this process: the more reduced and unstable food resources, along with population concentration (due to migration and reduced niche), led foragers to intensify their collection of available plants; intensive collecting was continued when the rich subtropical vegetation (in particular wild rice) returned during the early stage of the Holocene. This is when rice domestication originated.

The above hypothesis is made from the environmental perspective only, and the temporal and spatial resolutions of the postulation are very general and unclear. To understand the origins of rice domestication and rice agriculture, it is necessary to examine the transition from both environment and human perspectives, and formulate the understanding of the origins of rice agriculture on detailed case analyses.

Chapter 5

Archaeological Cultures Related to the Origins of Rice Agriculture

To explore the origins of rice agriculture, we must first understand the cultural contexts that allowed this change to occur. In archaeology it is generally thought that agricultural origins are the most significant event that happened during the transition from the Paleolithic to the Neolithic. Because the earliest rice remains have been found in the Middle Yangzi Valley and the Lower Yangzi Valley and slightly later in the Huai Valley, I will focus on the archaeological cultures in those areas. Due to limited data and imprecise chronology, these cultures are still poorly understood.

The biggest challenge in analyzing the cultural context of the origins of rice agriculture is to build a complete and detailed database. Current studies on the origins of rice agriculture only focused on a few representative sites. There is no comprehensive analysis of general cultural context concerning the origins. This may be one reason of the debates and deficiencies of existing studies discussed in Chapter 3. Most of the sites discussed in this chapter were discovered by chance. Both excavation and publication of these sites did not follow the standard procedure in Western archaeology. Flotation and piece plotting were not used in most sites, and the published reports are often very brief with incomplete information. Some excavation reports were not publicly issued.

The database presented in this chapter is the result of extensive collection and careful selection of all available published materials related to the origins of rice agriculture. It represents the most updated and comprehensive cultural context of the subject. However, the description of each site is not parallel due to the limitation of the source of information. To make the data of each site as informative and reliable as possible, I collate the information by using multiple sources whenever available and visiting a few important sites (listed in Chapter 1) to obtain first-hand information.

Unlike in Western archaeology, excavation reports in Chinese archaeology often use name of the excavation team as the author. This makes it difficult to know the name(s) of the investigator(s). However, based on limited information of these individuals and their research articles, a few important Chinese archaeologists can be briefed as follows.

Wenming Yan of Beijing University is the leading scholar on the origins of rice agriculture. He was the chief archaeologist of the excavations of Xianrendong and Diaotonghuan, and published a series of articles on the origins.

Jiarong Yuan of Hunan Provincial Institute of Archaeology is the investigator of the Yuchanyan excavations. His researches also enriched our knowledge of the Paleolithic cultures in the Middle Yangzi Valley.

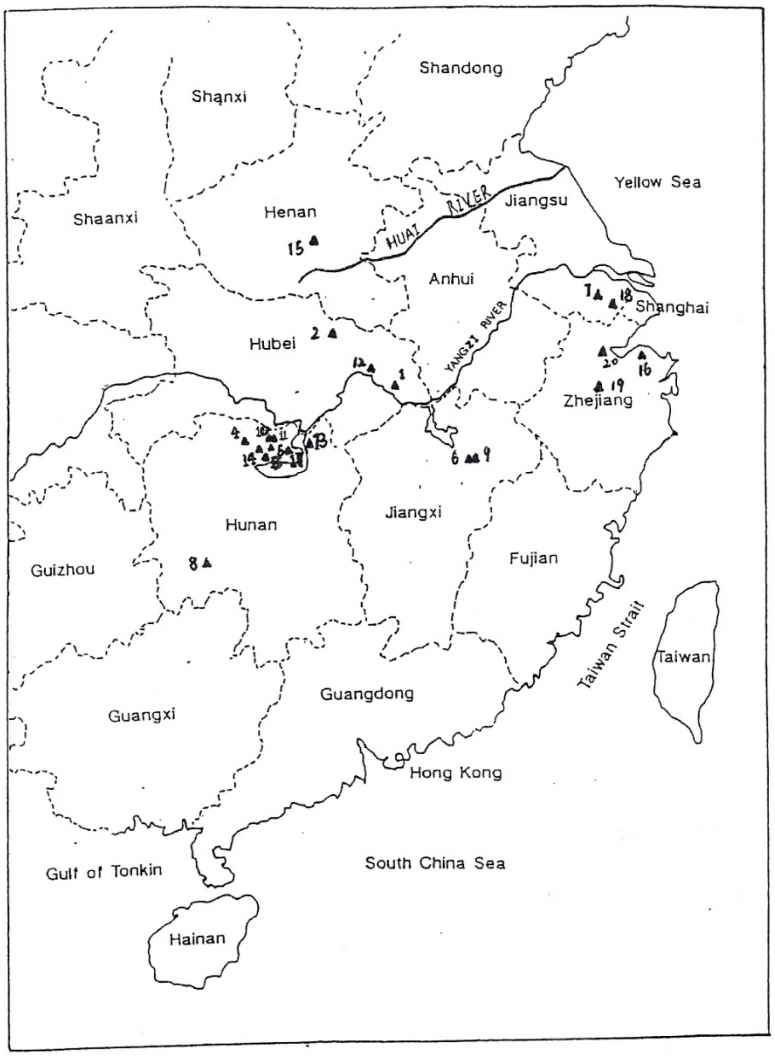
Anping Pei of Nanjing Normal University supervised the excavations of Pengtoushan, Bashidang and other Neolithic sites in the Middle Yangzi Valley. He published several articles on the origins of rice agriculture in the Middle Yangzi Valley.

Juzhong Zhang of Henan Provincial Institute of Cultural Relics is the principle investigator of Jiahu. He is the leading scholar on the “Huai Valley Hearth” theory of the origins of rice agriculture.

Another difficulty in analyzing the cultures of the Late Paleolithic and the Early Neolithic in these areas is the confusing chronology. Traditional Chinese Paleolithic chronology defines the Late Paleolithic as the period between 40,000 and 10,000 BP, which correlates to the middle and late Upper Pleistocene (Jia and Huang 1985). However, Chinese Neolithic archaeologists see the appearance of ground stone tools and pottery in archaeological assemblages as the beginning of the Neolithic (Zhang and Wei 2004). Recent archaeological discoveries of the oldest ground stone tools and pottery pushed the beginning of the Neolithic in China back to about 12,000 BP (Yan 1997, 1998). Since the origins of agriculture are mainly an event of the Neolithic, I follow the Chinese Neolithic tradition to set the chronological boundary of the Paleolithic and the Neolithic at 12,000 BP.

I will first discuss the Paleolithic cultures in the Middle Yangzi Valley and the Lower Yangzi Valley with an emphasis on those at the latest stage of the Late Paleolithic, for they provided cultural basis to the emergence of rice domestication (Figure 5.1). Then I will examine the Neolithic cultures in a chronological framework adapted from those presented by Chang (1986) and Yan (1997, 1998). Chang’s Chinese prehistoric chronology is the most familiar one to English readers and still largely stands up to new data. Yan’s framework is based on updated archaeological discoveries and has been adopted by most Chinese archaeologists. Accordingly, the

Neolithic cultures in the focused area can be divided into four periods: the Early Neolithic (12,000 – 9,000 BP), the Middle Neolithic (9,000 – 7,000 BP), the Late Neolithic (7,000 – 5,000 BP), and the Epi-Neolithic (5,000 – 4,000 BP) (Table 5.1). I will focus on the first three periods, because established rice agriculture has been convincingly identified in the late Neolithic, as demonstrated by sites such as Hemudu (Liu and Yao 1993).



1. Jigongshan
2. Zhangnaodong
3. Wuyashan
4. Yanerdong
5. Shiligang
6. Diaotonghuan
7. Sanshandao
8. Yuchanyan
9. Xianrendong
10. Pengtoushan
11. Bashidang
12. Chengbeixi
13. Fenshanbao
14. Hujiawuchang
15. Jiahu
16. Hemudu
17. Chengtoushan
18. Caoxieshan
19. Shangshan
20. Kuahuqiao

Figure 5.1 Archaeological sites discussed in Chapter 5

Period	Representative Cultures	Important Sites
Paleolithic (before 12,000 BP)	No defined culture of this period	Jigongshan, Zhangnaodong, Wuyashan, Yanerdong, Shiligang, Diaotonghuan, Sanshandao
Early Neolithic (12,000 – 9,000 BP)	No defined culture of this period	Yuchanyan, Xianrendong, Diaotonghuan, Shangshan
Middle Neolithic (9,000 – 7,000 BP)	Pengtoushan Culture	Pengtoushan, Bashidang, Chengbeixi
	Lower Zaoshi Culture	Zaoshi, Fenshanbao, Hujiawuchang
	NA	Kuahuqiao
	Peiligang Culture	Peiligang, Jiahu
Late Neolithic (7,000 – 5,000 BP)	Daxi Culture	Chengtoushan
	Hemudu Culture	Hemudu, Luojiajiao
	Majiabang Culture	Caoxieshan

Table 5.1 Chronological chart of related cultures and sites discussed in Chapter 5

5.1 Paleolithic Background in the Middle and Lower Yangzi Valleys

The Paleolithic remains in the Middle Yangzi Valley and the Lower Yangzi Valley are very limited and fail to demonstrate clear regional developmental sequences. To help the reader understand the Paleolithic cultural background, the discoveries of human and cultural remains from the beginning of human occupation are summarized. Then I focus on those sites which date to immediately before the transition to the Neolithic.

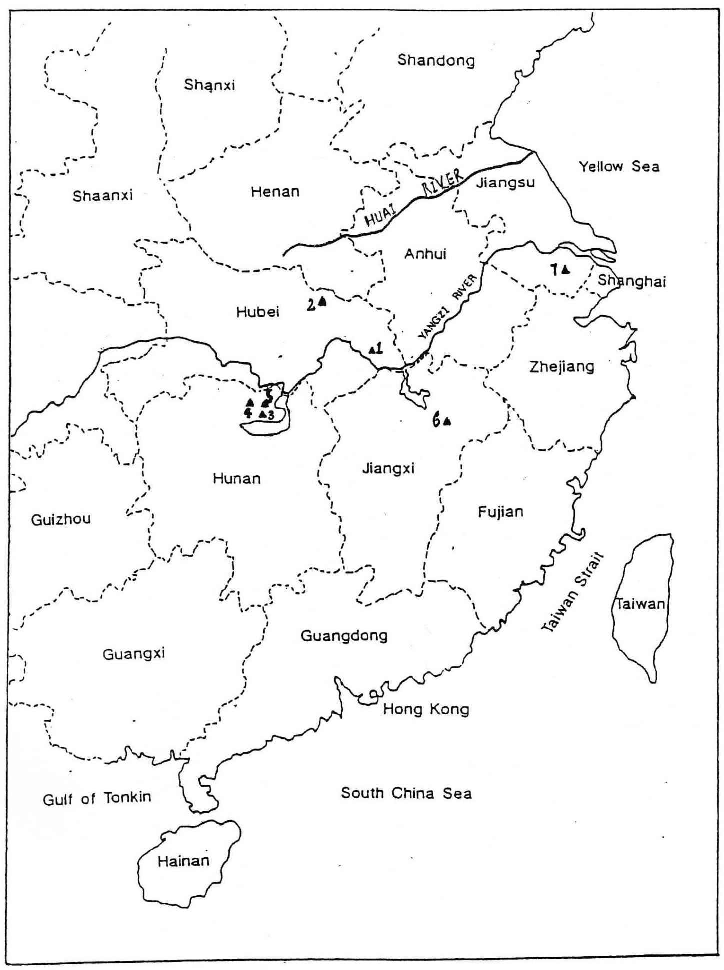
The earliest human cultural remains in the area are roughly dated to 800,000 – 700,000 BP, which is correlated to the beginning of the Middle Pleistocene (780,000 – 128,000 BP) in China. Even with limited Paleolithic remains in the area, their distribution is not even. Most of the remains were found in Hubei, Hunan and Anhui provinces. Although a substantial number of sites were found along riverside terraces and in caves, very few of them have been excavated with detailed reports. In general, the Paleolithic cultures in the Middle-Lower Yangzi Valley remained the same tradition until the LGM. The characteristics can be summarized in the following ways.

The lithic assemblage is dominated by typical Southern China pebble technology. The raw materials are pebbles of coarse quartzes and sandstones obtained directly from local riverbanks. Tools are made by direct percussion and generally without secondary retouch. Tool types include all kinds of large size tools such as choppers (over 50%), points, handaxes, large-size scrapers and stone balls. Small-size scrapers and other small-size tools appeared in the later stage of this period. There are some slight differences between the Middle and Lower Yangzi Valley: fewer stone balls and more flake tools such as scrapers are found in the Middle Valley than the Lower Valley.

In terms of settlement patterns, most of the sites were located on terraces of the tributaries of the Yangzi River. In the Middle Yangzi Valley, most of the sites concentrated in the Middle Yuanshui Valley and the Lower Lishui Valley. Surveys indicate that there are more than 100 sites in each of these areas (Yuan 2004). Clusters of sites are common. Quantities of artifacts vary drastically among the sites: some only contain several tools, while others have thousands of artifacts. This could reflect the different functions of the sites: those with large quantities and a variety of tool types may have been central (residential) camps, some with the concentration of particular type of tool could be camps used for special activities such as hunting or butchering, and those with very few artifacts might be temporary locations used during hunting or other activities. A similar pattern is also found in the sites of the Lower Yangzi Valley. In a few well preserved sites, such as the lower stratum of the Jigongshan site (Liu and Wang 2001) in Jiangling County of Hubei Province, the distribution of artifacts within the site exhibits different functional zones.

Human subsistence is understood by examining tool types in conjunction with environmental background. The major tool types of those sites are large-size chopper and point. Various kinds of choppers were mainly used for cutting and the points were for digging. These activities were adapted to the environment during that time. In spite of fluctuations, the Middle Yangzi Valley and Lower Yangzi Valley were largely covered by subtropical vegetation that could have provided abundant plant resources. To cut trees and dig plant roots, local inhabitants were encouraged to make stone tools such as choppers and points (Wang 1997). The increase of flake tools including small-size scrapers in lithic assemblages toward the end of this period may reflect the appearance of a new type of subsistence. This change will be discussed in the following section.

Since the LGM, there was a clear change of cultural tradition in the Paleolithic sites of the Middle Yangzi Valley and Lower Yangzi Valley. Although many archaeological assemblages dating to this period have been found through survey and surface collection, only a handful of sites have been reported in detail. I will present the basic discoveries of the sites, describe some common characteristics of the cultures, and finally attempt to analyze their connection and impact to the earliest Neolithic cultures in the same area. A total of seven sites from this period are presented (Figure 5.2), of which five are located in the Middle Yangzi Valley − the upper stratum of Jigongshan, Zhangnaodong, Wuyashan, Yanerdong, Shiligang, and two − Zone M-H of Diaotonghuan and Sanshandao are in the Lower Yangzi Valley. Six of the sites were excavated, and one site description is based on surface collections.



1. Jigongshan
2. Zhangnaodong
3. Wuyashan
4. Yanerdong
5. Shiligang
6. Diaotonghuan
7. Sanshandao

Figure 5.2 Paleolithic sites in the Middle and Lower Yangzi Valleys

Jigongshan

Jigongshan, of Jiangling County in Hubei Province, is located on top of a small hill on an alluvial plain 8 km north of the Yangzi Valley. This is an open area site that was excavated by a joint team of Jiangling County Museum and Beijing University between 1992 and 1993. The principle investigators are Deying Liu of the museum and Youping Wang of Beijing University. This is the only Paleolithic site in China that provides evidence of different activity areas. The discovery of in-site functional differentiation is based on a careful lithic analysis adopted from Western archaeology. The data and analysis of the site were published in a preliminary report (Liu and Wang 2001).

The assemblages can be divided into two strata according to cultural characteristics. The lower stratum contains over ten thousand lithic artifacts of which the dominant tool type is pebble chopper belonging to the Early Paleolithic (Figure 5.3). Based on lithic analysis, the lower stratum is suggested as a living and working floor for tool making and animal butchering. The upper stratum contains mainly small-size (2-3 cm) flake tools made of quartzite (43%), quartz (33%), chert (20%), and mudstone (4%). These tools are still made by direct percussion, but there is also retouch. The most numerous tool type is scraper. Only two points were found, both of which are very small. The remaining artifacts are cores, flakes, and debitage (Figure 5.4). Based on geological sediment, the estimated date of the upper stratum is around 20,000 bp (ibid).

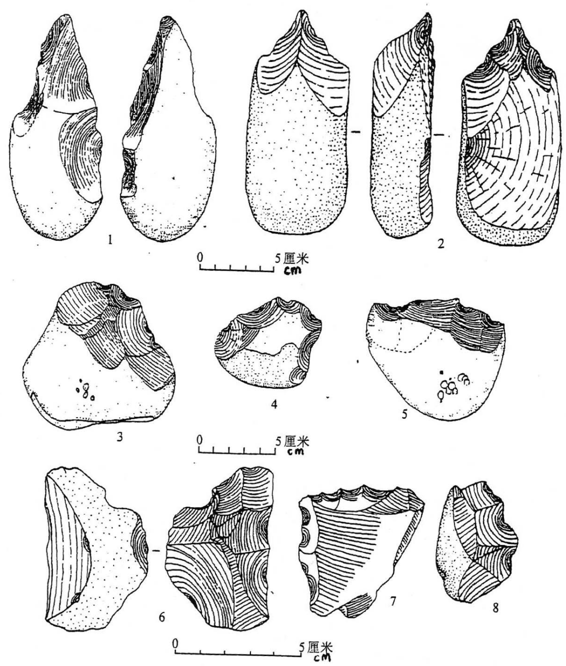


Figure 5.3 Lithic artifacts from the lower stratum of Jigongshan (after Liu and Wang 2001): 1,2 points; 3-5 choppers; 6-8 scrapers

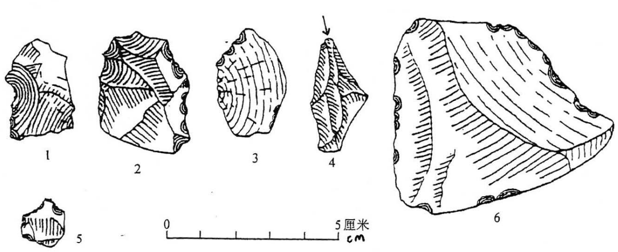


Figure 5.4 Lithic artifacts from the lower stratum of Jigongshan (after Liu and Wang 2001): 1 notch; 2,3 scrapers; 4 burin; 5 point; 6 worked flake

Between the lower stratum and the upper stratum the lithic assemblage shows difference in technology. In terms of the raw material, exotic high quality materials such as chert increased through time, but local pebbles were still the most common lithic material. Small-size scrapers replaced large-size choppers as the dominant tool type. Composite tools made of small thin flakes were used. The lithic technology of the upper stratum of Jigongshan is similar to North China chipped lithic tradition during the Late Paleolithic, which was adapted to the northern grassland environment. Therefore, this change may also indicate the increased importance of hunting in the human subsistence.

Zhangnaodong

Zhangnaodong, in Fang County, Hubei Province, is located 70 km east of the county seat. This is a rock shelter site that was excavated during two seasons in 1986. The principle investigator is Wanbo Huang of the Institute of Paleoanthropology, China Academy of Science. This is the only Paleolithic site in the Yangzi Valley that provides radiocarbon dating. A single radiocarbon date was taken on bone and dated to13,490 ± 150 bp, which places the site at the end of the late Paleolithic. There is only one brief report of the site (Huang et al. 1987).

The deposit can be divided into five strata and the assemblages from these the second to forth strata. According to their cultural characteristics, the researchers suggest that they belong to the same period. The assemblages consist of lithic artifacts and animal fossils (ibid).

Over two thousand lithic artifacts were recovered from three cultural strata at this site. The lithic materials used include black silica rock (44%), vein quartz (40%), with small amount of sandstone and mudstone. The majority of the artifacts were made of local pebbles. Tools were made by direct percussion, and some have retouch. Flakes dominate the lithic assemblage and a large number of cores were also found. The size of flakes ranges from 10 to 100 mm in length and 3 to 50 mm in thickness. The dominant tool type is the scraper. Other tools such as choppers and points are also presented. Most f the scrapers are middle to small-size, but a few large-size scrapers were found. The largest chopper weighs over 2,000 g. The so called “discoid chopper” was found in many surface collections of this period as well as in some Neolithic sites of the Middle Yangzi Valley (ibid).

Mammal fossils of twelve species were found. They include the giant panda (*Ailuropoda melanoleuca baconi*), stegodon (*Stegodon orientialis*), and Kirchberge’s rhinoceros (*Dicerorhinus cf. Kirchbergensis*), etc. (see figure 4.). This faunal assemblage belongs to the giant panda – stegodon fauna that was typical of the Yangzi Valley at this time. The existence of Kirchberge’s rhinoceros indicates that the environment during this period was likely cooler than today. It is also important to note that some bone fragments show evidence of firing and flaking (ibid).

Wuyashan

Wuyashan, Li County, Hunan Province, is situated on a small hill located on the terrace of the Daoshui River, which is a tributary of the Lishui River, a southward tributary of the Yangzi River. This is an open area site what was excavated in 1992 by Hunan Provincial Institute of Archaeology. Because there is no published report about the site, details of the excavation, including the investigators, are unavailable. The materials of this site came from a brief description (Yuan 2004).

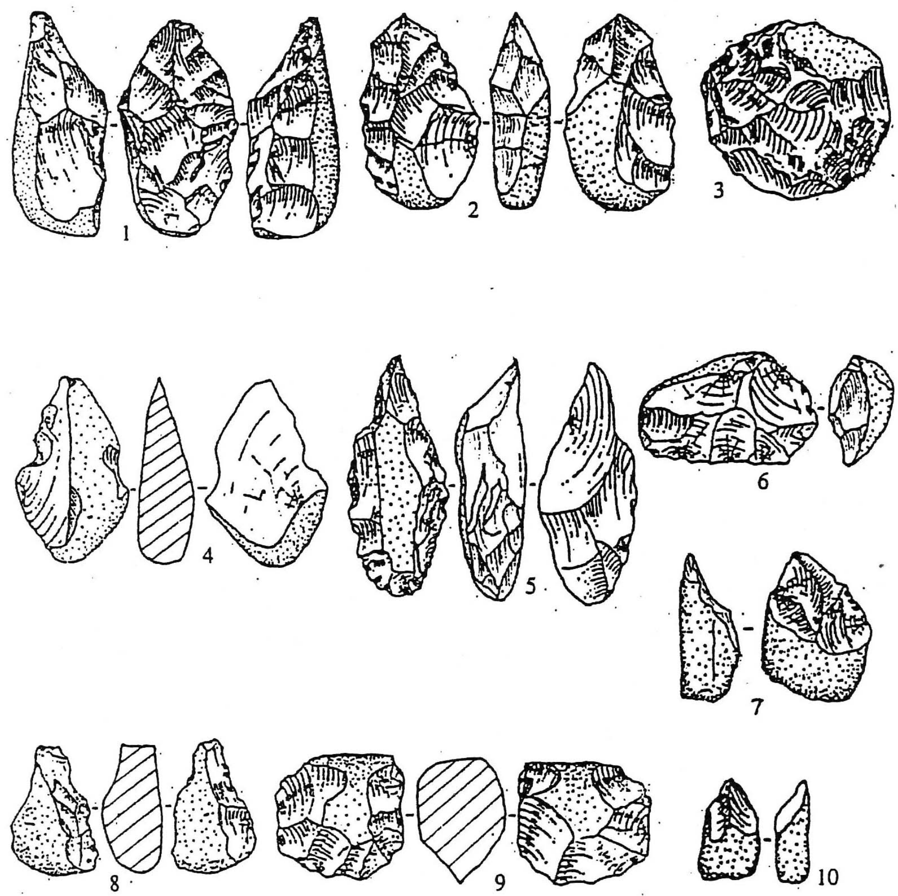


Figure 5.5 Lithic artifacts from Wuyashan (after Yuan 1995)
1,2,4,7,8,10 handaxe like implements; 3,5,6,9 choppers

Only stone tools were mentioned in this brief description (Figure 5.5). No quantity was listed and no illustrations of the lithic assemblage were presented. Lithic material is mainly silica rock, followed by sandstone. Other materials in small amount include chert, quartz and quartzite. Flake tools are the majority. Most were made by direct percussion and often lack of further modification. The toolkit consists of chopper, a handaxe-like implement, large points, scrapers, points, hammers, etc. 70% of them are small-size tools including various types of scrapers and points. The featured tool types of the site are a handaxe-like implement, the large point and the long scraper (ibid).

Based on the geomorphology and lithic characteristics, Yuan placed the site at the end of Upper Pleistocene and the Late Paleolithic. It is also mentioned that a number of other sites in Li County, such as Zhujiashan, Chenjiashanzui, Jinya, Hushan, Huashan, etc. also contain lithic assemblages similar to that of Wuyashan. All these assemblages are located in the same valley and represent a change of lithic technology toward small-size tool kits in the Middle Yangzi Valley at the end of the Paleolithic. Yuan used the term Wuyashan Culture to refer to these assemblages (ibid).

<u>Yanerdong</u>

Yanerdong, of Shimen County in Hunan Province, is located near the Dieshui River, another tributary of the Lishui River. Excavated in 1992 by Hunan Provincial Institute of Archaeology and Shimen Museum, the cave site consists of two small caves 7 m apart both with an elevation of 10 m. This is the only Late Paleolithic in the Yangzi Valley that has human remains found with artifacts and animal bones . No absolute dating has been done at this site. Based on lithic characteristics and faunal species, the site may date to the end of the Late Paleolithic. A brief report of this site was published in 1994 (Hunan Provincial Institute of Archaeology and Shimen Museum 1994)

Deposit of the site can be divided into seven strata. The unearthed materials from this site include lithic artifacts, bone tools (Figure 5.6), faunal remains, and human remains.

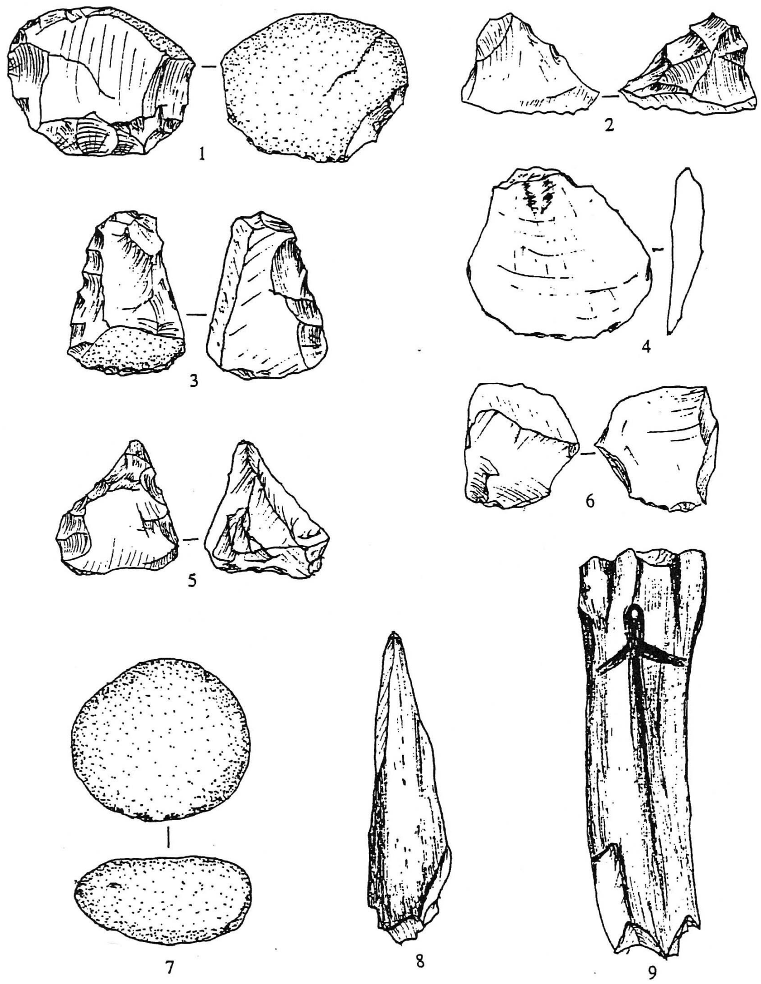


Figure 5.6 Artifacts from Yanerdong (after Hunan Provincial Institute of Archaeology and Shimeng Museum 1994)
1 chopper; 2-6 scrapers; 7 hand stone; 8 bone awl; 9 bone "handle"
(Scale: 5,6,9 1/1, others 2/5)

A total of 21 lithic artifacts were found. They were all made by direct percussion. Relatively large size artifacts include cores, choppers, hammers and scrapers, which were all made of local quartzites and sandstones. This shows evidence of the continuation of the local pebble tool tradition but also shows a change to smaller size tools. There are also some small-size cores and scrapers that were made of black chert. This type of small chert scraper has been found in many Early to Middle Neolithic sites in the Lishui Valley. The Yanerdong lithic assemblage indicates strong cultural connections to those later assemblages in the same region. One bone awl and another unidentified bone tool were found. The latter was burnt (ibid).

Animal remains are abundant and belong to the giant panda – stegodon fauna. Among them, oriental stegodon, Chinese rhinoceros and giant tapir are now extinct. The animal bones show a moderate degree of petrifaction. These phenomena suggest they belong to the end of the Upper Pleistocene (ibid). The animal remains were mainly ungulate teeth and mostly deciduous, which may be a product of selective hunting.

Human remains at this site include one broken piece of limb bone, one part of the lower jaw, and teeth. They were identified as *Homo sapiens sapiens* (ibid).

<u>Shiligang</u>

Shiligang, Li County in Hunan Province, is an open area site located on a small mound on the terrace of Lishui River. The site has not been excavated but surface collection in 1998 did provide a large number of lithic artifacts. Based on lithic characteristics, the site was dated to the end of the Late Paleolithic. The information of this site came from a brief description (Yuan 2004)

A total of 182 lithic artifacts were collected, of which 134 are debitage. The lithic assemblage shows the following characteristics.

1) In general, stone tools are very small.

2) Black chert is the major raw material, followed by quartzite, vein quartz, silica rock, and sandstone.

3) Tool kits consist of scrapers, choppers, and points. Scrapers are the majority. There are only 3 choppers, all small in size.

4) Direct percussion is still the primary manufacture technique, but some fine tools show traces of pressure flake.

5) There appeared some fine small tools such as long and narrow flakes, tongue-like scrapers and discoid scrapers, which indicate the improvement of lithic technology (ibid).

Shiligang as well as Wuyashan and Yanerdong are all located in the Lishui Valley and their cultural relationships are reflected in the lithic assemblages. The Shiligang assemblage is similar to the Yanerdong assemblage and shows some differences from the Wuyashan assemblage. It still contains pebble tools, but has an increasing percentage of black chert microlithic tools, which indicate cultural connections to the microlithic tradition of the Early and Middle Neolithic in this area (ibid).

Diaotonghuan

Diaotonghuan, of Wannian County in Jiangxi Province, is a cave site located in the Dayuan Basin, a limestone area south of the Yangzi River. The site, along with the adjacent Xianrendong site, was excavated in 1993 and 1995 by a joint Sino-American team led by Wenming Yan of Beijing University and Richard "Scott" MacNeish of Andover Foundation for Archaeological Research in Boston (MacNeish and Libby eds. 1995). According to the most recent chronology of the two sites, zones M-H of Diaotonghuan belong to the Late Paleolithic (Figure 5.7), whereas the remaining zones of Diaotonghuan and the complete assemblage at Xianrendong are dated to the Neolithic or even later (Zhao 1998). I only discuss on zones M-H of Diaotonghuan here.

Zone M, the lowest cultural stratum, only contains one flake. The above Zone L yielded eleven flakes and a few animal bones. Lithic tools and identifiable animal bones were found in each of the zones from K to H. Here I can only discuss the lithic artifacts, because details of the faunal remains from these zones are not available.

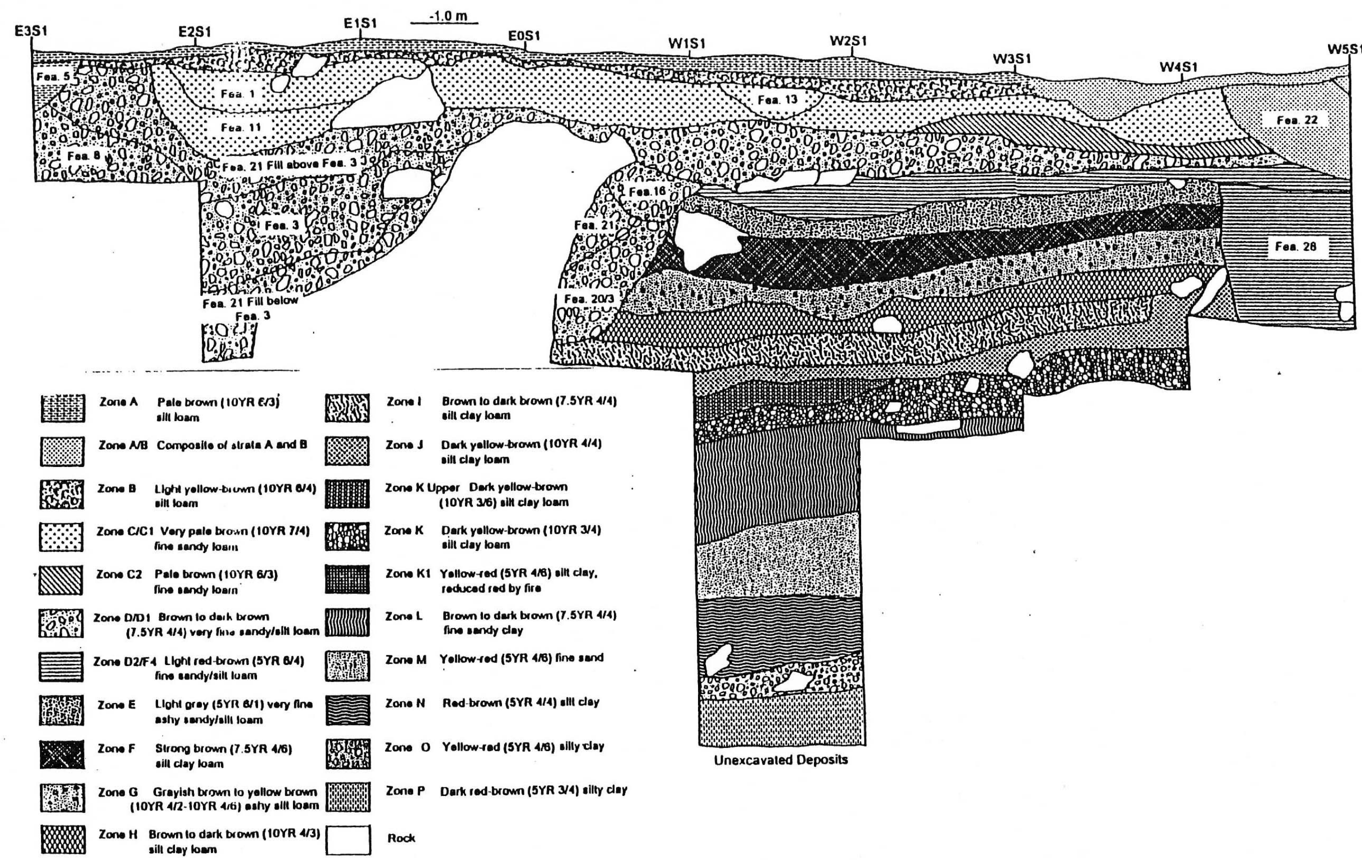


Figure 5.7 Stratigraphic profile of Diaotonghuan (after Zhao 1996)

Based on the original report (MacNeish 1995), the lithic assemblage of the late Paleolithic in Diaotonghuan shows the following characteristics:

1) There was a mixture of two different lithic traditions: one is the traditional Southern China pebble industry that is made of sandstones and mica schist and consists of heavy-duty tool types such as choppers and hammers, the other industry includes small flake tools made of cherts and quartz and featuring scrapers, points and spokeshaves.

2) Direct percussion continues to be the dominant tool-making technique, but pressure flaking was used as well. Small tools such as scrapers and points were mostly retouched with pressure flaking.

3) A few microblades and tongue-shaped cores were found, but they seem different from those typical microblades and microcores found in North China (Gai 1985).

4) The small flake tool tradition is different from those found in North China but similar to small flake lithic technology of this period in other areas of the Yangzi Valley. The small tools were made from quartz and chert flakes that are small and thin. They were flaked by direct percussion and often with retouch.

In addition to stone tools and animal remains, these zones also contained some organic items and limestone inclusions that might be features (MacNeish 1995). However, no detailed information describing them is available.

Sanshandao

Sanshandao, Wu County in Jiangsu Province, is a small island in Lake Tai south of the Yangzi River. The site was excavated in 1985 by Nanjing Museum. The principle investigator is Chun Chen. A total of 5263 lithic artifacts were found from sand and pebble stratum in front of the entrance of a cave. A brief report of the site was published (Chen et al. 1987).

Only lithic artifacts were found in the site (Figure 5.8). Based on the 1019 described artifacts, small size flake tools were overwhelming, accounting for over 98% of the assemblage. Like those found at other sites, the artifacts were primarily made by direct percussion. Raw materials were mainly chert, chalcedony and agate. The dominant tool type is scrapers of various types. The thumb-nail scrapers are similar to those found in North China microlithic assemblages. Another common tool type is point. Many flakes exhibit evidence of use without retouch. Based on lithic characteristics and sedimentary geology, the researchers placed this lithic assemblage at the transition from the Pleistocene to the Holocene. Because no pottery was found, the researchers infer it dates to the end of the late Paleolithic (Chen et al. 1987).

However, there are questions concerning the chronology of the assemblage. First, although raw materials and debitage were found in the Sanshan island, the water-transported stratum of the assemblage raised the question of whether the Sanshan artifacts were found *in situ*. Besides, the general characteristics of the assemblage are more developed than those found in the Middle Yangzi Valley and the Lower Yangzi Valley during the end of the late Paleolithic, which still show evidence of the pebble tool tradition from South China. Therefore, it is possible that the Sanshan site might be the Early Neolithic in age.

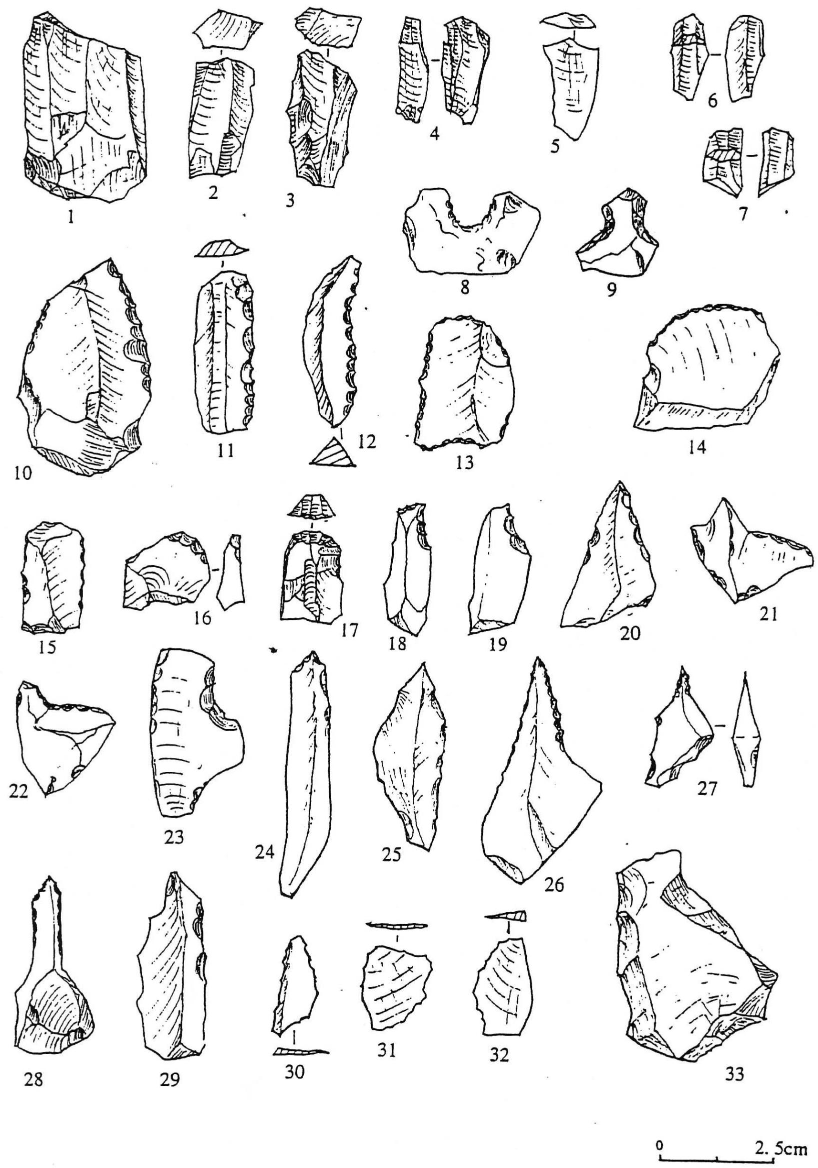


Figure 5.8 Lithic artifacts from Sanshandao (after Chen et al. 1987)
1-4 cores; 5-7 flake-blades; 8-19 scrapers; 20-25 points; 26-29 awls; 30-32 worked flakes; 33 chopper (all names follow original researchers' terms)

Summary

Based on the above archaeological assemblages and other surface collections, the basic characteristics of the cultures at the end of the Late Paleolithic in the Middle Yangzi Valley and the Lower Yangzi Valley are summarized below.

The lithic technology shows a transition from pebble industry to microlithic industry. Pebble tools still existed in every lithic assemblage, but their percentage declined when compared to the earlier period. In the meantime, small flake tools became more common. Direct percussion is still the major tool making technique, but secondary retouch was often used in small tools. Although many local pebbles were still used to make tools, more exotic fine-grained materials, particularly chert, were used to make small fine tools. Many small and thin flakes were used directly or as part of Composite tools. Scrapers of various kinds became the predominant tool type. Other popular lithic artifacts are cores, flakes, choppers and points. It is clear that the lithic technology of this period continued the local pebble tradition from the prior period, but was influenced by the microlithic tradition of North China during this period. However, it was distinct from its North China counterpart. The absence of typical microblades and microcores is noticeable. Meanwhile, the flake tool kits and several distinctive tool types, such as the discoid chopper and black chert scraper, exhibits cultural connections to the local Early and Middle Neolithic cultures.

In terms of settlement patterns, the number of cave sites increased although there are still some open area sites found on riverbank terraces. This trend could result from the oscillating cold and dry environment, as caves may have been better dwelling places in that situation. The site clusters common in the earlier period are not seen, but the number of artifacts at individual sites has increased considerably. This could indicate the extended use of certain sites and the increased degree of sedentism during this period. The long term occupation of Diaotonghuan cave is an example of this pattern.

In human subsistence, hunting appears to have increased in importance although plant collecting was still used to acquire food. The increase of the proportion of small flake tools like scrapers and worked flakes is similar to the small flake tool tradition in North China during the late Paleolithic, which was adapted to the grassland environment to utilize animal resources. In the Middle Yangzi Valley and the Lower Yangzi Valley, the environment during this period was fluctuated between forests and grassland, which allowed hunters to be successful. The coexistence of lithic artifacts and animal remains in several cave sites also support this postulation.

5.2 Early Neolithic Cultures in the Middle and Lower Yangzi Valleys

Four sites dated to the period between 12,000 and 9,000 BP have been found in the Middle Yangzi Valley and the Lower Yangzi Valley (Figure 5.9): Yuchanyan is located in the Middle Yangzi Valley, Xianrendong and Diaotonghuan are in the Lower Yangzi Valley, and Shangshan is near the Yangzi Delta. The first three sites are cave sites and the last one is an open area site. They all contain the earliest rice remains.

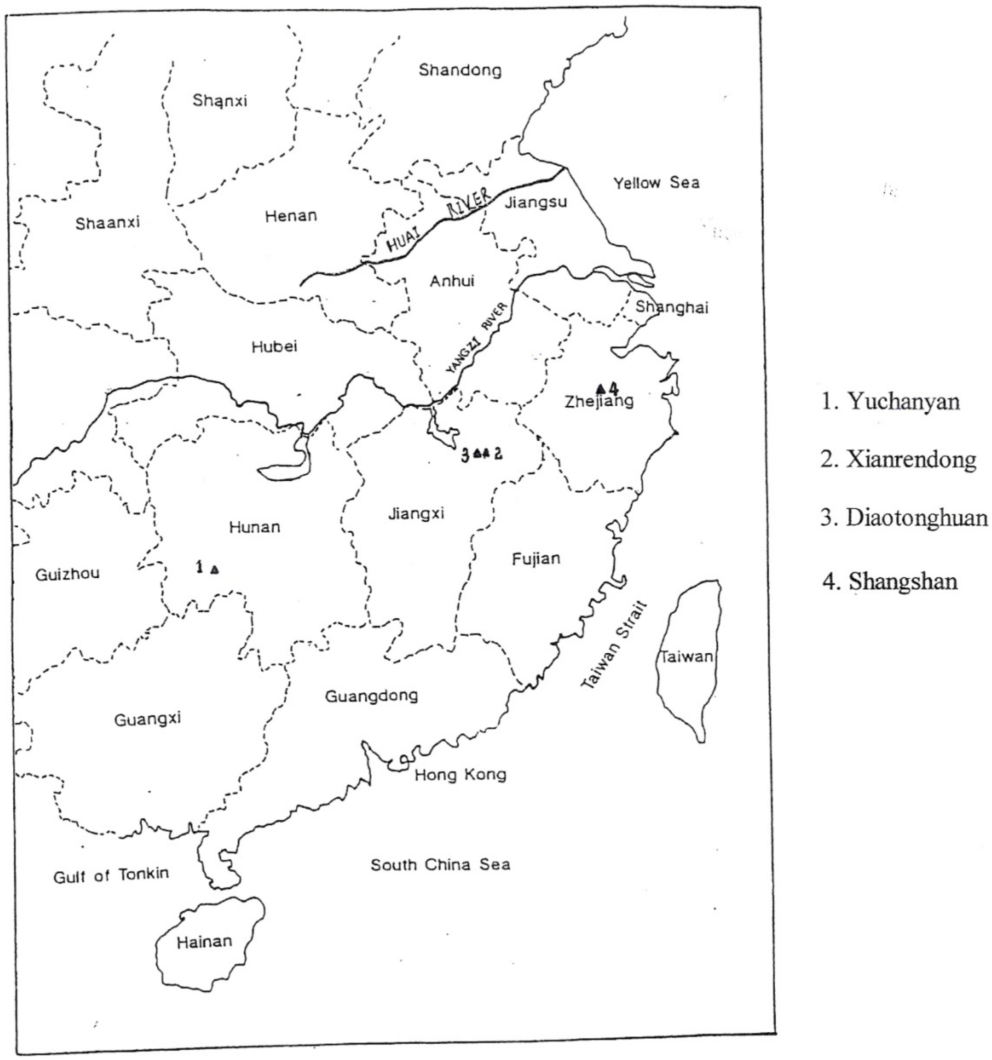


Figure 5.9 Early Neolithic sites in the Middle and Lower Yangzi Valleys

<u>Yuchanyan</u>

Yuchanyan, in Dao County, Hunan Province, is a cave site located at the southern edge of the Middle Yangzi Valley. The precise location of the site is 25˚30’

N and 111˚30’ E. The cave is carved into a limestone hill in a small basin surrounded by mountains of the Nanling mountain chain, which is considered the boundary of the Yangzi Valley and the Pearl Valley of South China. The cave faces south and overlooks a broad plain of the basin. It has a sunny and spacious entry way that is 12 – 15 m wide and 6 – 8 m deep, and the floor is about 5 m above current land surface. The area features a typical subtropical climate with annual precipitation of 1296 mm and annual average temperature of 18 ˚C (Yuan 1999).

The site was found in 1984 and excavated by a team led by Jiarong Yuan of Hunan Provincial Institute of Archaeology in 1993 and 1995 (Yuan 1996). In 2004 and 2006, the site was excavated again by a joint Sino-American team led by Wenming Yan of Beijing University and Ofer Bar-Yosef of Harvard University. The most important discoveries of the site are the oldest rice remains with traces of domestication along with the earliest pottery. Two brief reports disclosed the data from the 1993 and 1995 excavations. The details of recent excavations are not available, but some of the most recent discoveries were obtained by personal communication (Zhenkai Xia 2004, Jiarong Yuan 2006).

Radiocarbon dating indicates the date of the site is at least 12,000 BP. Although there are no ground stone tools found in the site, the discoveries of pottery and possibly the earliest domesticated rice remains allow me to tentatively place the site at the very beginning of the Neolithic (Yuan 1999).

The cultural stratigraphy is about 1.2 –1.8 m thick. The deposit is well preserved. The original cave floor was very bumpy, covered by various sizes of rocks.

The floor was flattened, clearly by human activities, through fitting small stones in between rocks then covering them with layers of white-grey and yellow sandy clays during the long term human occupation. Hearth remains, about 40 – 50 cm in diameter and less than 10 cm thick, were found in association with abundant burnt animal bone and charcoal. Since the western part of the deposit is thick, complex and contains hearth remains and most of the cultural remains, it may have been the main area of human activities (ibid).

The archaeological assemblage consists of lithic and organic artifacts, a few potsherds, as well as plant and animal remains. Faunal remains include bones of over 20 species of animals. Through sifting and flotation, a large number of plant seeds and nuts were also recovered, of which the most important remains are rice husks (Yuan 1999).

A total of about 1,000 lithic artifacts were found. The raw materials are mainly pebbles of sandstone, with a few quartz rocks. The manufacture technology is direct percussion, flaking the whole pebble along one or more edges. Secondary retouch was not common and most flakes were used directly. Small size flake tools predominate, and there are very few large tools. The tool types include scrapers, choppers, knives, hammers and hoe-shaped implements (Figure 5.10). In addition, notched flakes found in the site show usewear on the notch, suggesting they were net-sinker (ibid). The lithic technology clearly continued the late Paleolithic tradition of the Middle Yangzi Valley and the Lower Yangzi Valley and showed the dominance of small flake tools, particularly various scrapers.

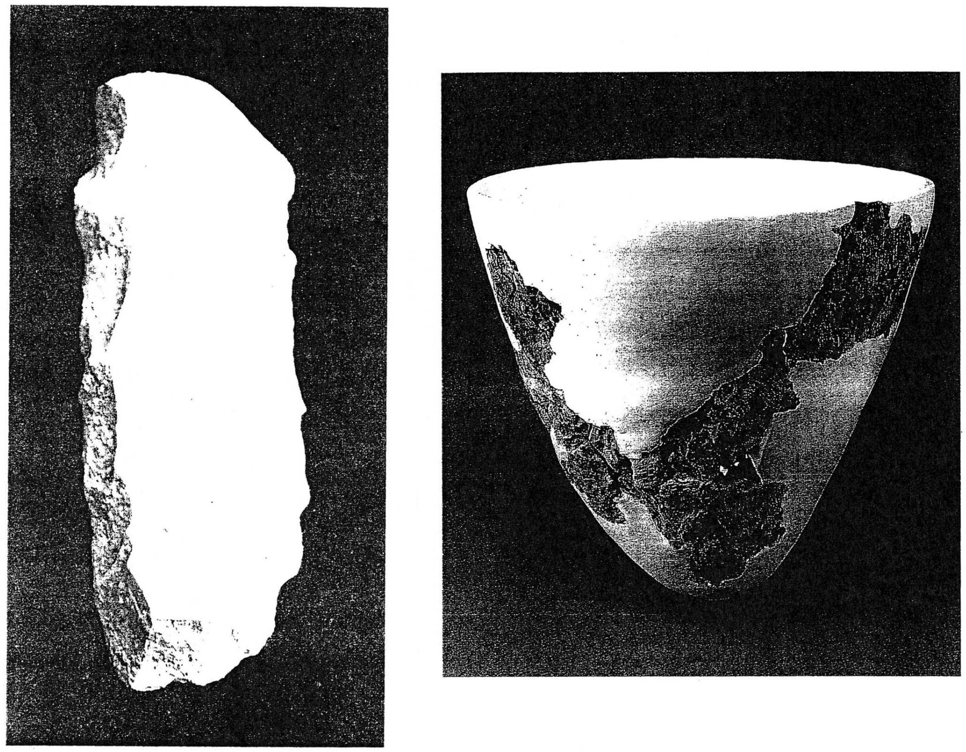


Figure 5.10 Lithic and ceramic artifacts from Yuchanyan (after Yuan 1999)
Left: stone hoe-shaped implement (95DMT7:27);
Right: reconstructed pottery *fu* cooking vessel (95DMT9:26)

Organic artifacts made of bone, antler, animal teeth and shell were found. Bone tools are made of animal's limb bones. The tool types include bone shovels (Figure 5.11), bone pricks, antler shovels, perforated shells and teeth ornaments. Shovels were made by direct percussion, while pricks are further polished either partially or completely. The cutting edge of these tools is smooth, showing clear usewear. Animal fangs have a circle of groove around the root, probably from being bound together as ornaments. Some of the perforated shells have a sharp edge, which might be used as cutting tools (ibid).

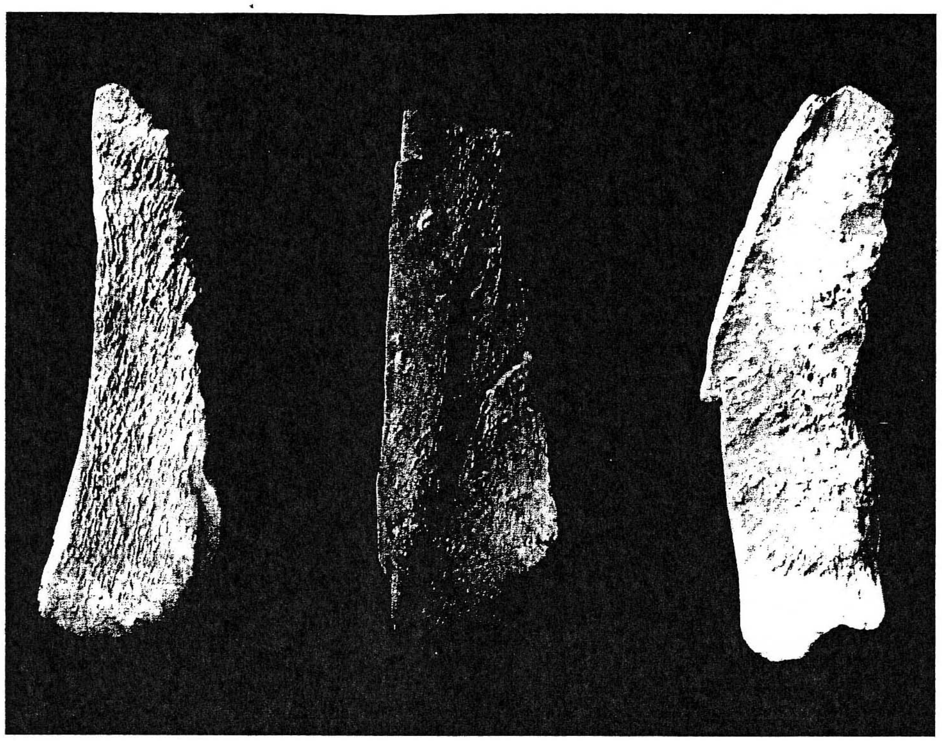


Figure 5.11 Bone shovel (95DMT1) from Yuchanyan (after Yuan 1999)

Potsherds were very primitive when compare to those found later. They are dark-brown with charcoal and coarse sand tempers. The surface is impressed with knitted patterns. The wall is nearly 2 cm thick and very fragile, showing a very low firing temperature. The potsherds were made by a slab modeling technique. Although most potsherds are too small to show clear tool type, one pile of potsherds from the 1995 excavation has been reconstructed as a *fu* kettle-shaped vessel (Figure 5.10), with a mouth of 31 cm in diameter and 29 cm high (ibid).

A lager number of faunal remains were found in the site, including mammals, birds, fish, tortoises, shells. Among the mammals are bears, raccoon dogs, civet cats, deer, pigs, etc. In total 28 species were found. Most of them are large herbivores and small carnivores. An interesting phenomenon is that bird remains account for over 30% of the total fauna. A total of 27 species of bird have been identified, including wild goose, duck, crane and swan. 5 species of fish and 33 species of shells were also identified. All of these remains reflect a rich swampy subtropical environment of the area at the time of human occupant. This is also supported by equally rich plant remains recovered from the site. They have been divided into over 40 different types, of which 17 species have been identified. Some of these plants, such as Chinese gooseberry, wild grape, hackberry, plum, are edible (ibid).

The most important discovery of the site is rice husks. Two of them were recovered by flotation in 1993, and two more were found *in situ* in the 1995 excavation. Since 2004, five more rice husks were found in recent excavations (Yuan 2006, personal communication). They were reportedly all from the lower layers of the site. Being examined by scanning electron method, the 4 reported husks were identified as the most primitive ancient cultivated rice species. They have the characteristics of wild rice, as well as two domesticated rice subspecies – *indica* rice and *japonica* rice, thereby representing the initial stage of evolution from wild rice to cultivated rice (Yuan 1999).

Xianrendong and Diaotonghuan

Xianrendong and Diaotonghuan are two adjacent caves on the edge of the Dayuan Basin. They are located at Wannian County in northern Jiangxi Province of the Lower Yangzi Valley. The precise location of these two sites is 28˚44’ N and

117˚13’ E. Dayuan Basin is small (about 4 km from west to east and 1 km from north to south) and swampy, located in a limestone area south of the Yangtze River. The two sites unearthed the earliest rice remains in the Lower Yangzi Valley.

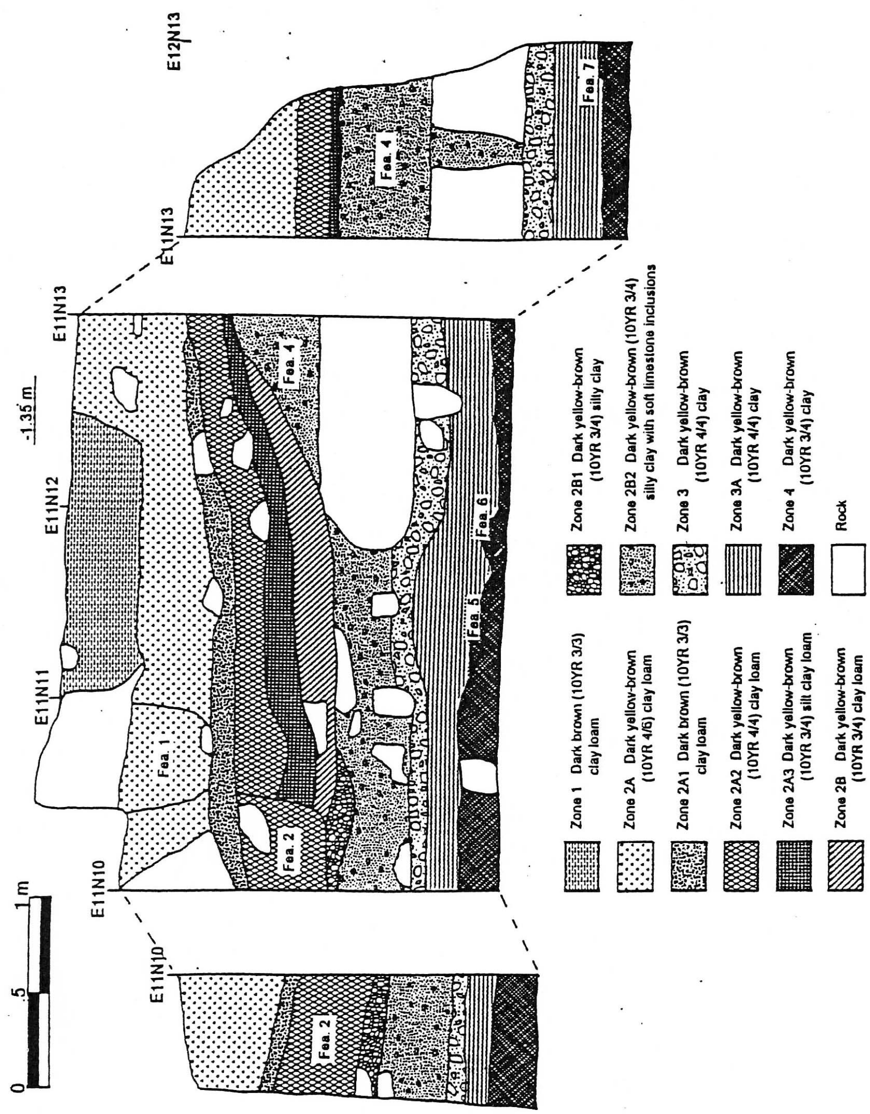


Figure 5.12 Stratigraphic profile of Xianrendong (after Zhao 1996)

Xianrendong was initially excavated by Jiangxi Museum in 1961 and 1964. The unearthed data including lithic, pottery and bone artifacts, hearths, shell and animal bones were published in two brief reports (Jiangxi Cultural Relics Administration 1963, Jiangxi Museum 1976). The study of the stratigraphy and animal remains indicated the age of the site is from the end of the Upper Pleistocene to the Early Holocene (Huang and Ji 1963).

In 1993 and 1995, Xiangrendong, along with Diaotonghuan (also called Wanddong in the original report), were excavated by the Sino-American Team led by Yan and MacNeish (MacNeish and Libby eds 1995). The two caves are within the same ecological niche and only 800 m apart. Considering the similarity of cultural remains from the two caves, Yan (1997) suggested that they belonged to the same prehistoric culture, and were probably by the same group of people.

The establishment of chronology for the two sites is very difficult, because of the complicated stratigraphy (Figure 5.7, 5.12) and questionable radiocarbon dates. The radiocarbon dating of the 1961 and 1964 excavations has long been considered problematic (Institute of Archaeology, CASS 1984). A bone sample from a lower layer was dated to 8575 ± 235 bp, while an unidentified shell sample from an upper layer was dated to 10,870 ± 240 bp. Even the dates obtained during the 1990s contain some inevitable errors, because the radiocarbon dates of samples from limestone areas are likely to be older than their actual ages (Lab of C14 of Beijing University and C14 Lab of Institute of Archaeology, CASS 1982). The excavators also recognized this problem and adjusted the dates of the stratigraphy based on cross-dating using methods such as cultural comparison and pollen analysis (MacNeish and Libby 1995, MacNeish 1997, Zhao 1998). Based on radiocarbon dates, stratigraphy and cultural comparison, Zhao proposed the most convincing chronology (Table 5.2) of the two sites, which divided Zones M-I of Diaotonghuan to the late Paleolithic, Zones G-E and Xianrendong Phases VI-IV to the Early Neolithic, Zones D-C and Phases III-II to the Middle Neolithic, and the remaining to the Epi-Neolithic and Bronze Age (Zhao 1996, 1998).

Diaotonghuan Zones	**Xianrendong Phases**	**MacNeish and Taylor's**		**New Estimates**	**New Reference**
		Estimates	**Reference**		
Zone B	—	4500	Shang pottery	2000-5000	Geometric pottery
—	Phase I	—	—	4000-5000	Shijiahe Culture
Zone C	Phase II	9000	Pengtoushan culture	7000-8000	Lower Zaoshi Culture
Zone D	Phase III	11300	?	8000-9000	Pengtoushan Culture
Zone E	Phase IV	11900	?	9000-10000	Ceramic seriation
Zone F	Phase V(?)	15200	?	?	?
Zone G	Phase VI(?)	17400	C14 date	?	?
Zone H	—	19700	C14 date	?	?
Zones I-M	—	27000-25000	?	?	?

Table 5.2 Estimated Chronology of Xianrendong and Diaotonghuan (after Zhao 1996)

The remains of the late Paleolithic have been discussed in previous section, only Phases VI-IV of Xianrendong and Zones G-E of Diaotonghuan are presented here. Because there is no illustration of artifacts found during the 1993, 1995 excavations, drawings of unearthed artifacts from 1962 and 1964 excavations are used to illustrate some artifacts (Figure 5.13).

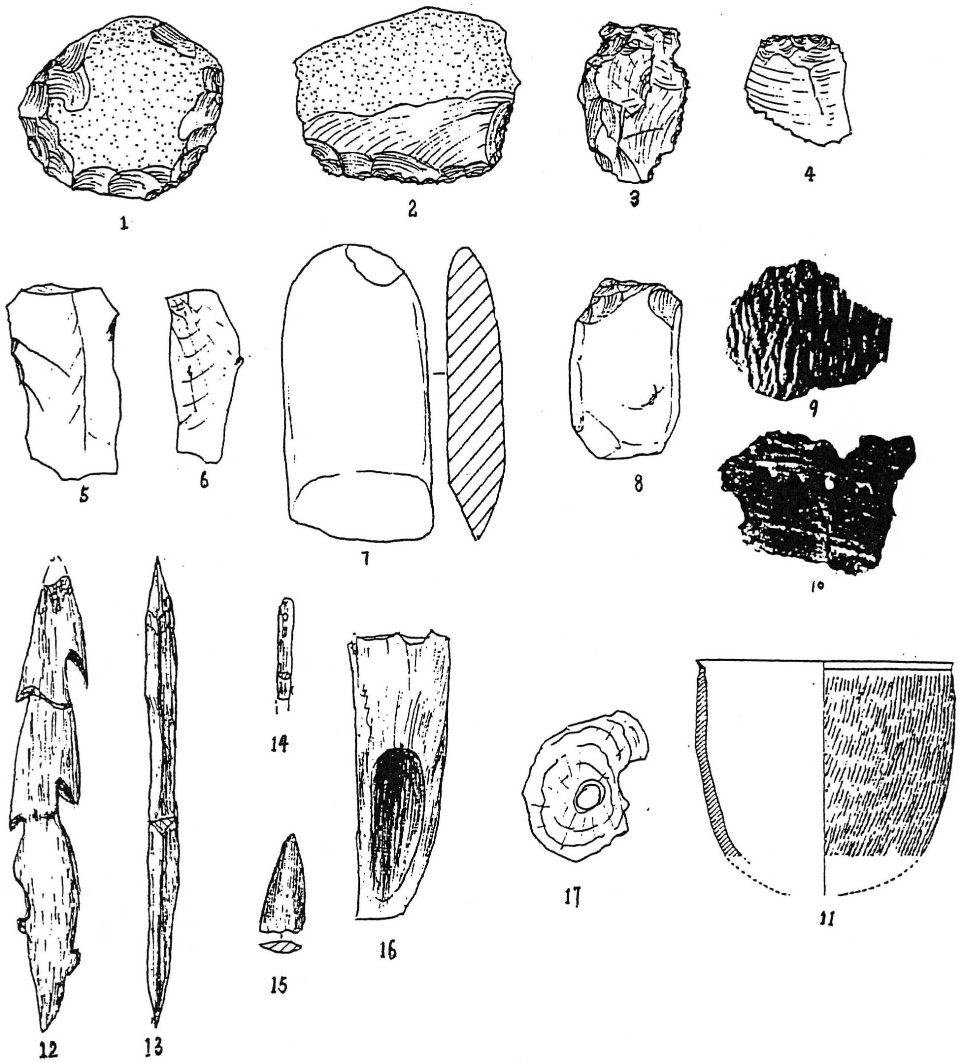


Figure 5.13 Artifact from Xianrendong
1,2 pebble chopper; 3,4 worked flakes; 5,6 blades; 7,8 polished stone adzes; 9,10 potsherds; 11 reconstructed pot; 12 bone harpoon; 13 bone awl; 14 bone needle; 15 bone arrowhead; 16 antler chisel; 17 perforated shell (scale ½)

The cultural assemblage of Xianrendong Phase VI and Diaotonghuan Zone G (12,000 – 11,000 BP) includes lithic and organic artifacts. Lithic technology generally continued the earlier tradition but exhibit some changes. According to the original researcher (Cunnar 1995), lithic typology shows a major shift with chipped stone tools such as scrapers and worked flakes becoming dominant. A microblade technology became part of the toolkit. Pebble tools such as choppers and hammers still existed. The dominance of chipped stone tools in lithic assemblages continued through the Middle Neolithic. In addition, some perforated mollusk-shell tools have sharp edges, and were probably used as harvesting tools. The most important discovery dating to this phase is the appearance of wild rice phytoliths in Zone G of Diaotonghuan. This supports the argument that wild rice grew in the Yangzi Valley and was exploited by local inhabitants as early as 12,000 BP (Zhao 1996, 1998).

The remains of Xianrendong Phase V and Diaotonghuan Zone F (dated between 11,000 and 10,000 BP) differ from the previous phase in two aspects. One change is the appearance of ground stone tool technology, as evidenced by one ground projectile point recovered from Zone F of Diaotonghuan (MacNeish 1995). The other change is the absence of rice phytolith during this phase. This could be the result of a deteriorating environment related to the Younger Dryas (Zhao 1996, 1998). A recent study of phytoliths in the Yangzi Delta supported this argument (Lu et al. 2002).

In the assemblage of Phase IV at Xianrendong and Diaotonghuan Zone E (dated to 10,000 – 9,000 BP), the continuation of the lithic and bone tool traditions is presented. However, two changes occurred: the first one is the return of rice phytoliths and the possible emergence of the earliest domesticated rice, which may be associated with the environmental amelioration of this phase (Zhao et al. 1995, Zhao 1996, 1998); the other change, the appearance of pottery is more significant. The potsherds are very primitive and brittle, suggesting a very low firing temperature. The paste is coarse and was tempered with crushed rocks or quartzite of variable sizes. The surface shows traces of wiping with a toothed implement (Hill 1995).

In summary, the Early Neolithic saw the continuous occupation of Diaotonghuan cave and the beginning of use of the Xianrendong cave. Lithic technology showed some changes in the ratio of types of chipped stone tools and the appearance of ground stone tools later. Bone tools were also used but without details. Pottery was invented in the last phase. Wild rice and other plants appeared with cultural remains, suggesting their utilization by humans. The earliest domesticated rice may have appeared at the end of this period. Abundant animal bones were also found, illustrating the importance of hunting during this period. The effect of the Younger Dryas was significant, as evidenced by the absence of rice phytoliths and the increased numbers of animal remains in the assemblages of this period.

Shangshan

Shangshan, in Pujiang County, Zhejiang Province, is an open area site located on a hill in the Puyang River Valley on southern edge of the Yangzi Delta. The precise location of the site is 29º27’36’’ N and 119º58’25’’. Found in 2000, the site was excavated by Zhejiang Provincial Institute of Archaeology and Pujiang Museum (2007) in 2001, 2004 and 2005-6 seasons. The area of the site is approximately 20,000 m^2, of which 1,800 m^2 have been excavated. The data from the excavations were disclosed in a brief report (ibid) and a research article (Zheng and Jiang 2007). Six calibrated radiocarbon dates indicate the site is dated to 11,400 – 8,600 BP. The discoveries of the site consist of pits, house floors, stone tools and pottery (Zhejiang Provincial Institute of Archaeology and Pujiang Museum 2007). Rice husk impressions and rice phytoliths were found in pottery (Zheng and Jiang 2007).

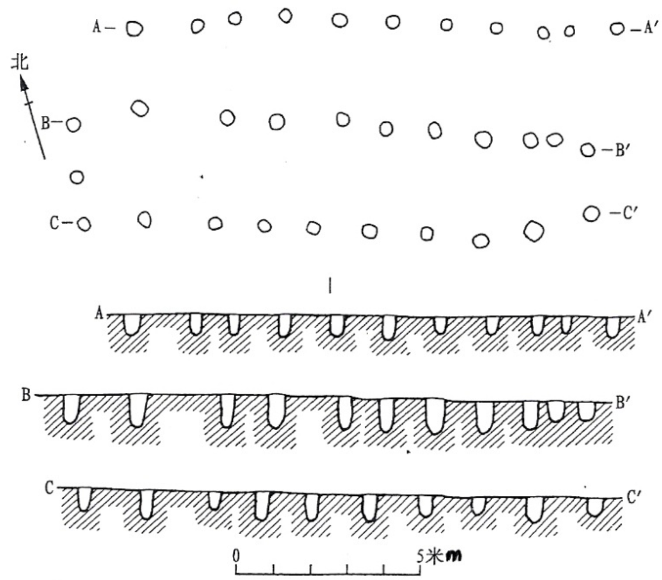


Figure 5.14 Plan and profile of house floor at Shangshan Site (after Zhejiang Provincial Institute of Archaeology and Pujiang Museum 2007)

The number of pits and house floors is unknown. The shape of pits includes round, square, rectangular and irregular. Potsherds, stone tools and organic remains were found in some pits. House floors contain a certain number of small holes. In one case, thirty three holes form three parallel lines (Figure 5.14), which may represent a rectangular building similar to the Hemudu pile-dwelling (Zhejiang Provincial Institute of Archaeology and Pujiang Museum 2007).

Stone tools are primarily chipped and pebble tools and the number is unknown. They were made by direct percussion and some have retouched traces. Most are flakes and cores. A few ground stone tools were also mentioned in the report. Lithic tool types include chisel, adze, and ball (Figure 5.15). Sickle-shaped knife and grinding plate are also reported, but the lack of details of these tools makes it difficult to evaluate their actual functions (ibid).

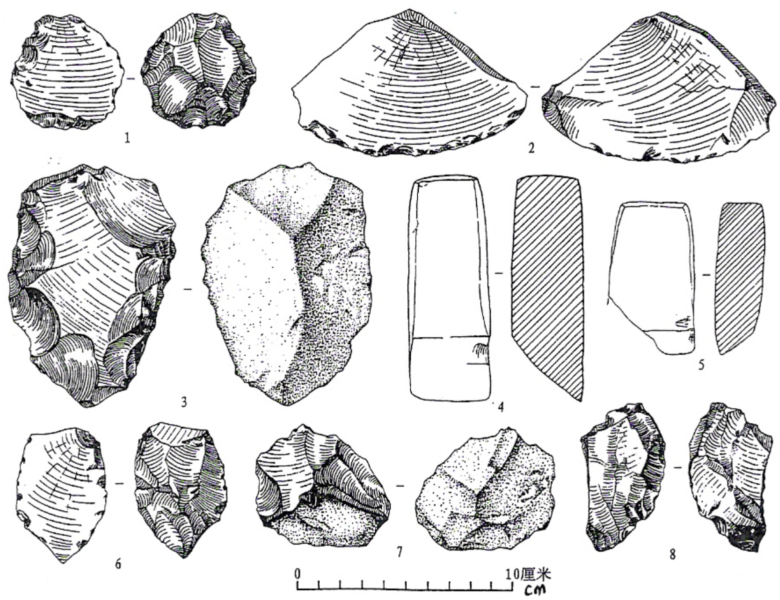


Figure 5.15 Lithic artifacts from Shangshan Site (after Zhejiang Provincial Institute of Archaeology and Pujiang Museum 2007)

Pottery is mainly charcoal tempered. The color is light yellow and coated with a red slip. Pottery vessels were formed by slab-modeling. The technique is crude: the firing temperature is approximately 800 degrees, the vessels are very fragile, and the wall is often over 2 cm thick. The surface is often undecorated. The tool type includes basin, jar, pot, plate and cup (Figure 5.16) (ibid).

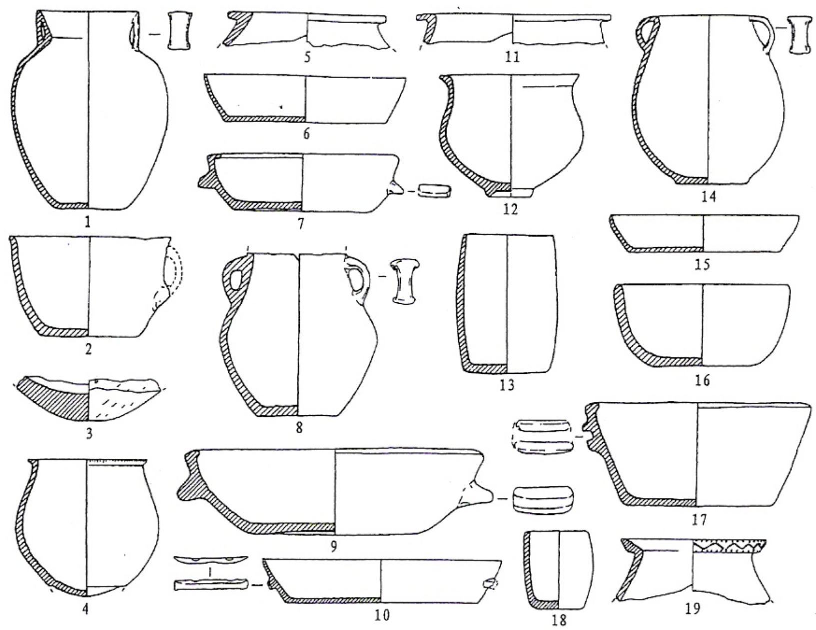


Figure 5.16 Pottery from Shangshan Site (after Zhejiang Provincial Institute of Archaeology and Pujiang Museum 2007) Scale: 1,6, 10, 14, 15 1/14; remaining 1/7

Rice remains were preserved in pottery, including husk impressions, charred rice husks in tempers, and fan-shaped phytoliths from rice stalks. The rice is shorter in length and greater in width than wild rice. This suggests that the Shangshan rice was probably at an early stage of domestication (Zheng and Jiang 2007). This viewpoint is challenged by Fuller et al. (2007), who argued that morphological characteristics, particularly the length/width ratio of rice grains, are not sufficient to identify wild/domesticated rice. They pointed out that grain immaturity, which was caused by the harvesting of immature rice grains, often leads to exaggerated L/W ratios and makes the identification problematic.

5.3 The Middle Neolithic Cultures

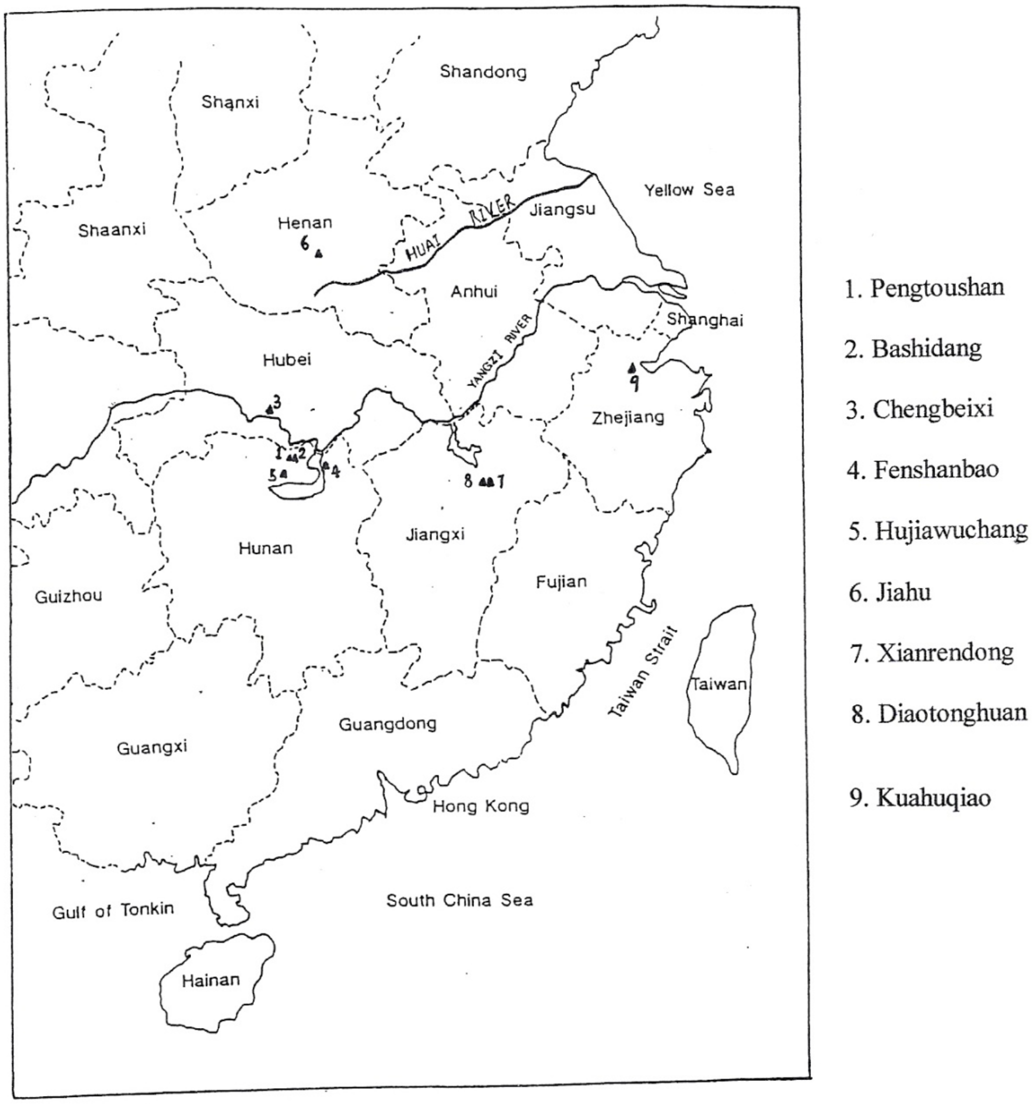


Figure 5.17 Middle Neolithic sites in the Middle Yangzi Valley, the Lower Yangzi Valley and the Huai Valley

More sites with rice remains were found during the Middle Neolithic period. In the Middle Yangzi Valley, a number of sites belonging to this period can be placed into two continuous cultures: Pengtoushan Culture (9,000 – 7,500 BP) and the Lower

Zaoshi Culture (7,500 – 7,000 BP) (Pei 2000). In the Lower Yangzi Valley, this period is represented by the Xianrendong and Diaotonghuan assemblages, and the Kuqhuqiao site. Another important site of rice domestication – Jiahu, located in the Huai Valley, also appeared during this period (Figure 5.17).

The sites of the Pengtoushan Culture concentrate on the areas surrounding the Dongting Lake in Hunan Province and along the terraces near the Yangzi River in the southwestern Hubei Province (Figure 5.18). Although many sites have been discovered, only seven of them have been excavated. All of the excavated sites contain rice remains. Among them, the Pengtoushan, Bashidang and Chengbeixi sites yield important information concerning the origins of rice agriculture.

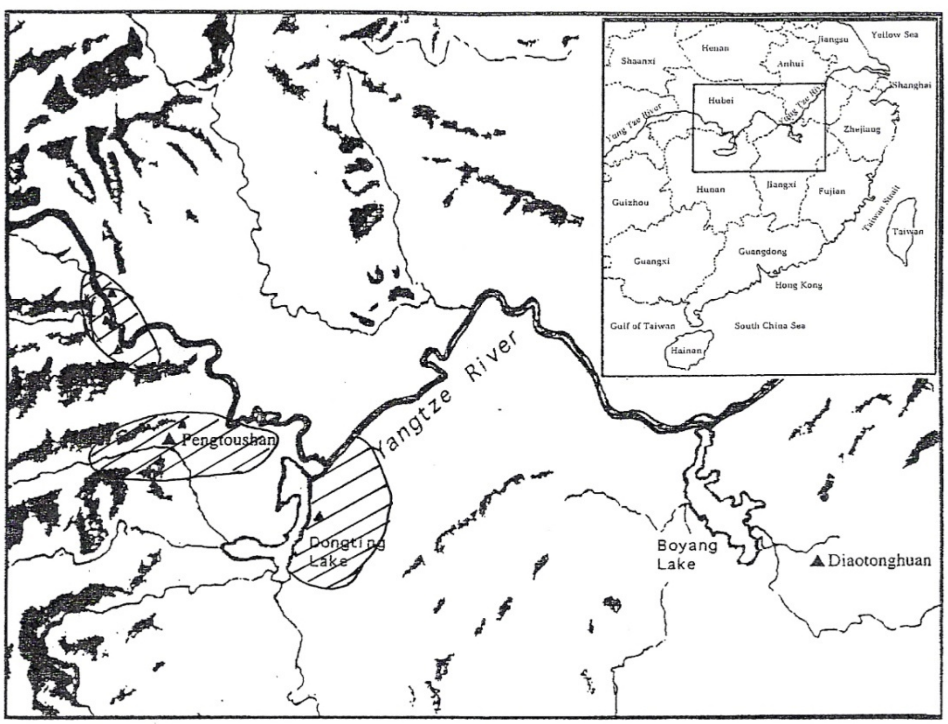


Figure 5.18 Distribution of the Pengtoushan Culture (after Pei 2002)

The lower Zaoshi Culture is generally considered the successor of the Pengtoushan Culture. It is thought to have inherited the original area of the Pengtoushan Culture but also expanded to the adjacent area. In general, the Lower Zaoshi Culture is more developed than the Pengtoushan Culture. In the lithic toolkit, ground tools increased in quantity and typological variety. As to pottery technology, the wall of pottery vessels became thinner, more types of vessels were manufactured, and the surface decoration became more complex as well. Rice remains continued in some sites, and more domesticated animals were found. Houses and burials became more common, showing an increased sedentism. Although a lot of sites have been discovered and excavated, only a few of them have accessible and relatively detailed reports. The Fenshanbao and Hujiawuchang sites represent the Lower Zaoshi Culture.

<u>Pengtoushan</u>

Pengtoushan is located on a small hill in the Linyang alluvial plain on the northwest edge of the Dongting Lake in Hunan Province. Its precise location is 29˚40’ N and 110˚45’ E. This is an open area site that was discovered and excavated by Hunan Provincial Institute of Archaeology and Lixian Museum in 1988. The principle investigator is Anping Pei. The Pengtoushan site represents the Pengtoushan Culture, the earliest Neolithic culture in the Middle Yangzi Valley. The discoveries of the site is abundant, including stone tools, pottery, house floors, pits, burials, and most importantly, rice husks in the form of pottery temper. Twenty-four radiocarbon dates clearly placed the site between 9,000 and 7,500 BP. The data of the site were published in a brief report (Hunan Provincial Institute of Archaeology and Lixian Museum 1990) and discussed in a few articles (Yan 1990, Pei 2000, 2006a, 2006b).

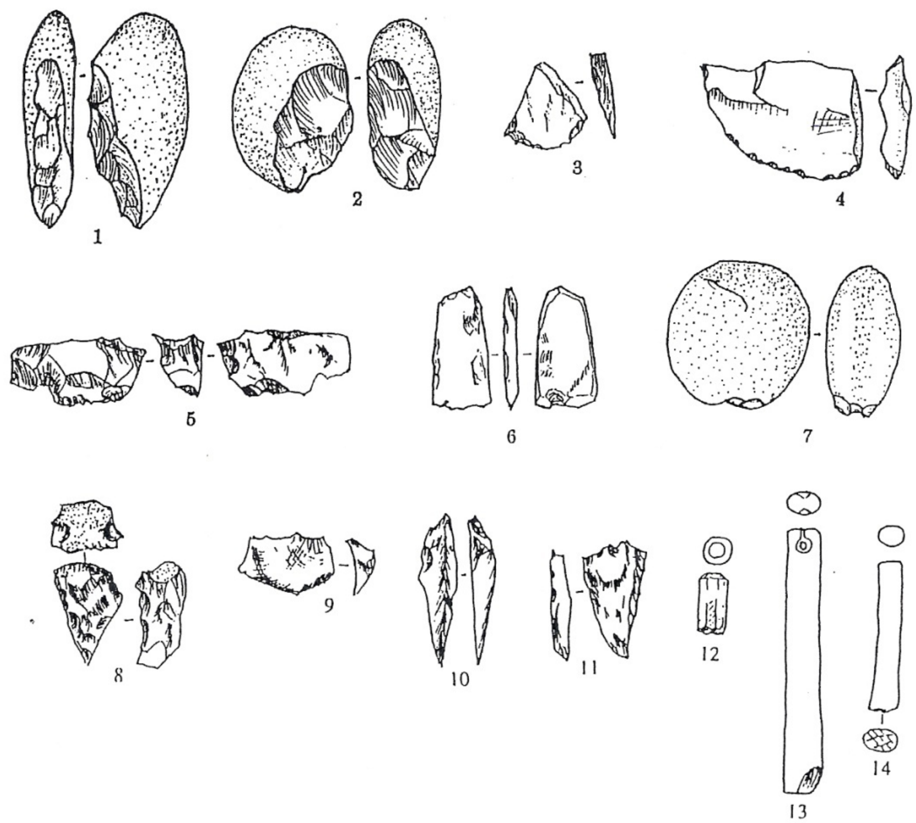


Figure 5.19 Lithic artifacts from Pengtoushan (after Hunan Provincial Institute of Archaeology and Lixian Museum 1990)
1,2 pebble choppers; 3,4,8-11 flakes; 6 axe; 7 hand stone; 12 bead; 13,14 pedants (scale: 5,8-11: ½, others ¼)

A number of stone tools were found at the site, but the quantity has not been made available. The tool types include chipped pebble tools such as choppers, scrapers, hammers; small scraper like tools made of black chert, burins and drills; and a few ground stone items such as pendants, beads, and small axes (Figure 5.19). The technique required to make these tools is quite simple. Most of the chipped stone tools were made by direct percussion. They resemble the pebble tools of the Early

Neolithic in the area, such as those from the Yuchanyan site. Small flakes were also made by direct percussion. Their shapes vary and are irregular. Most of them show usewear. The flake tools are generally less developed than their counterparts in North China. Ground stone tools were made of soft stones and used more as ornaments than as practical tools. It is noticeable that no clear agricultural tools were found at the site.

Pottery from Pengtoushan contains a large quantity of rice straw, grains, husks and other organic materials used as temper in the clay. The color of the clay is mostly black. The surface seems to have been covered by a thin red layer. The color of the surface is often uneven, showing poor control of firing atmosphere. Cord-marking is common of surface finish, but incision and carving were also used. The vessels are generally big, simple, coarse, and not well formed. Vessel types include cooking *fu* (kettles), pots, globular jars with two lugs, bowls, plates, etc (Figure 5.20).

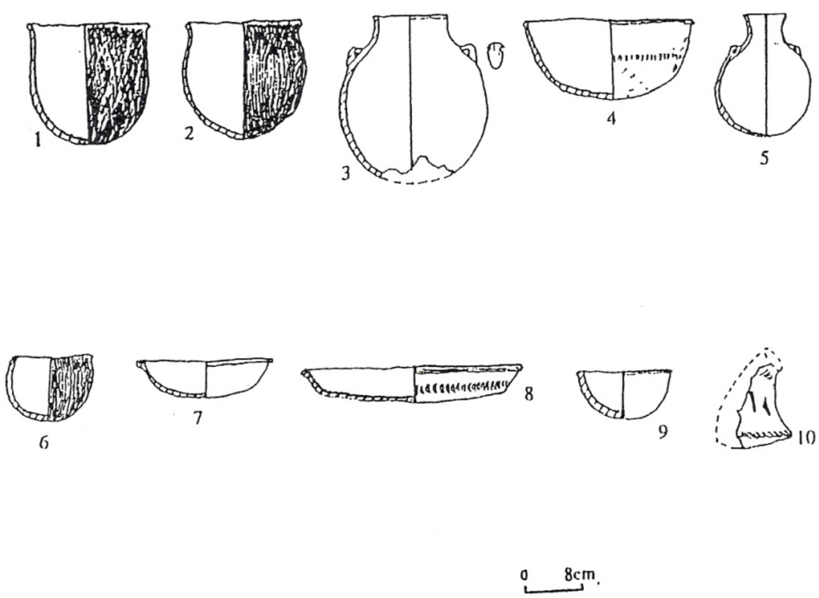


Figure 5.20 Pottery from Pengtoushan (after Hunan Provincial Institute of Archaeology and Lixian Museum 1990)
1,2 *fu* cooking vessel; 3,5 globular jars with two lugs; 4,6,7,9 bowls; 8 plate; 10 stand

The features at the site include large and small house floors, pits, and burials. The number of houses is not reported. One house is square and about 33.6 m^2 in size. The floor was covered by a mixture of sand and clay. Other houses are small, simple, round and semi-subterranean. Ovens, made of a mixture of fired clay and soil, were found inside these small houses. In one house, a pot was found on top of an oven, suggesting a possibly sudden abandonment of the site. In total 15 pits and 18 burials were found. In the burials, human skeletons were not well preserved, but grave goods such as pots, polished stone pendants and beads, along with a few stone tools were found.

Rice grains and husks were found in large quantities at the site. Since they are contained in pottery and it is hard to take them out without damage to them, it is difficult to identify whether they are wild or domesticated rice. However, the size of the rice pollen at the site is quite large and similar to that of domesticated rice (Hunan Provincial Institute of Archaeology Pollen Lab 1990).

Bashidang

Bashidang is located on top of a small hill about 20 miles north of Pengtoushan. It is an open area site that was excavated by a team led by Anping Pei in three seasons from 1993 to 1996. The most significant discovery at this site is more than 10,000 well preserved rice grains and husks from the silt of an ancient watercourse (Figure 5.21). Although there is not radiocarbon dating of the site, it is placed at the same period as Pengtoushan based on cultural comparison. The data from this site were published in a brief report (Hunan Provincial Institute of Archaeology 1996) and a few articles (Pei 1998, 2000).

The cultural remains can be found in two strata, of which the upper one covers an area of over 30,000 m^2. Although the details of the cultural remains are not available, defensive ditches and walled fortresses were reported in this component. Many animal and plant remains were also found along with the rice remains in the silt of the ancient watercourse. Wild animals are few in both species and quantity. Only herbivores such as deer and muntjac are identified. The quantity of domesticated animals is comparatively larger, and includes ox, pig and chicken. Ox is the most commonly recovered domesticated animal. Some ox bones were made into tools. Also, many fish bones were found. Plant remains also include aquatic species such as water chestnut, lotus root and gorgon fruit (Hunan Provincial Institute of Archaeology 1996).

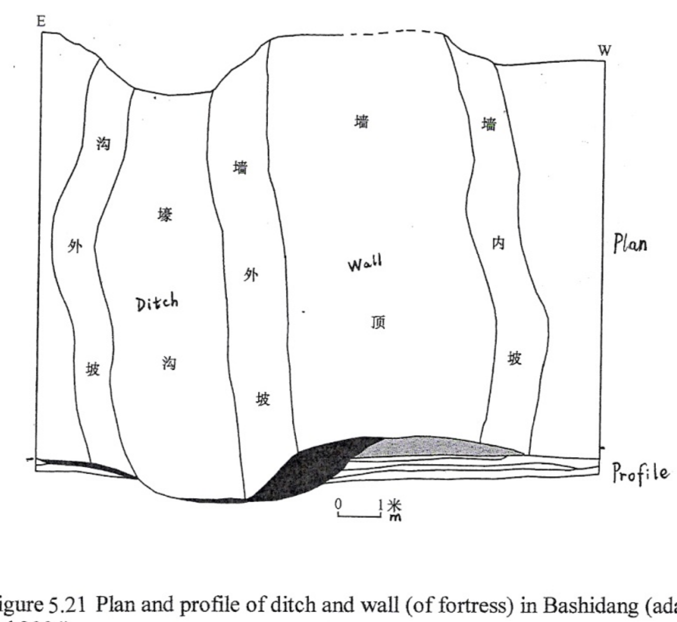


Figure 5.21 Plan and profile of ditch and wall (of fortress) in Bashidang (adapted from Pei 2004)

The rice remains were carefully studied and yield important information that make up the deficiency of the Pengtoushan site and shed light on the status of rice during this period. The measurement of the widths and lengths of the rice grains indicates that the length of the rice is smaller than that of cultivated *indica* rice but close to cultivated *japonica* rice, its width is smaller than both modern cultivars and contemporary wild rice, and the ratio of length/width is quite similar to that of cultivated *indica* rice. The examination of the glume epidermal phytoliths of some grains shows the similarity to those of cultivated *indica* rice. It is concluded that the Bashidang rice remains share the characteristics of both cultivated *indica* and *japonica* rice, and probably closer to cultivated *indica* rice. This phenomenon suggests that the Bashidang rice represents ancient cultivated rice that was prior to the *indica-japonica* differentiation of cultivated rice (Zhang and Pei 1997, Pei 1998).

Chengbeixi

Chengbeixi is located on the western bank of the Yangzi River in Hubei Province. Its precise location is 30˚28’ N and 110˚27’ E. The open area site was excavated by Hubei Provincial Institute of Archaeology in 1983 and 1984. The site yielded a variety of remains such as lithic tools, bone tools, pottery, as well as fish and animal bones. According to the three radiocarbon dates, the site is dated to approximately 9,000 – 7,500 BP (Yang 1991). The data of this site were published in a brief report (Hubei Provincial Institute of Archaeology 1996).

The number of stone tools recovered from the site is limited, probably due to the small size of the excavation. The principle tool type is stone axes. Most of them are chipped pebbles with irregular shapes and crude workmanship, but a few are fully polished. Other tool types include the adze, chisel, stone balls, and net-sinkers. They were also made of chipped pebbles (Figure 5.22). Some were polished along the edge, while others were polished fully. In addition to lithic tools, the toolkit includes a spindle whorl of fired clay, one bone needle, one bone drill, and one bone spade (Hubei Provincial Institute of Archaeology 1996).

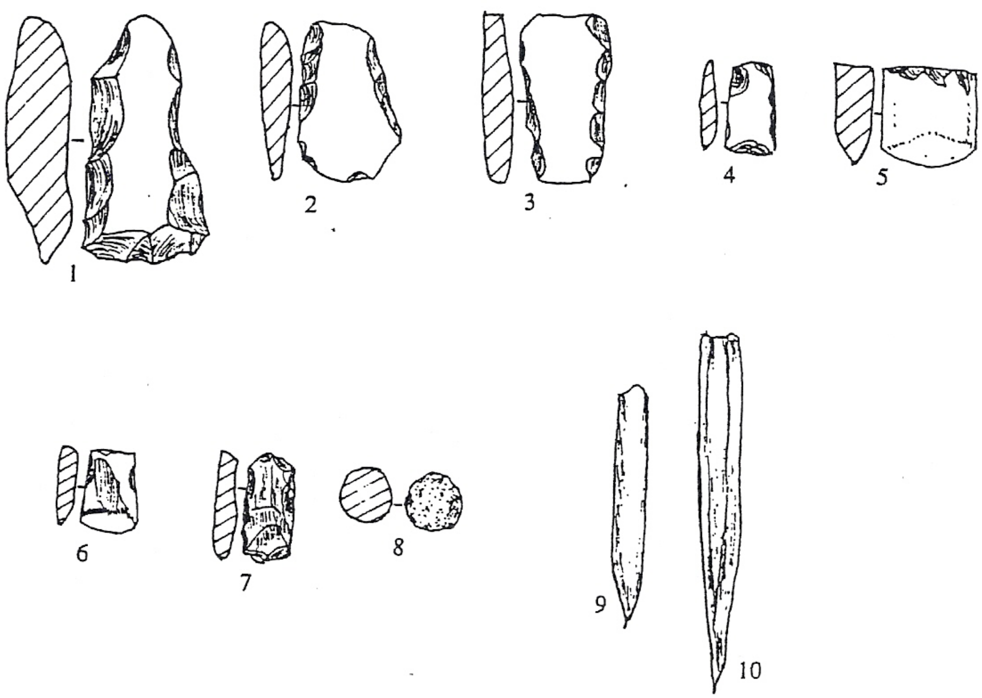


Figure 5.22 Lithic and bone artifacts from Chengbeixi (after Chen 1991)
1-5 axes; 6 adze; 7 chisel; 8 ball; (1-8 lithic artifacts) 9,10 bone awls
(scale: 1-8: 1/6; 9,10: 1/8)

Pottery from Chenbeixi is sand and charcoal tempered. The color varies from brownish red, greyish brown, black, yellow to white. Some were coated with a red slip. The pottery vessels were made by slab-modeling. The technique is crude, and the vessels are often asymmetric. Cord-marking is the major surface decoration, but stamping, incision and perforation were also used. The pottery vessel types (Figure 5.23) include cooking *fu* (kettle), pots, *dou* (round plate on a pedestal), bowls, plates, and globular jar with two lugs (ibid).

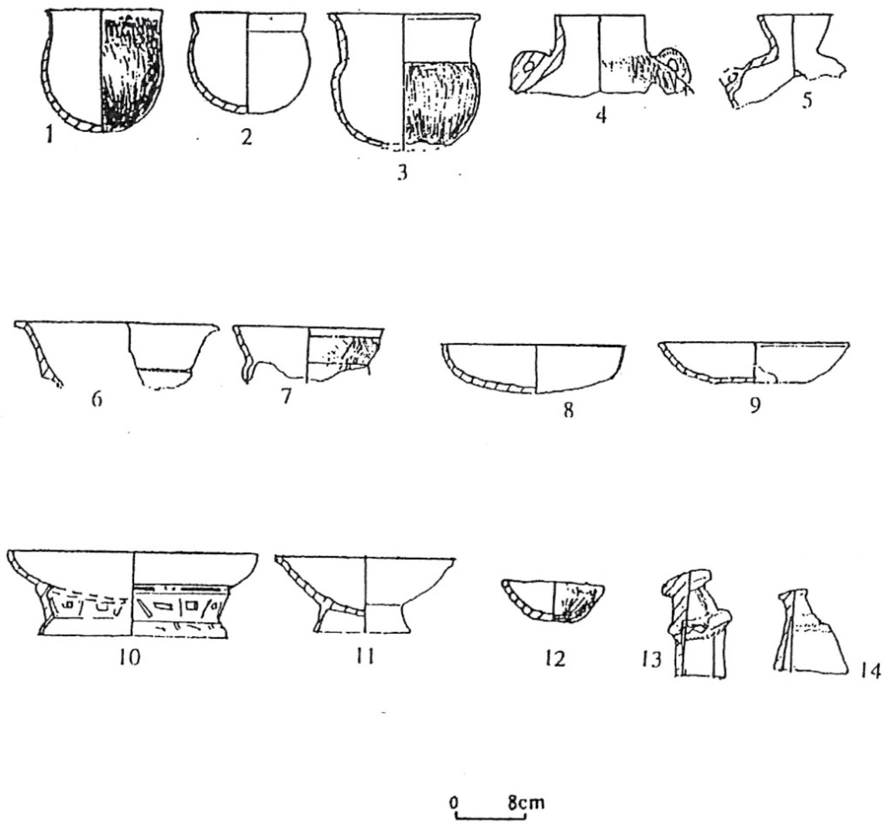


Figure 5.23 Pottery from Chengbeixi (after Chen 1991)
1-3 *fu* cooking vessel; 4,5 jars with two lugs; 6-9,11,12 bowls; 10 *dou*; 13,14 stands

The fauna remains include water buffalo, deer, cattle, turtle, mollusk shells, and fish. Their quantity is not included in the brief report. Rice husks and straw were found in the pottery temper. As in the case of Pengtoushan, these rice remains cannot be taken out of the pottery. Therefore, there can be no identification of the status of domestication of the rice from the site (ibid).

Fenshanbao

Fenshanbao is located on a small hill north of the Dongting Lake, about 140 km east of the Pengtoushan site. The open area site was excavated by a team from Yueyang Municipal Team of Archaeology and Cultural Relics Administration of Qianlianhu Farm in 1990 and 1991. The data from this site were published in two brief reports (Zhang 1992, Yueyang Municipal Team of Archaeology and Cultural Relics Administration of Qianlianhu Farm 1994) and one article (He 1995). Three radiocarbon dates were obtained for the site, and they dated to between 6,800 and 8,000 BP. Based on cross-dating and pottery comparison, He (1995) placed the date of the site between 8,000 and 7,800 BP. However, Yan (1998) preferred to put it within the chronological range of the Lower Zaoshi Culture – between 7,500 and 7,000 BP.

Three cultural layers were uncovered. The discoveries of the site include stone tools, pottery, house remains, post-holes, pits, burials, open pottery firing remains, and animal and plant remains. Imprints of rice husks were found in some pottery (Zhang 1992, Yueyang Municipal Team of Archaeology and Cultural Relics Administration of Qianlianhu Farm 1994).

The lithic toolkit includes pebble tools, small flake tools, and ground tools (Figure 5.24). Many flakes were used without secondary modification. The tool types consist of choppers, scrapers, axes, needles, and arrowheads. The first two types are made from pebbles or flakes, and the last three are partially or completely polished. The quantity and technique of the lithic assemblage are not reported. However, choppers and axes are suggested for purposes such as land clearing, as well as wood and bamboo working. Polished arrowheads imply the existence of hunting (ibid). But these inferences need more support from the analysis of lithic technology, usewear analysis, and probably experimental archaeology.

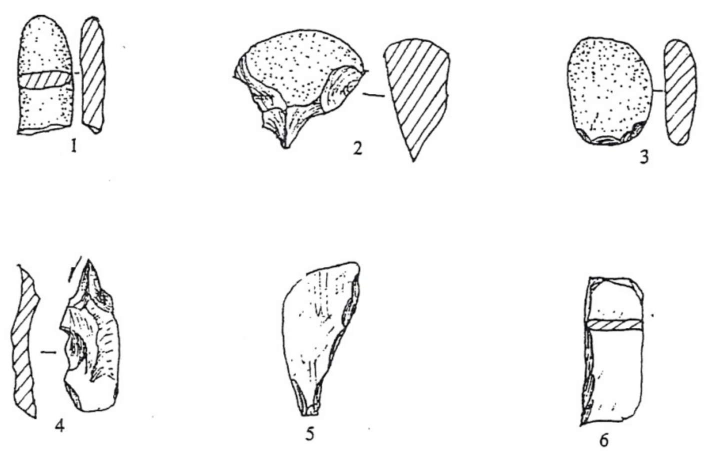


Figure 5.24 Lithic artifacts from Fengshanbao (after Yuyang Municipal Archaeology Team and Qianlianghu Farm Cultural Relic Administration 1994)
1 axe; 2,3 pebble choppers; 4 burin; 5,6 flakes (scale: 2,4 ½, others ¼)

Pottery shows a clear evolution of Pengtoudshan technology. In the early occupation of the site, pottery was mainly rice husks or wood charcoal tempered. Later, sands were added in temper, and rice husks gradually disappeared. Fine pottery became dominant by the end of the occupation. The vessels were all made by slab-modeling. The color was still mainly red or brownish red, but white and painted pottery emerged. Red-slip coating was common. Surface decoration includes cord-marking, incision, stamping, and combinations of these types. The vessel types (Figure 5.25) include pots, globular jars with two lugs, shoulder *fu* (kettle), bowls, *dou* (round plate on a pedestal), stands and lids (ibid).

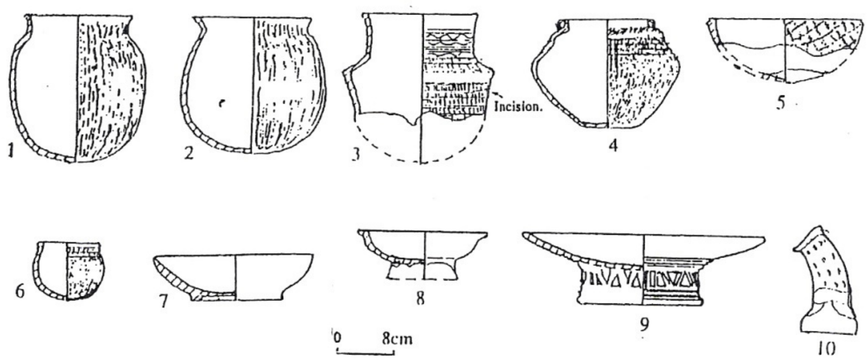


Figure 5.25 Pottery from Fengshanbao (after Yuyang Municipal Archaeology Team and Qianlianghu Farm Cultural Relic Administration 1994)
1-3 *fu* cooking vessel; 4 jar; 5-8 bowls; 9 *dou*; 10 stand

Post-holes, probably the remains of pile-dwellings, were found throughout the occupation. House floors appeared a little later and lasted to the end of the occupation. The house floor of about 10 m^2 was covered by sands and fired clay. A big post-hole was located in the center. Burials, all secondary, were found within the living area. Grave goods were commonly a few pottery vessels (ibid).

<u>Hujiawuchang</u>

Hujiawuchang, another important Lower Zaosi site, is located less than 50 km south of the Pengtoushan site. It was excavated by a team from Hunan Provincial

Institute of Archaeology in 1986. Radiocarbon dates of the site range from about 7,600 BP to 7,100 BP. The site yielded remains of stone tools, pottery, fired clay, post-holes, one burial, abundant animal bones, and one sample of rice grain in pottery. The data were published in a brief report (Hunan Provincial Institute of Archaeology 1993) and discussed in an article (Yuan 1995).

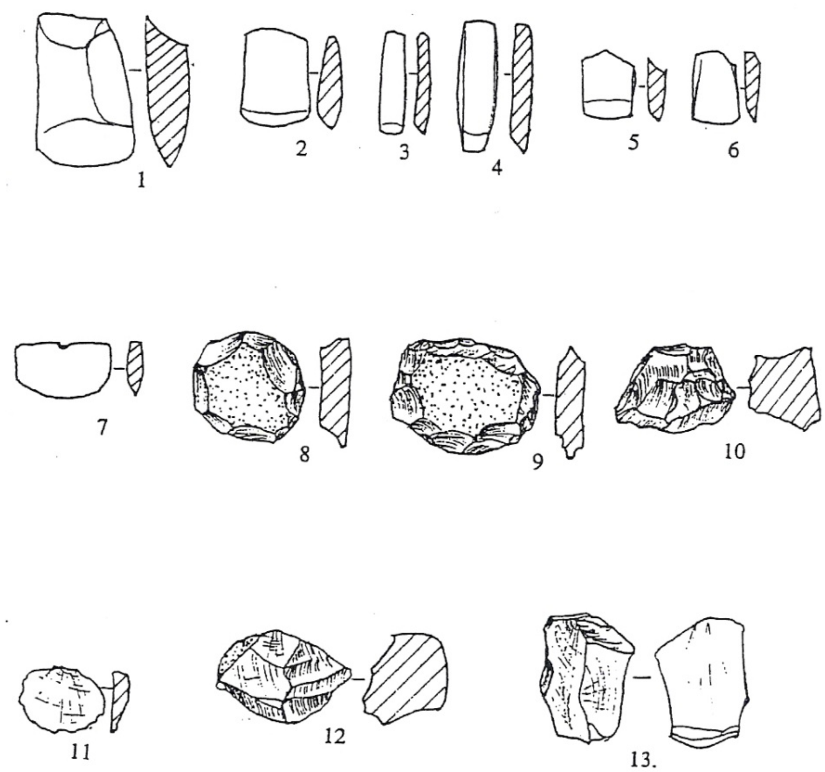


Figure 5.26 Lithic artifacts from Hujiawuchang (after Hunan Provincial Institute of Archaeology 1993)
1,2 axes; 3,4 chisels; 5,6 adzes; 7 knife; 8-10 discoids; 11,13 flakes; 12 flake core (scale: 1-7 1/6, 8-11 ¼, 12,13 ½)

The lithic assemblage (Figure 5.26) is dominated by pebble tools and small flakes of chert. The most important chipped tool is the so-called discoid chopper, which was found in many sites of the culture and probably used for cutting bamboo and wood (Yuan 1995). Ground stone tools represent only a small proportion of the toolkit, however, it is noticeable that they increased in quantity, typological variety and technique when compared with their Pengtoushan counterpart. In total 22 pieces of ground stone tools were found from an excavation area of 160 m^2. Their types include axes, adzes, chisels and a knife (Hunan Provincial Institute of Archaeology 1993).

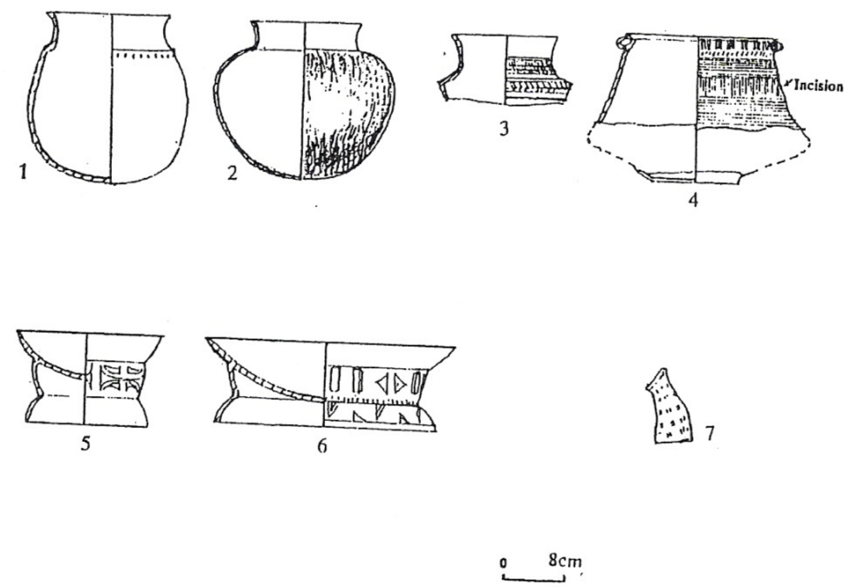


Figure 5.27 Pottery from Hujiawuchang (after Hunan Provincial Institute of Archaeology 1993)
1-3 *fu* cooking vessel; 4 jar; 5-6 *dou*; 7 stand

Pottery (Figure 5.27) at this site also showed a clear advancement in technique, decoration and typological variety. They are mainly charcoal and sand tempered, but find sand tempered pottery was also present. The technique was mainly slab-modeling, but a slow wheel was probably used for trimming. The color was mainly black and red. Red slip coating was also seen in many vessels. Surface decoration includes cord-marking, incision, stamping, punctuation, carving and perforation. Vessel types consist of plates of different forms, pots, jars with two lugs, cooking *fu* (kettles), lids, bowls, and stands. Some vessels were very well formed and symmetrical. This may be a result of the use of slow wheel (ibid).

The remains of post-holes, burial and fired clay were found in the site. But they are so poorly preserved that the details are not available (ibid). Even though, their existence clearly indicates a certain degree of sedentism.

A large number of animal remains were found. The identified species include water buffalo, goat, pig, deer, rat, rabbit, as well as birds, fish and shells. The remains of pig, water buffalo and goat are particularly numerous, probably because they were domesticated by humans (ibid). The faunal composition of the site is comparable to that of the Bashidang site. In both cases, wild animals were significant fewer in number than possibly domesticated species, demonstrating an increase in domestication and food production in human subsistence during this period.

In terms of the rice remain, only one grain was found in a pottery stand. Since it can not be taken out and identified, its status is unknown. However, pollen analysis indicates a warmer and more humid climate in the site of its occupation than that of the Pengtoushan site. The amelioration of climate could have benefited the development of rice domestication and agriculture (ibid).

Xianrendong and Diaotonghuan

As we mentioned earlier, Phases III-II of Xianrendong and Zones D-C of Diaotonghuan are dated to the Middle Neolithic (Zhao 1996, 1998). Lithic and bone technology continued in the earlier tradition, but some new tool types are of interested as they may be associated with agricultural activities. Stone adzes and hoes appear in the toolkit, probably used for tilling. Some stone weights may have been used with digging sticks to plant rice. Many large shell tools found from this period could have been used as harvesting tools. Pottery technology improved significantly. Grog-tempered and fine sand-tempered pottery became dominant. Surface treatments include plain, incision, and fine cord-marked. Cord-marks were initially applied on both sides but later only on exterior surfaces. Section modeling and coiling techniques were used to make pottery in this period (MacNeish and Libby eds. 1995). Pottery technology of this period is similar to that of the Pengtoushan and Lower Zhaoshi cultures in the Middle Yangzi Valley.

Studies of rice phytoliths from the site show an increase in domesticated rice in spite of the fact that wild rice still existed. Isotopic analysis of human skull fragments also suggests paddy rice agriculture in this period (MacNeish et al. 1995). A substantial number of faunal remains were still found from this period. The identified species include macaque, hare, leopard, wolf, raccoon dog, hog badger, polecat, civet, wild pig, Chinese water deer, muntjac, spotted deer, sheep, etc. In addition, large quantities of mollusk shells were found (Huang and Ji 1963, Redding 1995).

Kuahuqiao

Kuahuqiao, Xiaoshan District, Zhejiang Province, is an open area site located on the shore of Lake Xianghu. The precise location is 120º18' N and 30º05' E. The site was found in 1990 and excavated in 1990, 2001 and 2002 seasons. Fourteen calibrated radiocarbon dates place the site to 8,200 – 6,900 BP. Although the site was disturbed by modern constructions, its water-logged condition preserved rice assemblages of biological and archaeological remains, including a dugout canoe, some pits and house floors, lithic and ceramic artifacts, bamboo and wooden tools, and plant and animal remains. The discoveries are presented in a comprehensive report (Zhejiang Provincial Institute of Archaeology and Xiaoshan Museum 2004).

The features of the site include one burial, four house floors and unknown number of pits. The burial is disturbed and only the skull fragments and some upper body bones were preserved. The dead is identified as a child. No grave goods are found. House floors were also poorly preserved. Two are rectangular and two are rounded. The biggest house is near square, with 5.7 m long and 4.7 m wide. The lack of posthole and wooden construction parts indicate that the structure was not pile-dwelling. Pits are often rounded and some contain organic remains such as wooden artifacts, plant remains and animal bones (ibid).

The artifacts consist of stone tools, bone and antler tools, wooden and bamboo tools, and pottery. One hundred and thirty five stone tools, primarily polished, are made of local materials such as sandstone. Tool types include adze, ax, chisel, arrowhead, hammer, grinding pestle and pendant (Figure 5.28).

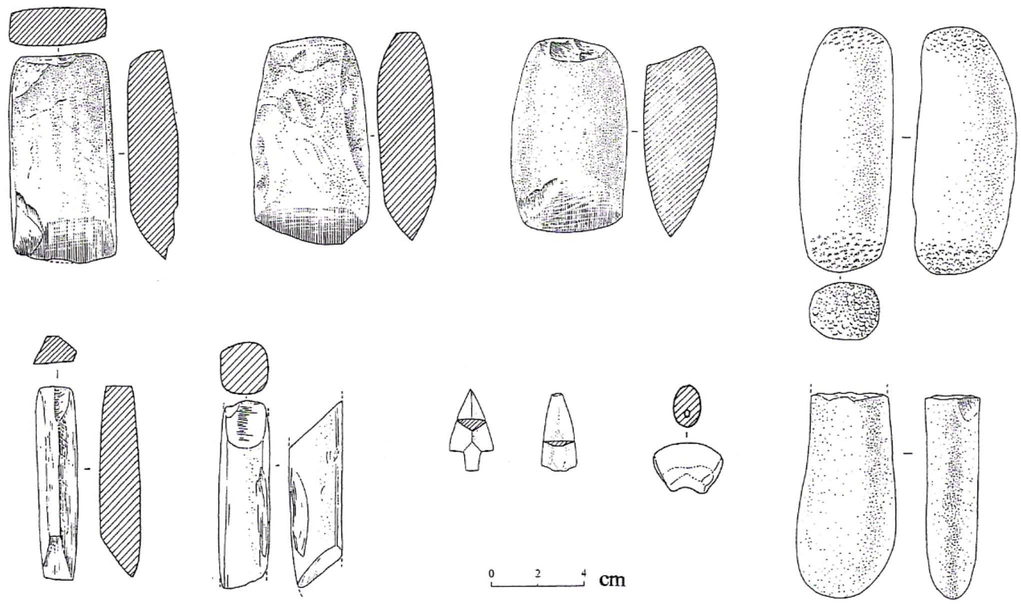


Figure 5.28 Lithic artifacts from Kuahuqiao (after Zhejiang Provincial Institute of Archaeology and Xiaoshan Museum 2004)

Over one hundred organic tools were found, including bone hoes, bone spear, bone dagger, bone saws, bone awls, bone needles, bone arrowheads, and antler hoes (Figure 5.29). The number of wooden and bamboo tools is 126. The tool types include awl, harpoon, arrow, arrowhead, oar, shovel, handle, and some unidentified production, fishing, weaving and construction tools (Figure 5.30).

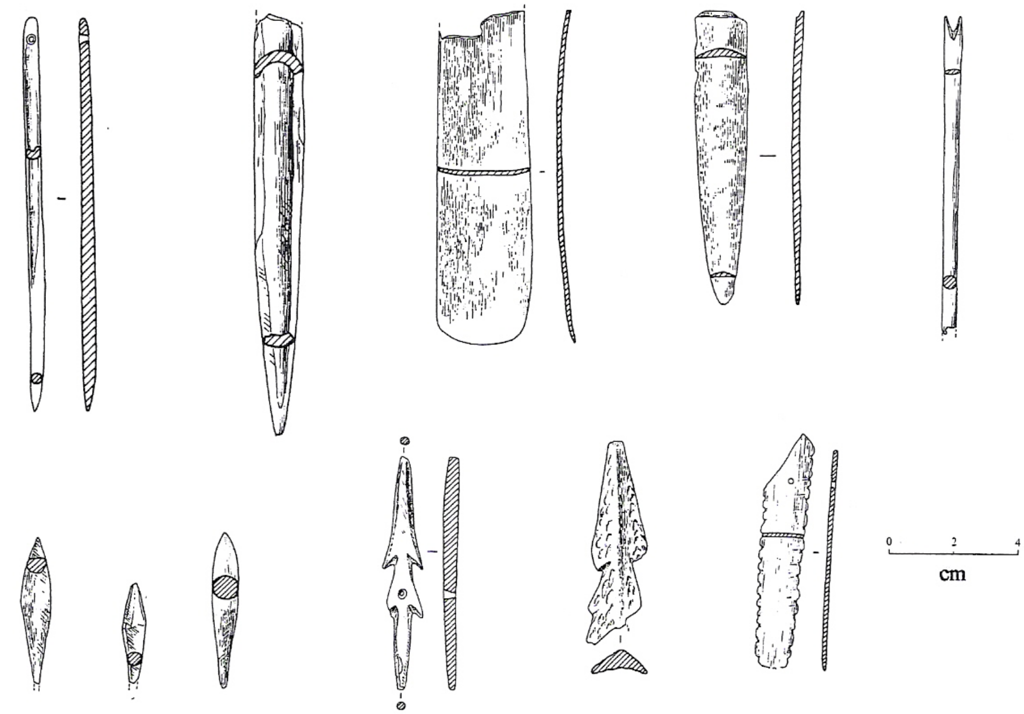


Figure 5.29 Bone artifacts from Kuahuqiao (after Zhejiang Provincial Institute of Archaeology and Xiaoshan Museum 2004)

Tens of thousands of potsherds were found, and over two hundred vessels were reconstructed. Most are sand or charred tempered, and a few are shell tempered. Some are covered by red or grey slip and painted with various geometric motifs. The surface decoration also includes cord-marking, incision and stamping. The technology is developed, as evidenced by well-formed shape, thin and even wall, and high firing temperature. Slow wheel was used in body modification and surface finishing. *fu* cooking kettle is the major type (52%). Other types include jar, bowl, plate, basin, lid, stand, etc. (Figure 5.31) (ibid).

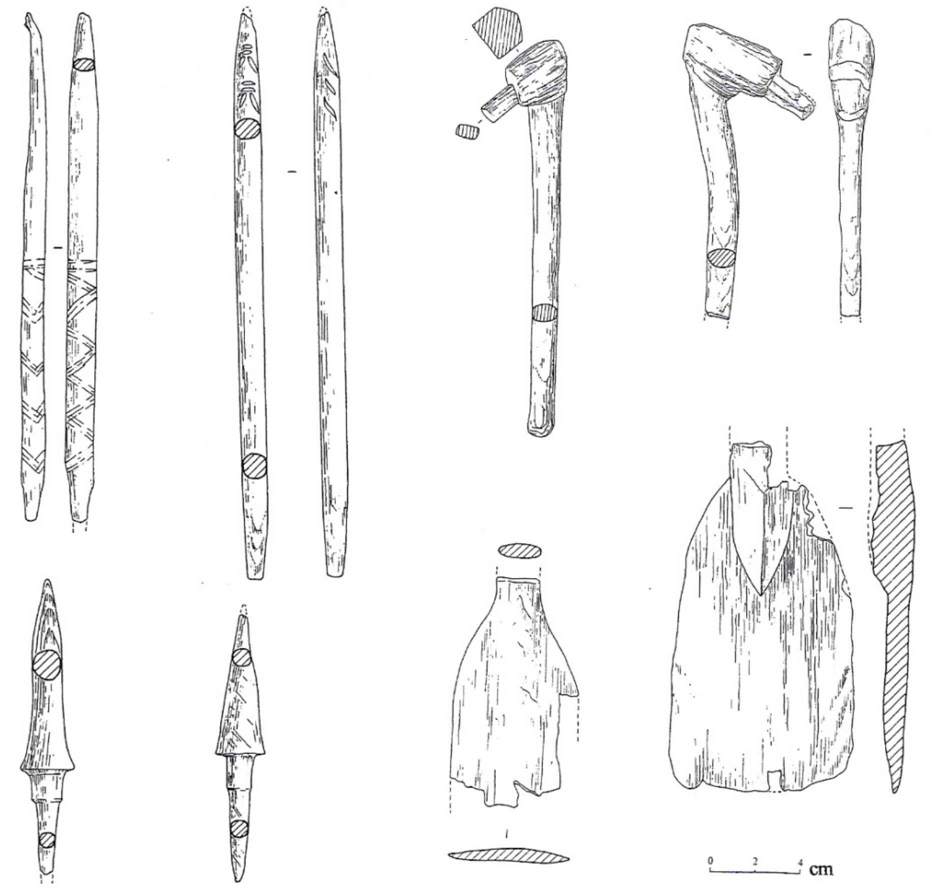


Figure 5.30 Wooden artifacts from Kuahuqiao (after Zhejiang Provincial Institute of Archaeology and Xiaoshan Museum 2004)

The faunal remains were found in large quantity (5125 pieces) and well preserved. They represent four categories: reptile, birds, mammals, and fish. Terrestrial animals include raccoon dog, badger, bear, rhinoceros, tiger, rat, wild boar, deer, Sika deer, water buffalo, Sumantra serow, as well as domesticated dog and pig. Rich plants remains were also preserved. The plants include nuts, acorns, water caltrop and seeds of species such as *leguminosae, cucurbitaceae, theaceae, and* *polygonaceae*. The most important plant remains are over one thousands rice husks and grains. The morphological characteristics, including length, width, and L/W ratio, indicate that more than half of the rice remains are clearly distinctive from wild rice and represent ancient domesticated rice (ibid).

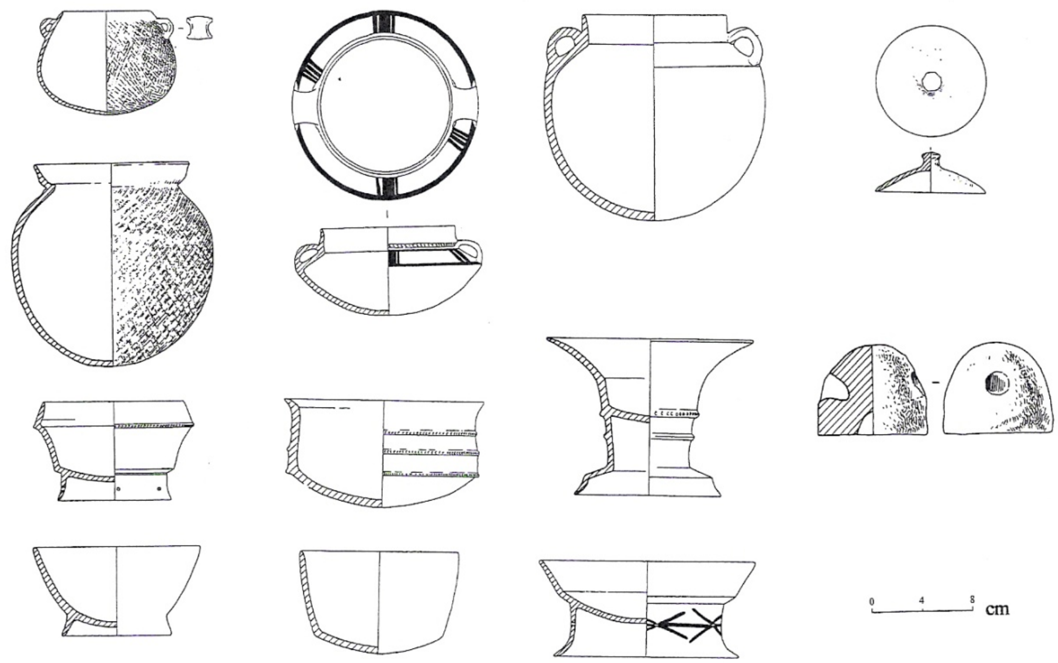


Figure 5.31 Pottery vessels from Kuahuqiao (after Zhejiang Provincial Institute of Archaeology and Xiaoshan Museum 2004)

Jiahu

Jiahua, Wuyang County, Henan Province, is located on a river terrace in the northern part of the Huai Valley. The precise location of the site is 33˚36’ N and 113˚40’ E and the size of the whole site is about 55,000 m^2. The site was excavated by a team led by Juzhong Zhang of Henan Provincial Institute of Cultural Relics during six seasons from 1983 to 1986. Jiahu yielded the earliest rice agricultural remains north of the Yangzi Valley. Unlike those cultures of the Yangzi Valley, the Jiahu assemblage belongs to a typical Middle Neolithic culture in North China – Peiligang Culture, which is mainly distributed in the Yellow Valley. Radiocarbon dating of the site is between 8,500 and 7,500 BP. The data of Jiahu were published in two excavation reports (Henan Provincial Institute of Cultural Relics 1989, Zhang et al. 1998).

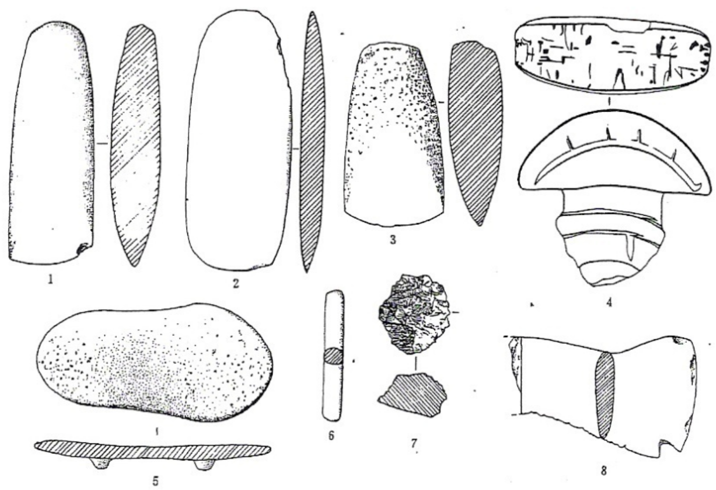


Figure 5.32 Lithic artifacts from Jiahu (after Henan Provincial Institute of Cultural Relics 1989)

The excavated area is about 2,400 m^2, which contained over 400 remains of houses, pits, earthenware kilns, more than 300 burials, along with thousands of lithic and organic artifacts, pottery, animal bones, horns, teeth and plant remains including some possibly domesticated rice remains (ibid).

In lithic assemblage (Figure 5.32), ground stone tools are the majority. The tool types include axe, shovel, teeth-bladed sickle, grinding pestle and plate, and various chipped scrapers. There are also a substantial quantity of tools made of bone, antler, animal tooth and shell. These tool types include arrowheads, harpoons, noodles, knives, etc (Figure 5.34). Other organic artifacts include eight turtle carapaces with unidentified symbols and two bone flutes (Figure 5.34, 5.35). Organic artifacts are all polished and fine (ibid).

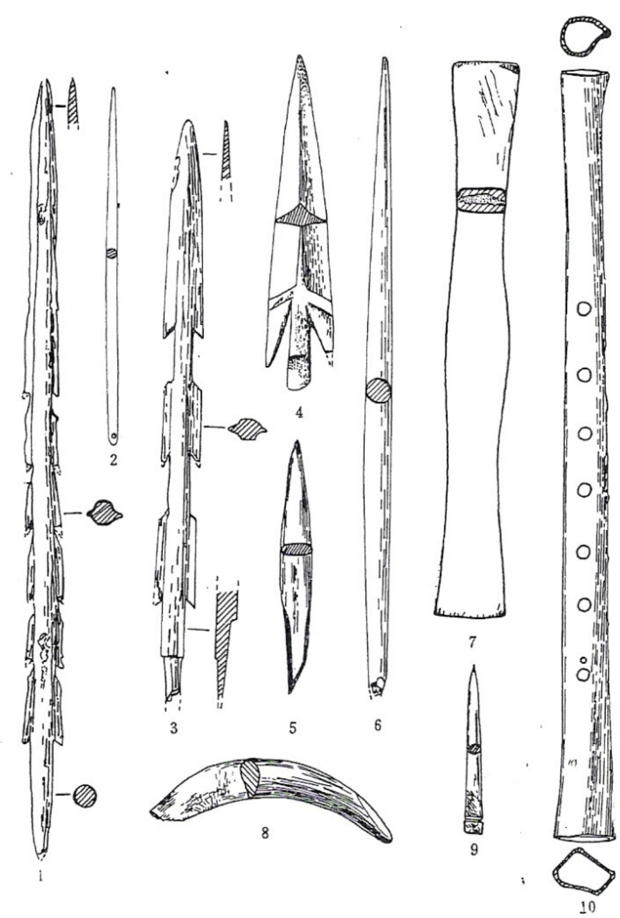


Figure 5.34 Bone artifacts from Jiahu (after Henan Provincial Institute of Cultural Relics 1989)

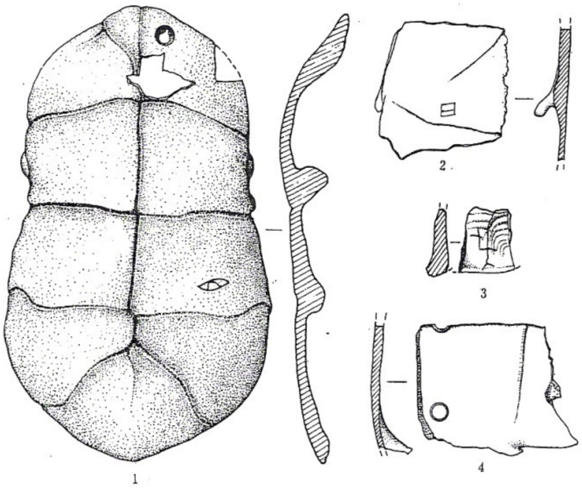


Figure 5.35 Turtle shell artifacts from Jiahu (after Henan Provincial Institute of Cultural Relics 1989)

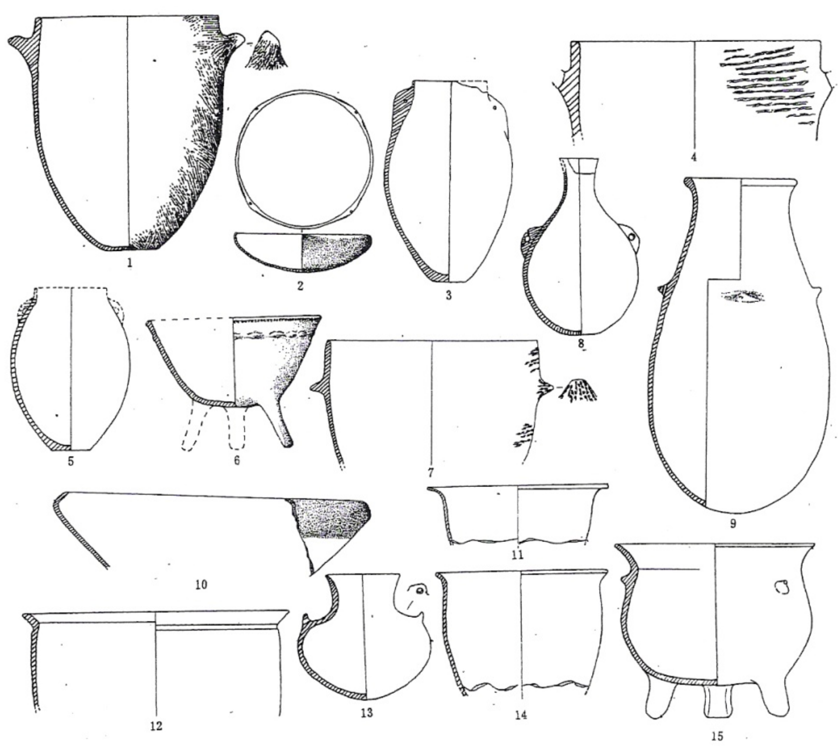


Figure 5.33 Ceramic artifacts from Jiahu (after Henan Provincial Institute of Cultural Relics 1989)

The pottery of Jiahu (Figure 5.33) is dominated by red ware. Some brown and few grey and black wares were also found. The color and thickness are often uneven, showing a relatively poor control of modeling and firing. The surface was polished and mostly without decorations. Utensils consist of *ding* (cooking vessels), bowls, pots, basins, jars, urns, cups and spoons. Other pottery artifacts include stands, file, wheels and balls. Animal sculptures of pottery were also found (ibid).

Large quantities of faunal remains were found. The identified species consist of pig, deer, dog, raccoon dog, ox, chicken, alligator, wildcat, hare, various fish, shell, turtle, tortoise, etc. Plant remains include carbonized seeds of oak trees as well as rice husks and grains (ibid). Through phytolith and scanning electron microscopy analyses, some rice grains were identified as proto-*japonica* primitive domesticated rice with some characteristics of common wild rice (Zhang and Wang 1998). It was mentioned that domesticated millet remains were also found in the site (Yan 1997).

More than 30 house remains were found. They are all semi-subterranean, and round or oval shape. Some houses consist of two, three or four rooms between 2 and 6 m^2. The over 300 burials can be divided to several cemeteries and yield most of the artifacts. More than 300 storage pits and over 10 kilns contained most of animal and plant remains and some artifact (Zhang et al. 1998).

5.4 The Late Neolithic Cultures

The period between 7,000 and 5,000 BP saw a flourishing of agricultural cultures in the Middle Yangzi Valley and the Lower Yangzi Valley and the spread of rice agriculture northward to the Huai Valley and the Yellow Valley. In general, the Daxi Culture is considered the successor of the Lower Zaoshi Culture in the Middle Yangzi Valley, covering the whole Late Neolithic period. It is more complex in the Lower Yangzi Valley, where the general cultural sequence is the Hemudu Culture (7,000 – 6,500 BP) → the Majabang Culture (6,500 – 5,700 BP) → the Songze Culture (5,700 – 5,300 BP) (Yan 1998).

I will focus on the Hemudu site, because it yielded incomparably abundant remains of domesticated rice and other plant and animals, and the technology and settlements are compatible with the established farming economy. Besides, it is superior to all other remains of this period in terms of dating, quantity, and quality of the remains. Hemudu represents the development of agricultural culture in the Lower Yangi Valley. Meanwhile, I briefly summarize the basic characteristics of the Daxi Culture that is Hemudu's contemporary in the Middle Yangtze Valley. Finally, a discussion of the two sites with the oldest paddy field and irrigation evidence will be presented (Figure 5.36).

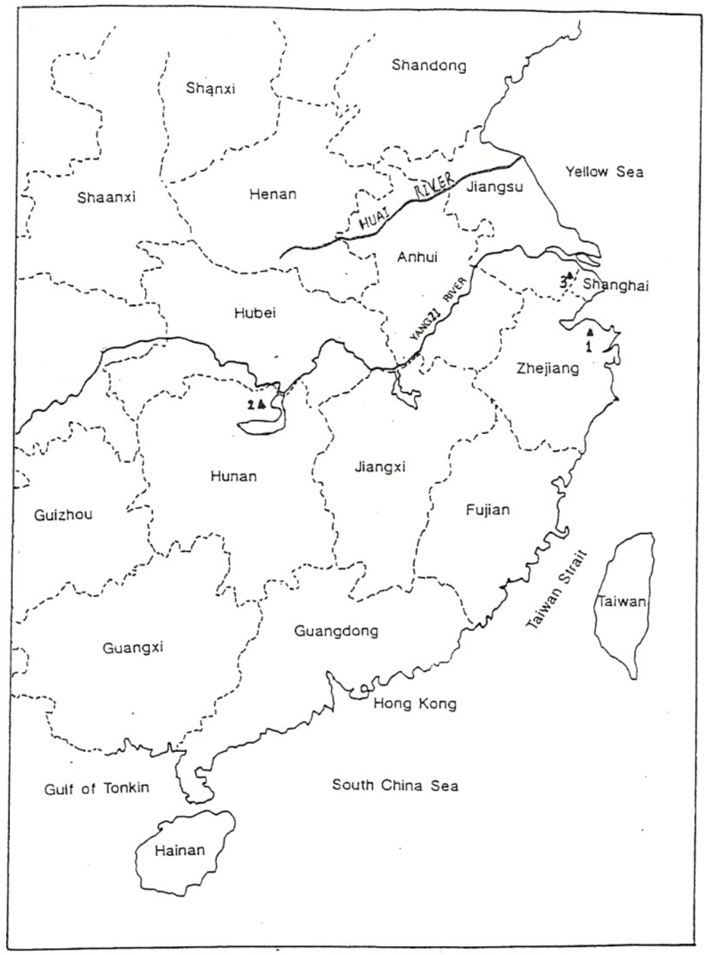


Figure 5.36 Late Neolithic sites in the Middle and Lower Yangzi Valleys

Hemudu

Hemudu is located on an alluvial plain south of the Yangtze Mouth and Lake Tai in Zhejiang Province. Its precise location is 29˚58' N and 121˚22' E. The plain on which the site lies has vast areas of peats beneath the surface, suggesting that at the time of occupation the site was surrounded by forests and ponds as well as rivers. The site was excavated a team of Zhejiang Museum and Zhejiang Provincial Administration of Cultural Relics during the 1973-74 and 1977-78 seasons. Hemudu is the most well-known and representative early rice agricultural site in China. The cultural deposit was about 4 meters thick and can be divided into four natural strata (Figure 5.37). From the lowest to the top, the radiocarbon dates of these strata are 7,100 – 6,500 BP, 6,500 – 6,000 BP, 6,000-5,500 BP, and 5,500 – 5,000 BP, respectively. The original data of Hemudu were published by a brief report (Zhejiang Provincial Administration of Cultural Relics and Zhejiang Museum 1978) and a comprehensive report (Liu and Yao 1993).

Due to the excellent preservation conditions, the site yielded very rich remains such as abundant animal and plant remains (including rice straw, husks and leaves), as well as lithic and organic tools, pottery, foundations of pile-dwellings, pits, and burials. (ibid). The lowest stratum of the Hemudu deposit, Stratum 4, contains crucial information related to the study of origins of rice agriculture. The following summary focuses on the Stratum 4.

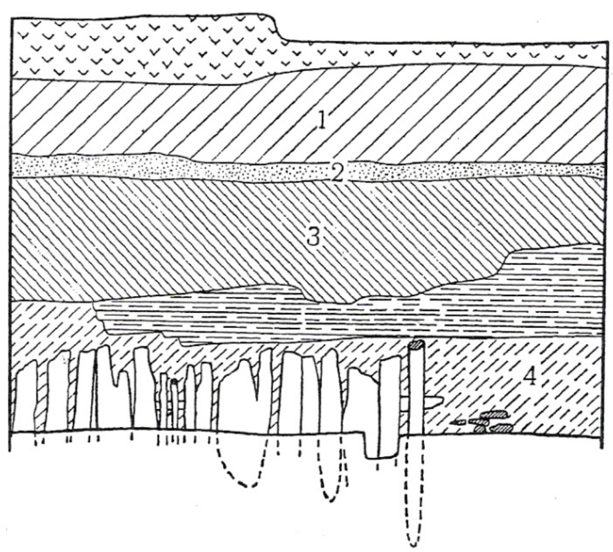


Figure 5.37 Stratigraphic profile of Hemudu (after Zhejiang Museum 1978)

The cultural assemblage is abundant, including 2383 artifacts. Bone artifacts are the majority, totally 1934 pieces. Other categories include lithics (385), wooden items (328), and fired clay (191). Lithic tools (Figure 5.39) were made of black chert. Most of them were partially polished. The tool types consist of grinding stones, axes, chisels, adzes, stone balls, pebble pestles, and net sinkers. The majority of bone tools are arrowheads. Other types include whistles, chisels, drills, spades (Figure 5.40), needles, daggers, net shuttles, fishing spears, and sickles (Figure 5.41). A total of 144 wooden tools (Figure 5.42, 5.43) were found. The types consist of projectile points, handles, thread-spindles, oars, daggers, small sticks, spades, and spindle whorls. Also included in the toolkit are fired clay tools: 177 spindle whorls and 14 pellets. The final tool class is a type of butterfly shaped stone or wooden artifacts, which were probably part of house decoration or mounted on the end of spears (ibid).

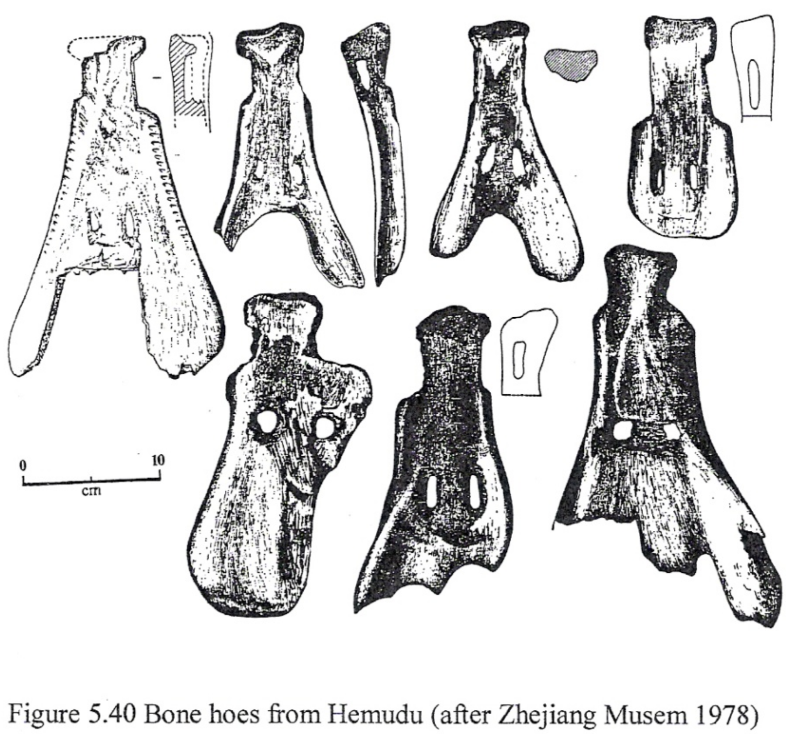


Figure 5.40 Bone hoes from Hemudu (after Zhejiang Musem 1978)

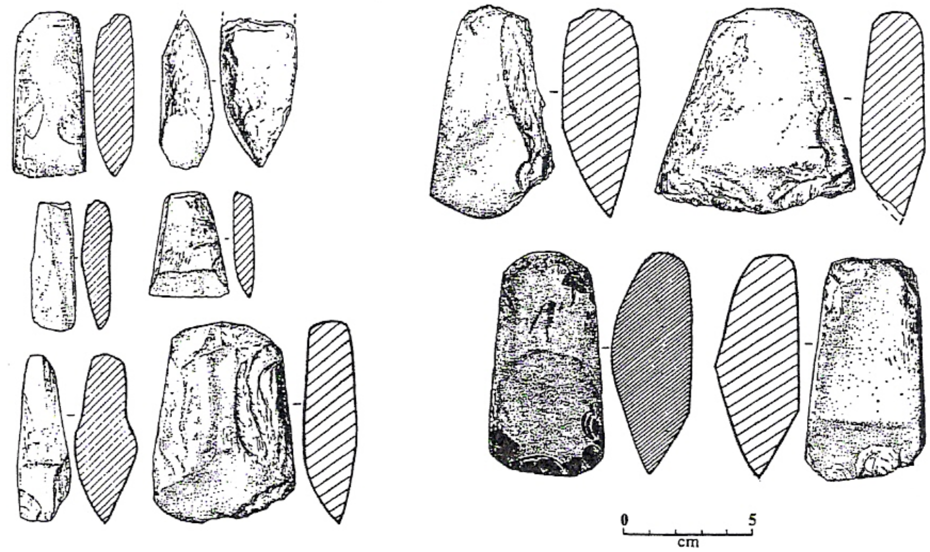


Figure 5.39 Lithic artifacts from Hemudu (after Zhejiang Musem 1978)

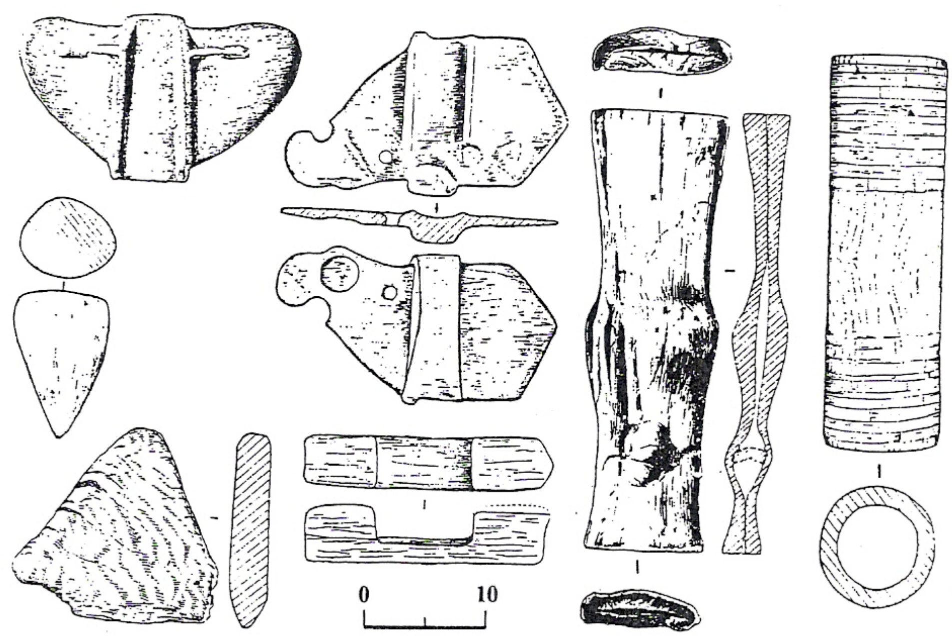


Figure 5.43 Wooden artifacts from Hemudu (after Zhejiang Musem 1978)

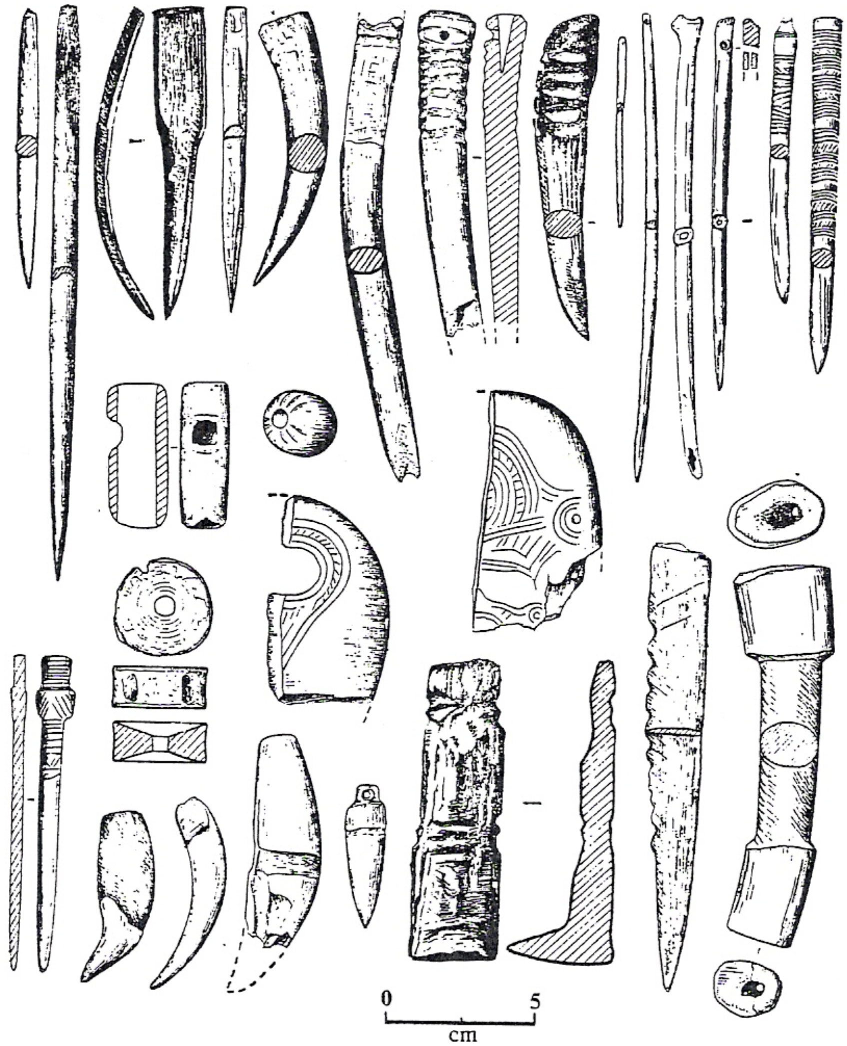


Figure 5.41 Bone artifacts from Hemudu (after Zhejiang Musem 1978)

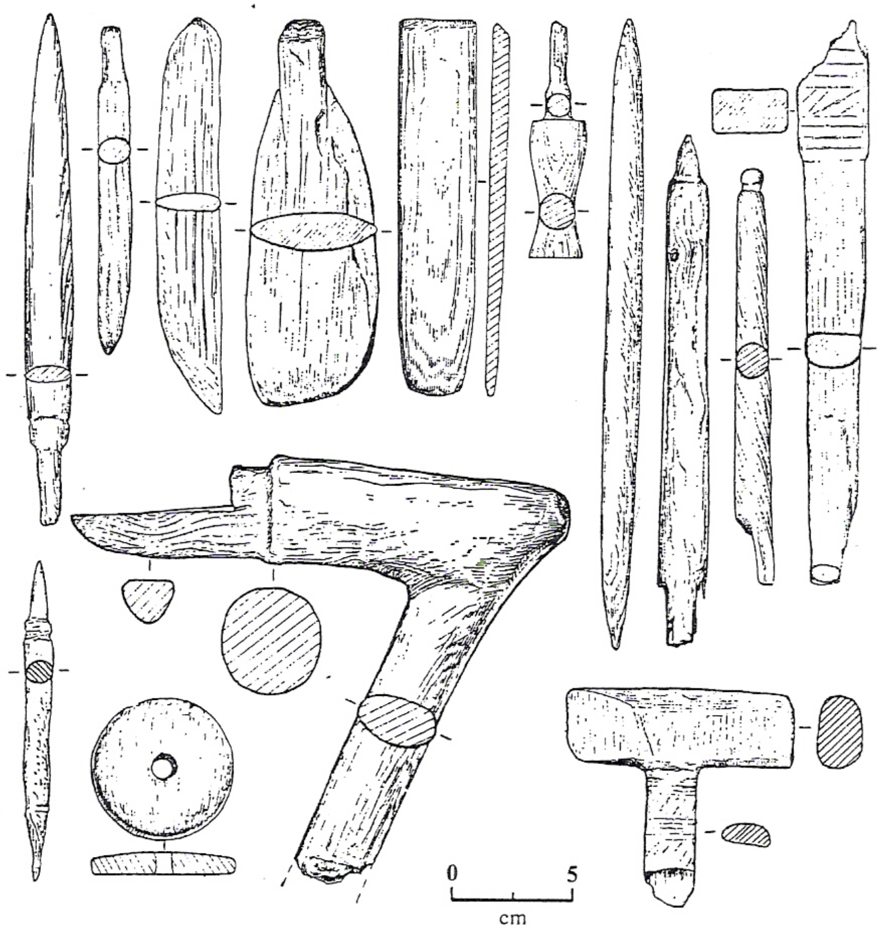


Figure 5.42 Wooden implements from Hemudu (after Zhejiang Musem 1978)

Pottery remains (Figure5.44) are also rich. 952 vessels were found. They are all black. The majority of them are organic tempered, and the remaining are sand tempered. A few organic tempered vessels were covered by a white slip and painted with brown and dark brown motifs. They are all handmade, thick and porous. The pottery types include *fu* (kettle), pots, bowls of various size and forms, plates, stands, lids, and small containers. In one of the *fu* vessels, the remains of over-cooked rice were preserved. The surfaces of some vessels are decorated by cord-marking and incision. The motifs include animals, plants, and some geometric designs (ibid).

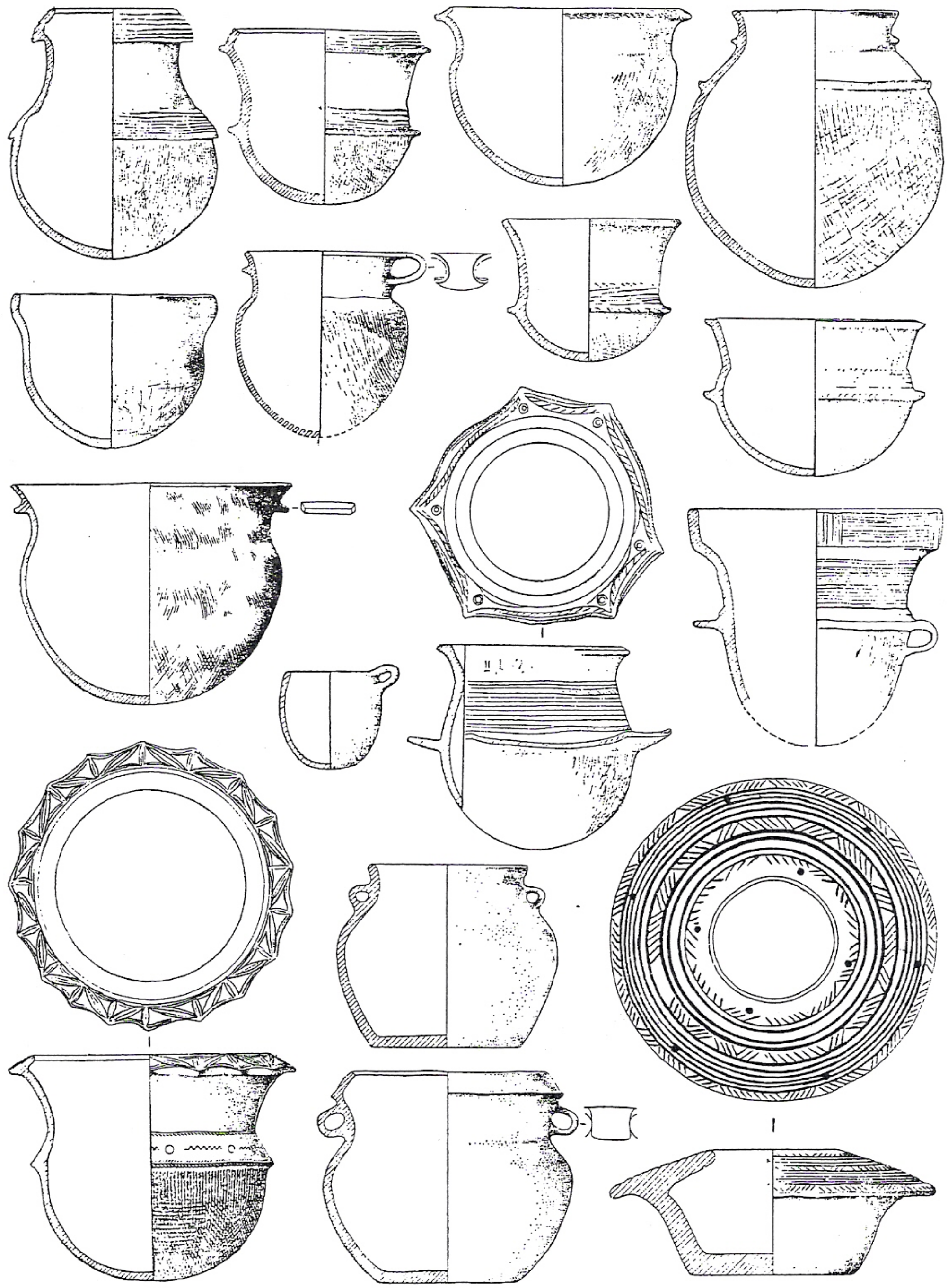


Figure 5.44 Pottery from Hemudu (after Zhejiang Musem 1978)

The artistic achievement of the Hemudu inhabitants was also reflected in other artworks (Figure 5.45), such as ivory bird sculptures, various ornaments made of stone, bone and animal teeth, including beads, rings, and hair-pins. They were probably able to produce loom textiles from some fibers and make clothes. Unfortunately, the only supportive evidence for this is the bone needles (ibid).

Figure 5.45 Artworks from Hemudu (after Zhejiang Musem 1978)

Not only were the Hemudu people capable artists, they were also skillful craftsmen of wooden buildings (Figure 5.38). Well-made wooden house components, such as piles, wall timbers, floorboards, and various forms of joinery, have been recovered. Following house foundations, the buildings include three longhouse style large pile-dwellings that were further delineated to smaller rooms. A corridor or long balcony was built in front of each house (ibid). This type of building is often used in humid tropical and subtropical areas. Identical structures can be seen in Southeast Asia today (Bellwood 1978).

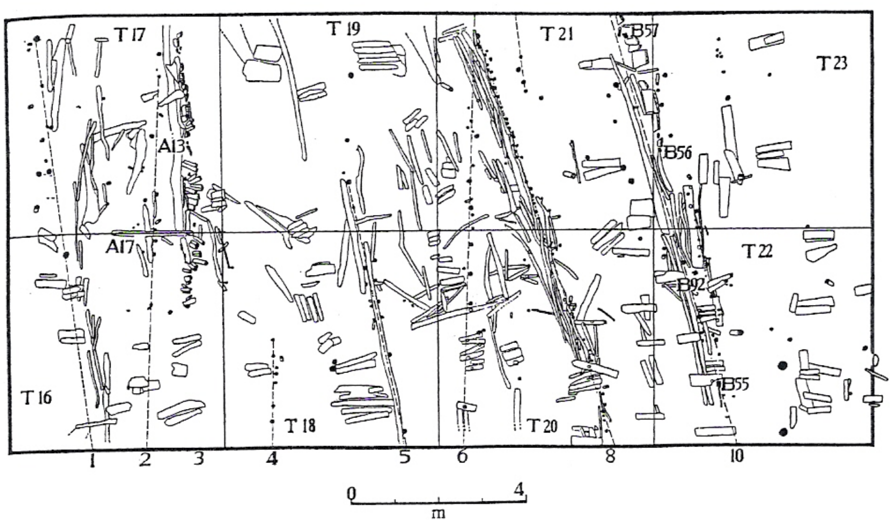


Figure 5.38 Partial plan of pile dwelling in Hemudu (after Zhejiang Musem 1978)

Because they were waterlogged, a large number of plant and animal remains were preserved. Among the plants: rice grains, husks, and stalks were found in almost all areas of the excavation. The rice deposits ranged from 10 – 20 cm to 30 – 40 cm in thickness, probably representing 120 tons of rice grains (Yan 1982). It was once thought that these rice remains were all domesticated *indica* rice, but the recent study of the remains indicates the inclusion of a few wild rice grains (Tang et al. 1994). This discovery is important to understand the process of rice domestication. Other plants found include bottle gourds, acorns, water caltrop, the sour date, and probably fox nut. Faunal remains consist of three categories and 61 species are represented. Terrestrial animals include macaques, pangolin, rat, porcupine, bear, raccoon dog, polecat, hog badger, river otters, oriental civet and rasse, masked palm civet, tiger, Asiatic elephant, rhinoceros, wild boar, deer, muntjac, water buffalo, as well as domesticated dog and pig. Aquatic animal remains were identified as whale, shark, river and sea fish, river and sea turtles, crocodiles, mollusk shells, and crab. 8 species of birds were identified (Liu and Yao 1993).

It is clear that the Hemudu Culture remains of the Hemudu site are stunningly rich. It depicts a developed farming community that enjoyed a rich environment and exploited a wide variety of food resources by means of hunting, fishing, and farming. They were also sedentary, constructing complex structures and producing work of art. The evidence provides the basis for further exploration of the development of agricultural culture from a variety of perspectives.

Daxi Culture

The Daxi Culture succeeded the Lower Zaoshi Culture in the Middle Yangtze Valley. Remains from dozens of sites have been reported. Based on two comprehensive studies of the Daxi Culture (Meng 1992, He 1995), its basic cultural characteristics can be summarized as follows.

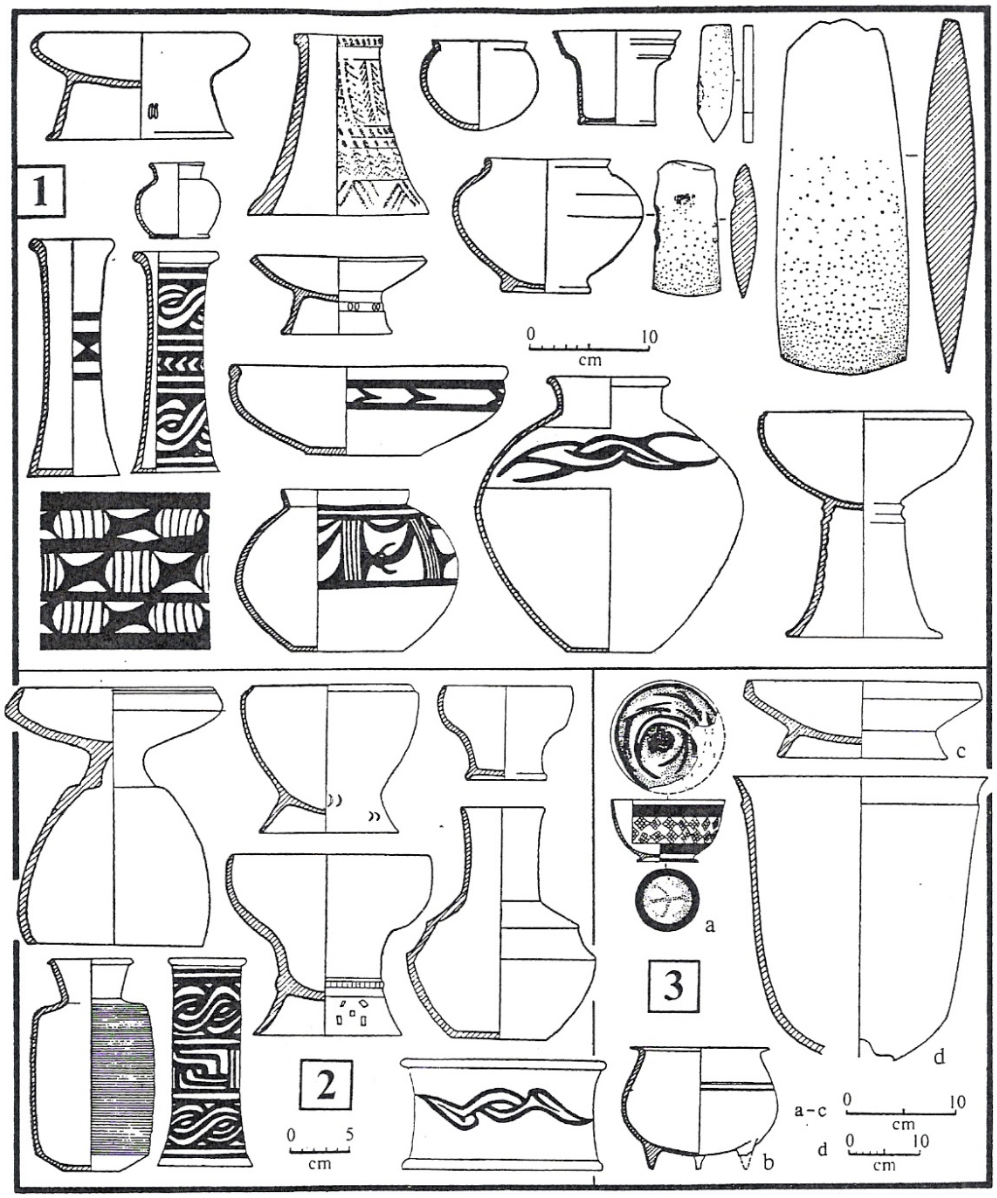


Figure 5.46 Pottery of the Daxi Culture (after Chang 1986)

First, tools were made of stone, bone, clay, and shell. The Daxi stone tools are significantly different from those of the Pengtoushan and Lower Zaoshi Cultures.

They were mostly well polished. The tool types include axes, adzes (Figure 5.46), chisels, pestles, sickles, and spindle whorls. Perforated shell tools were also found. Ornaments were made of jade, stone, bone, ivory, and animal teeth. The types consist of ear ornaments (pendants and rings of turquoise, stone, and jade), necklaces (made up of jade rings, jade half-rings, and shell beads), armlets, and bracelets (ibid).

Second, pottery (Figure 5.46) was mostly red. They were mainly hand made, but the rims of some vessels appear to have been refined on a slow wheel. The paste was tempered with find sand or crushed shells, as well as rice husks and other plant materials. Vessel types consist of bowls, cups, urns, plates, pots, bottles, and basins. A type of cylindrical bottle is the most characteristic vessel of the Daxi Culture. Painted pots were abundant. The painting was black on red with various designs. Surface decorations also include stamping, incisions, cord-markings, etc (ibid).

Third, square house foundations (Figure 5.47) were found in many sites. The walls were built of gray clay mixed with fired clay fragments and some grog. The exterior surface was plastered with clay mixed with some rice husks and rice straws. The wall was then burned or baked. Posts were made of wood or bamboo. A hearth was located at the center. The floor was plastered with clay and tempered with fine sands. Storage pits were often found in the dwelling area. They sometimes contained animal remains including pigs, water buffalos, sheep and fish. Simple pottery kilns (Figure 5.49) were also found in some sites. Human burials (Figure 5.48) were found in most sites; however, grave pits are often unidentifiable, and there were no caskets. The orientation and posture of the dead varied from site to site and within the same cemetery. Most of the bodies were south oriented, but others pointed to north or west. The postures were stretched or flexed. Some lay face up while others face down. The quantity of grave goods also varied from nothing to more than thirty items. Grave items were mostly tools, pottery vessels, and ornaments (ibid).

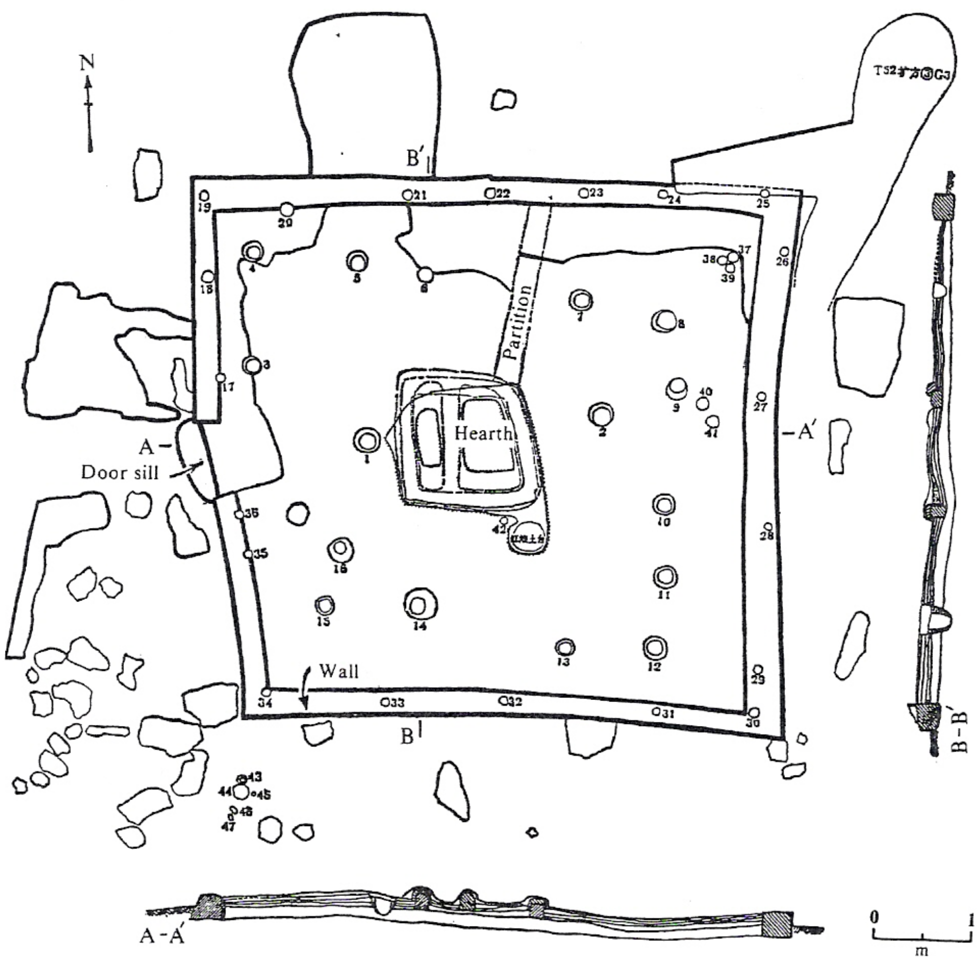


Figure 5.47 House floor of the Daxi Culture (after Chang 1986)

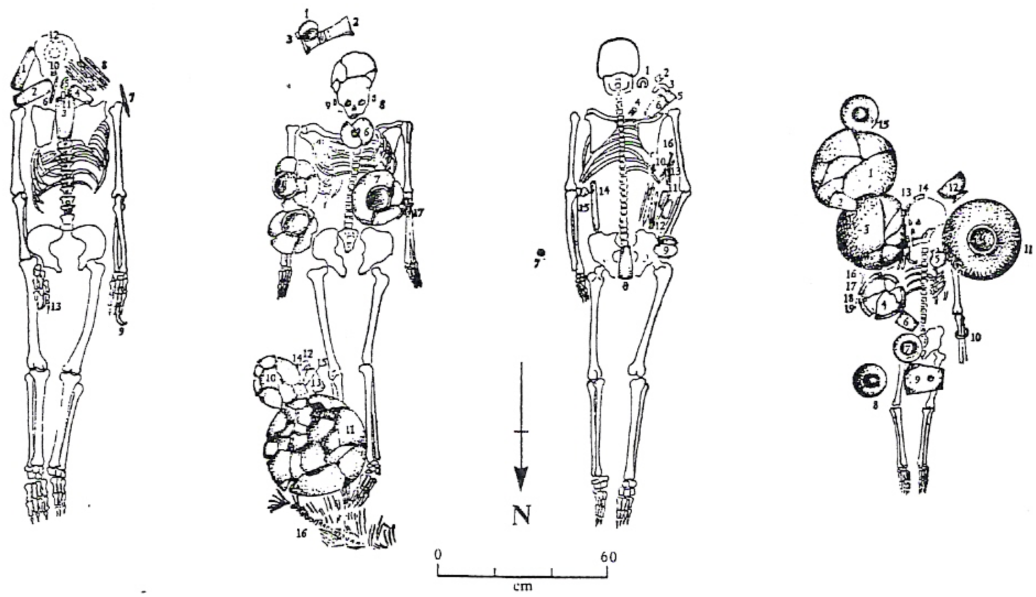


Figure 5.48 Human burials of the Daxi Culture (after Chang 1986)

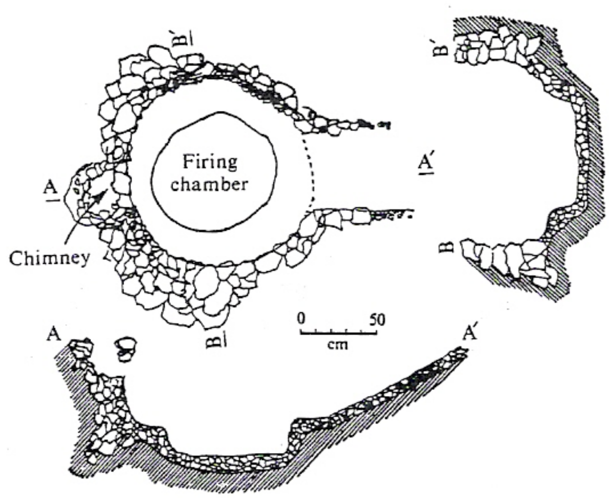


Figure 5.49 Pottery kiln of the Daxi Culture (after Chang 1986)

Paddy Field Remains

A rice field system, including paddy field and associated irrigation system, provides important and direct evidence of rice agriculture. In recent years, such evidence was found in two sites of the Late Neolithic in the Yangzi Valley – Chengtoushan in the Middle Yangzi Valley and Caoxieshan in the Lower Yangzi Valley. These, along with other archaeological assemblages mentioned above, support the hypothesis that there was established rice agriculture during this period.

The Chengtoushan site is located in Li County, Hunan Province. It is not far from the Pengtoushan and Bashidang sites which date to the Middle Neolithic. The paddy field remains belong to the Daxi Culture and date to 6,500 – 6,300 BP. This is the oldest rice field remains in the world. Three northwest-southeast parallel earthen banks divided the field into two parts. The maximum length of each bank is about 40 m. The width of the two parts is 4.6-5 m and 2.5 m, respectively (Figure 5.50). The soil contains rice remains such as roots, stems, and carbonized grains. Large quantities of rice grain phytoliths and leave were found in the soil, of which 95% were identified as *japonica* rice. The primitive irrigation system consists of three pits and three trenches on the west side of the field. Two trenches are clearly connected to one pit near the field (Hunan Provincial Institute of Archaeology 1999).

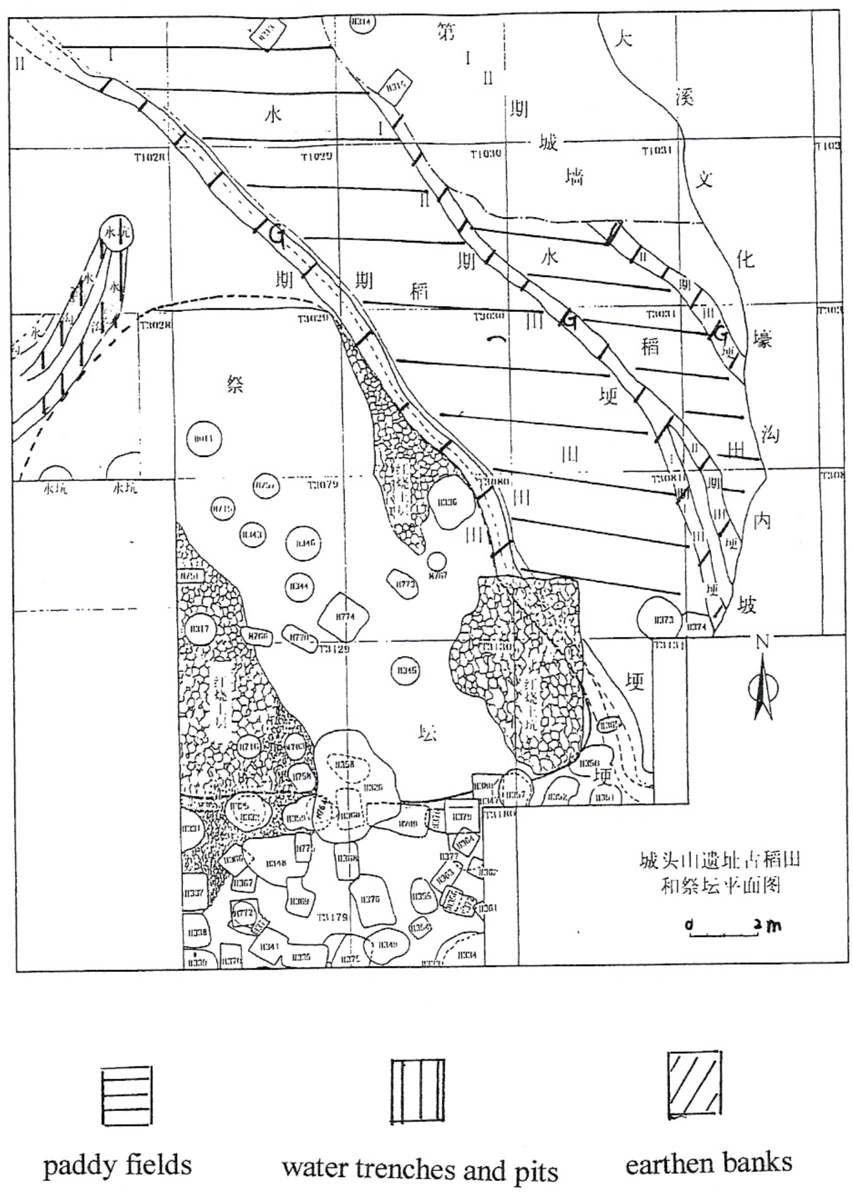


Figure 5.50 Plan of paddy fields at Chengtoushan (after Hunan Provincial Institute of Archaeology 1999)

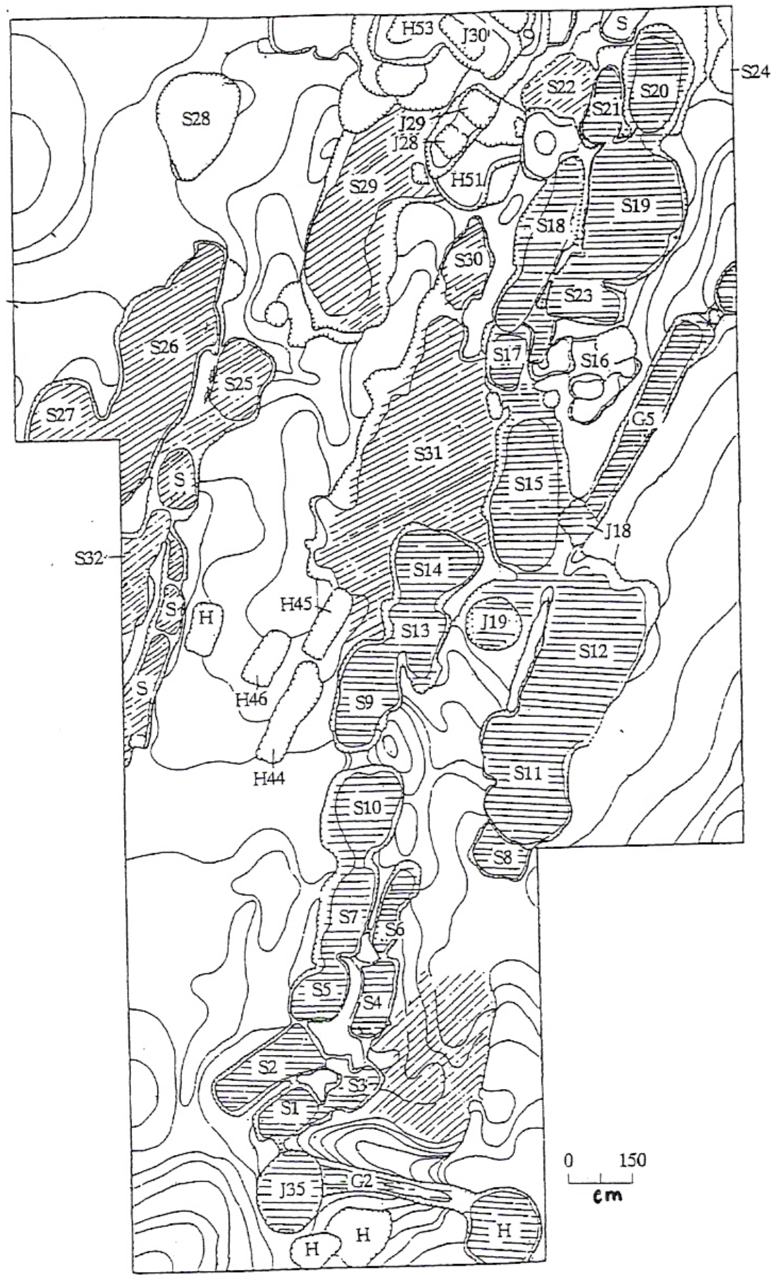


Figure 5.51 Plan of paddy fields at Caoxieshan (after Zou et al. 2000)
S: paddy fields; G: water trenches; D: water ponds; J: wells

Caoxieshan is located in Wu County, Jiangsu Province. It belongs to the Majiabang Culture and is dated to around 6,000 BP. The paddy field found here

(Figure 5.51) is more complex than that of Chengtoushan. The field is formed by clusters of small pond-shape fields and can be divided to three chronological phases. Fields of Phase I are generally larger than those of later phases. They were the original alluvial field with slight modification, and did not have an irrigation system. Fields of Phase II were dug after those of Phase I were filled. The fields are small and pond-shape, often connected by watercourses. They also had affiliated pits and wells to store water. They use underground water and were all connected. Fields of Phases III are similar to those of Phase II, but are located in newly exploited areas. Larger water ponds were added to the irrigation system. This system is considered better than the previous one, because the water level of the field could be adjusted through the adjacent pond. The structure of these fields indicates a large scale and well designed distribution. The studies of some preserved carbonized rice grains and phytoliths indicate that they are domesticated *japonica* rice (Zou et al. 2000).

5.5 Summary

The developments of archaeological cultures pertinent to the origins of rice agriculture are presented in this chapter. The development process is divided to Early Paleolithic (pre-LGM), Late Paleolithic (post-LGM), Early Neolithic, Middle Neolithic and Late Neolithic. The cultural aspects consist of technology, subsistence and site/settlement patterns.

Until the LGM, the Paleolithic technology in the Middle-Lower Yangzi Valley was dominated by typical Southern China pebble industry that is characterized by large size pebble tools made of local coarse pebbles. The sites often formed clusters along river terraces. Function differentiation was presented at both inter-site and intra-site levels. The subsistence strategy was mainly plant-dependent gathering and hunting. In general, human cultures were greatly conditioned by natural environment during this period.

After the LGM, the late Paleolithic of the Middle-Lower Yangzi Valley witnessed a series of cultural changes. The lithic technology shows a transition from pebble chopping tools to small flake tools made of external fine lithic materials. Secondary retouch indicates the improvement of manufacture techniques. Cave sites increased and the quantity of artifacts and long-term site occupation suggest increased sedentism. Hunting became more important in human subsistence, as the food procurement model changed from forager type to collector type.

In the Early Neolithic, lithic technology basically continued the previous tradition. Organic tools were found in tool kits, some of which were related to plant harvesting. Pottery was invented in this period, mainly for use in cooking. The sites are all caves within restricted basins. This could be related to the fluctuating and deteriorating environment. Human subsistence depended on hunting, fishing and gathering. The appearance of primitive domesticated rice in these sites indicates human harvesting and consumption of rice, but they were probably resulted from intensive harvesting rather than intentional cultivation.

During the Middle Neolithic, the area of rice domestication expanded to include the Huai Valley. The development of technology is represented by the appearance of ground stone tools and the increasing diversity of pottery technology. Domesticated rice increased its importance in human subsistence. Root-crops such as water caltrop, lotus root and a few animals like ox, pig and chicken were probably also domesticated in this period. Fishing was still important, but hunting and gathering became less important. Site patterns show an apparent shift to alluvial plains, probably to accommodate rice farming. Primitive farming villages probably appear, as suggested by house remains, storage pits, burials, and protective constructions.

In the Late Neolithic, rice agriculture became established and rice was fully domesticated. In terms of technology, ground stone tools became more sophisticated and a slow wheel was used to make fine pottery vessels. Craft specialization became evident, as indicated by large quantities and high quality of wooden objects and ornaments made of various materials. Rice agriculture became the dominant subsistence strategy, as demonstrated by large quantities of rice remains, a whole set of farming tools, and paddy fields with irrigation systems. Animal domestication, fishing, gathering and hunting also contributed to the subsistence. The development of sedentary farming villages was reflected in the building of large scale houses, an increasing number of in-site burials, and the appearance and differentiation of grave goods.

<u>Chapter 6</u>

A Comparative Analysis of Origins of rice agriculture

So far, I have presented the environmental and cultural background as it pertains to the origins of rice agriculture based upon the available data. As one of this dissertation's goal, I want to give readers, particularly those having difficulty accessing the materials due to language barriers or the lack of background in Chinese archaeology, the most updated information on the origins of rice agriculture. This makes it possible for them to evaluate various viewpoints on these related issues. Meanwhile, this background presentation allows me to provide a new understanding of the origins of rice agriculture, which is the ultimate goal of this research.

As to the center of the origins of rice agriculture, recent studies all point to the eastern part of China, but the debate over the exact area: the Middle Yangzi Valley, the Lower Yangzi Valley or the Huai Valley continues. The review of the theories in Chapter 3 indicates that defining the center of rice agricultural origins, Harlan's theory prevails over that of Vavilov's. As mentioned in Chapter 2, Harlan believed that determining a center of agricultural origins should start with archaeological data, draw support from the distribution of the wild relatives of the domesticated species, and from evidence of related studies such as ecology, genetics and paleoenvironment (Harlan 1971). The time of the origin is contingent on the establishment of its center, so these two issues are often combined. I will follow Harlan's strategy and analyze data related to these two questions.

In terms of why and how rice agriculture started, no totally convincing answer has been presented to date. As indicated above, environmental factors, population growth, or a combination of factors have been suggested to answer these why and how questions. They all, however, lack the support of archaeological evidence. The review in Chapter 2 shows the strength and potential of those processual, post-processual and evolutionary theories that have not been applied to the study of origins of rice agriculture. I agree with Bar-Yosef and Meadow (1995) that no single factor is adequate to answer the why question, and the evolutionary process of agricultural origins had a punctuated equilibrium characterized by two threshold events – the emergence of the earliest domestication (e.g. the Natufian) and the establishment of early farming communities. This hypothesis resonates in the studies of agricultural origins in various parts of the world (Price and Gebauer eds. 1995). In the following analysis, I look for various factors related to the emergence of rice domestication and the development of rice agricultural societies in order to form my own model.

Given the short history of archaeology-based research on the origins of rice agriculture, it may be helpful to consider the Middle East, where issues of agricultural origins have been intensively and extensively explored for more than a century. I consider the study of agricultural origins in the Middle East as a comparative guide, because influential theories on agricultural origins have been developed for the region, and because there is a similar and more detailed developmental sequence of agricultural origins that can be compared with the Yangzi Valley. The most recent studies on the origins of agriculture in the Middle East, as represented in a series of publications by Bar-Yosef and his colleagues (Bar-Yosef and Meadow 1995, Bar-Yosef 1998, 2002, 2003), constitute the comparative basis of our study and are summarized in the following section.

6.1 Studies of the Origins of Agriculture in the Middle East

Although there are numerous studies and publications on the origins of agriculture in the Middle East, the studies by Bar-Yosef contain the most comprehensive and updated analysis of cultural development from the last hunter-gatherers to the earliest farmers, providing a model of agricultural origins based on modern understanding of agriculture and related issues (Price and Gebauer 1995). In this section, we first summarize the basic cultural sequence in the Middle East that is related to agricultural origins, and then compare it to that in the Yangzi Valley.

The cultural sequence related to the transition from hunter-gatherers to the earliest farmers in the Middle East starts with two cultures – the Geometric Kebaran and the Mushabian. The Geometric Kebaran, dated to 14,500 – 12,800 BP, is located in the Mediterranean coastal belt and maybe represented by the site of Ohalo II. The Mushabian, which is contemporaneous with the Geometric Kebaran and lasted until the early Natufian, is found in the Levantine desert belt. Their hunting and gathering subsistence was adapted to the ameliorated environment after the LGM. The Natufian culture, dated to 12,800 – 10,000 BP, reflects the transition to the earliest farming in the Levant. The Natufian culture is characterized by dwellings, burials, art objects, numerous pounding and grinding tools, and a rich bone industry, radiocarbon dating, stratified sites. Additional archaeological traits divide it into two phases: the early Natufian (12,800 – 11,000 BP) and the late Natufian (11,000 – 10,000 BP). The Natufians were regarded by many scholars as the earliest farmers (e.g., Garrod 1932, Unger-Hamilton 1991), but recently it has been suggested they practiced as intensive and extensive harvesting of wild cereals as part of mobile subsistence. Only at the latter stage of the late Natufian when intentional cultivation occurred did the Natufians become the earliest farmers (Bar-Yosef and Meadow 1995). Including the late Natufian communities, many Pre-pottery Neolithic A (PPNA: 10,000 – 9,500 BP)) sites in southern Levant (e.g., Abu Hureyra and Mureybet) witnessed the emergence of agriculture in the Middle East. The Pre-pottery Neolithic B (PPNB: 9,500 – 7,500 BP) which followed is the period when early agricultural communities were established. According to recent consensus based on the development of the new farming-based subsistence, the PPNB archaeological assemblages (including their settlement patterns, architectural remains, art objects and technologies) all exhibit the basic characteristics of established agricultural communities (Price and Gebauer 1995).

This cultural sequence represents the transition from hunter-gatherers to the emergence of intentional domestication and the origins of agriculture. Despite the differences of specific cultivars and cultural characteristics between the Levantine and the the Middle Yangzi Valley, the Lower Yangzi Valley, and the Huai Valley cultures, the general process toward the origins of agriculture is argued to have been comparable. As one of the most recent comprehensive case studies on the origins of agriculture in the Middle East, Abu Hureyra (Moore et al. 2000) provides the most suitable sequence of development from foraging to farming for this comparative analysis.

Dated to 11,500 – 7,000 BP, Abu Hureyra represents cultural development from the Natufian to the Pre-pottery Neolithic, which is considered by Bar-Yosef and Meadow (1995) as the critical period for understand the origins of agriculture in the Middle East. Based on three settlements at Abu Hureyra, the site's cultural sequence can be divided into three periods.

Abu Hureyra 1, from 11,500 to 10,000 BP, is the period when local inhabitants began cultivating some wild plants to supplement their hunting and gathering subsistence. According to Moore et al. (2000), the Younger Dryas episode is considered as the primary factor caused the inhabitants to adopt agriculture during this period. The direct evidence of the beginning of domestication includes an intensified collection of fewer wild plants and the appearance of some domestic cereals such as rye.

The intermediate period, from 10,000 to 9,400 BP, witnessed a second phase of agricultural development. Only limited remains of this period were preserved, so we know little about human cultural development during this period. However, the preserved village structure indicates a continuous occupation of local inhabitants. The development of agriculture is supported by plant remains found in the settlement, including grains of free-threshing wheats, domestic einkorn, barley grains, lentils, and weed seeds.

Abu Hureyra 3 (9,400 – 7,000 BP) represents a period when agriculture became established. Five cereals: rye, einkorn, emmer, bread wheat, and barley; as well as at least three pulsed: lentils, peas, and vetches were domesticated. Sheep and goats were also domesticated during this period. Along with the development of agricultural economy, the settlement expanded and population increased. It is noted that no heavy agricultural tools were found in the site, which led Moore et al. (2000) to infer the use of wooden implements in agricultural activities.

Throughout the origin and development of agriculture in Abu Hureyra, the basic characteristics of the society did not have significant changes. First, hunting and gathering were always important subsistence strategies, even after the establishment of agriculture. Second, the inhabitants adopted sedentary lifeway at the beginning of the settlement and gradually increased the degree of sedentism. Third, division of labors, which appeared at the beginning of the settlement, was always based on gender. Fourth, families participated in large-scale economic activities that were organized by the community. Fifth, the society was egalitarian, but some members were distinguished by their special skills. Sixth, people were interested in the natural world which influenced their belief system, as evidenced by artworks with animal images.

6.2 Early Neolithic Adaptations in Middle and Lower Yangzi Valleys

The Early Neolithic culture in the Middle Yangzi Valley and the Lower Yangzi Valley is reflected in four archaeological assemblages that represent three cultural entities. The Yuchanyan assemblage represents the culture in the Middle Yangzi Valley, whereas the Xianrendong and Diaotonghuan assemblages and the Shangshan assemblage represent the Lower Yangzi Valley.

The most significant adaptive change is the appearance of domesticated rice. In Yuchanyan, four carbonized rice husks were found in the 1993 and 1995 excavations (Yuan 1999). Five additional rice remains were found in the recent excavations. The identification of the rice remains is based on scanning electron microscopy analyses of rice morphology. The length of the husks is similar to that of wild rice. The width is between that of *japonica* and *indica*, and the L/W (grain length/grain width) ratio is in the upper range of the *indica* variation, suggesting increasing width due to domestication. The length of glume hair is between that of common wild rice and *indica*, showing a trend of decreasing length as a result of domestication. The shape of the bi-peak tubercles on the lemma and other characteristics approach those of *japonica*, but essentially maintain the primitive conditions of common wild rice as seen in Hunan Province today. The awn on top of the lemma is not found in the rice husks, which is distinctive from wild rice and indicates the existence of primitive domestication. All these morphological characteristics of the rice husk remains allow the researchers to argue that the Yuchanyan rice remains represent a primitive stage of the domestication of common wild rice. At this stage the characteristics of wild, *indica* and *japonica* rice are all present (ibid).

In Xianrendong and Diaotonghuan, the evidence of rice domestication exclusively comes from phytolith analysis. Abundant rice phytoliths have been identified in soil samples from Zone G and above in Diaotonghuan (see Table 6.1). The differentiation of domesticated and wild rice is based on the statistics of the presence of double peaked glume cells (see Table 6.2). Starting from Zone E, domesticated rice coexisted with wild rice and the percentage of domesticated rice increased over time (Zhao 1996, 1998). The Shanghai rice remains all come from pottery tempers. Although they were identified as early domesticated rice (Zheng and Jiang 2007), some scholars questioned their accuracy of the identification which only relyed on the morphological characteristics (Fuller et al. 2007). Given the lack of details about the recovered rice remains and the general cultural background from the site, it is difficult to determine whether the rice remains are domesticated.

In spite of some concerns about the accuracy of morphological identification (Ahn 1992, Fuller et al. 2007) and phytolith statistical analysis (Higham and Lu 1998), the above results have been widely used to mark the beginning of rice domestication (Zhao 1996, Lu 1998, Yan 2000, Chen 2004, Bellwood 2005). I cautiously accept the status of the rice remains found these sites, but feel that the rice remains alone cannot substantiate the existence of intentional human cultivation during this period. In other words, it is unclear whether the appearance of some primitive domesticated rice traces was a result of intentional domestication or just intensive harvesting by foragers. Other aspects of those assemblages ought to be considered in order to make a sound argument. Generally speaking, the Early Neolithic adaptive changes represent a transition that was conditioned but not necessarily determined by the environment. The environment of this period includes the oscillating amelioration from 12,000 to 11,000 BP, the Younger Dryas episode until 10,000 BP and the Holocene amelioration. The Yuchanyan assemblage was only adapted to the pre-Younger Dryas environment, which shows a continuation of previous trends. The Diaotonghuan and Xianrendong assemblages span the whole transitional period.

After the Younger Dryas, we see the appearance of a new lithic tradition characterized by small flake tools in the previous pebble-based lithic assemblage. This is demonstrated by lithic tools at sites such as Pengtoushan (Hunan Provincial Institute of Archaeology 1990). Unlike those coarse heavy pebble tools, these small flake tools were mostly made of non-local fine-grained materials such as cherts. The adaptive advantage of these tools is apparent: they are light weight and easy to be carried, so hunter-gatherers could easily move and more efficiently process game. Smaller tools could fit what Binford (1979) named “personal gear”. In this sense, small flake tools indicate increasing mobility, complex task demand, and increasing processing volume. However, we ought to correlate this aspect with settlement patterns and food resource availability to better assess the general adaptive changes.

As mentioned in Chapter 5, the number of sites dropped after the LGM and the location of sites changed from riverbank terrace to isolated small hill/mound on fluvial plains and caves. Following the hunter-gatherer adaptation model by Binford

(2001), this pattern suggests the food procurement strategy changed from forager to collector. Given the density of sites in the pre-LGM site clusters (e.g., Fang et al. 1992), the resource in the niche was not sufficient to support hunting groups which require a larger territory. Although no specific study exists on the site density after the LGM, the number and spatial distribution of sites indicates a decreasing site density and expanding territory, which made the hunting-dependence strategy possible. The appearance of small flake tools reinforced this possibility. With this easy-to-carry “personal gear”, humans were able to increase their mobility to procure food resources. On the other hand, the presence of pebble tools and food remains in the sites suggests that humans kept heavy duty and durable tools in their residences and brought their games and other procured food to the residence. According to Binford (2001), this is considered a collector strategy.

The resource availability is conditioned by the environment and is reflected in the plant and animal remains. As reported in Chapter 4, the post-LGM environment before the Younger Dryas episode fluctuated but was a generally warm and humid environment in the Middle-Lower Yangzi Valley. Coniferous and evergreen broad-leaved forests and grasslands could have provided abundant ungulates as well as nut and seed resources. In low-lying areas, watery environments could contain rice and aquatic resources. The Yuchanyan niche is a good example of such a rich environment. A large number of faunal remains were found in the site, including 28 species of mammals, more than 27 species of birds, 5 species of fish, tortoises, and 33 species of shells. Bird remains are particularly abundant, accounting for over 30% of the total fauna. Additionally, there is evidence for the utilization of over 40 different varieties and 17 identified species of plants. This reflects a typical broad-spectrum approach to subsistence that includes intensified resource utilization and wide diet breadth.

In summary, human adaptation after the LGM led to a collector strategy that is characterized by increased logistical mobility in expanded territories but deceased mobility within individual niches. The former is represented by an increase of small flake tools and the number and distribution of sites. The latter is shown in the presence of pebble tools and abundant food remains in sites along with the long-term occupation of the site (e.g., Diaotonghuan). This pattern of between-patch mobility increase and within-patch residential mobility decrease is not uncommon among late hunter-gatherers (Binford 2001). Given this interpretation, it is feasible to evaluate the significance of domesticated rice remains from the Early Neolithic in the Middle Yangzi Valley and the Lower Yangzi Valley.

As indicated by the tool kits and food remains of the sites with rice remains, it is clear that before the Younger Dryas episode the inhabitants subsisted on broad-spectrum resources including mammals, reptiles, birds, fish, plant seeds, and nuts obtained through hunting, collecting, and fishing. In low-latitude sites such as Yuchanyan, Xianrendong and Diaotonghuan, wild rice grew in nearby swampy fields. Phytolith analyses at both areas indicate the existence of wild rice around the time of occupation (Yuan 2000, Zhao 1996). Given the proportion of rice remains in the whole food inventory and the rich natural resources of the sites, there was no need for local inhabitants to conduct cultivation activities such as field preparing, sowing and seed storage. The tool kits only provided cutting tools like worked flakes and scrapers for rice harvesting, suggesting cultivation was not undertaken since those activities are not substantiated by the tool types from the sites. Therefore, rice harvesting but not cultivating is the most plausible explanation of the appearance of primitive domesticated rice remains found from these sites.

It is notable that the emergence of domesticated rice during this period was conditioned by the environment. As indicated by phytolith evidence in Diaotonghuan (Zhao 1996) and elsewhere (Lu et al. 2002), rice disappeared from the Yangzi Valley during the Younger Dryas episode and returned sometime after the beginning of the Holocene. Therefore, the domesticated rice in Yuchanyan and Diaotonghuan was not continuous. Botanical studies indicate that crops can be completely domesticated within two centuries (Hillman and Davis 1990), and that significant genetic changes in wild rice can occur after only five generations under cultivation (Oka and Morishima 1971). This means rice could have been domesticated within a very short period of time and in multiple places. Furthermore, domesticated rice and its wild relatives such as *O. rufipogon* and *O. nivara* are interfertile (Chang 1976). This means the domestication of rice must be intensive and sustainable, or it could easily return to wild rice. Therefore, perhaps the earliest rice domestication in Yuchanyan and Zone G of Diaotonghuan are the results of intensive human harvesting and that hit a dead end when wild rice disappeared from the area because of the Younger Dryas episode. Possibly after the return of wild rice at the beginning of the Holocene, another wave of rice domestication in the Middle Yangzi Valley, the Lower Yangzi Valley and the Huai Valley led to the origins of rice agriculture.

6.3 The Origins of Rice Agriculture in the Middle Neolithic

Based on archaeological discoveries of rice remains, it is clear that wild rice returned to the Middle Yangzi Valley and the Lower Yangzi Valley at the beginning of the Holocene (Zhao 1996), and reached the northern part of the Huai Valley around the Holocene Optimum of 8,000 BP (Zhang and Wang 1998). Except for several isolated incidences in the Lower Yangzi Valley and the Huai Valley, as demonstrated by the discoveries at Xianrendong, Diaotonghuan, Kuahuqiao and Jiahu, evidence suggests rice domestication concentrated in the Middle Yangzi Valley. Considering the cultural relationships among the sites containing domesticated rice remains, I first analyze the Middle Yangzi assemblages, and then discuss the remaining two areas.

Rice ecology is helpful to understand the optimal conditions for the growth of rice. Current wild rice, common wild rice, which is regarded as the progenitor of domesticated rice, grows in open swampy habitats. Although perennial wild rice grows in deep swamps which remain moist throughout the year, annual wild rice grows in temporary swamps and ditches that are parched in the dry season. Annual wild rice needs a dry season for its existence, and its abundance is in relative proportion to the degree of drought during the dry season (Oka 1988). Domesticated rice growth favors abundant precipitation, warm temperatures, and soils with high water-retention capacity. Modern domesticated rice tends to grow best in flat fields with irrigation systems to provide and drain water if necessary. These factors can increase the fertility of soils and benefit the growth of the plant (Han and Qu 1991). It is clear that although a warm and humid environment generally favors the growth of wild rice, only those areas with natural water irrigation and drainage were optimal for primitive rice agriculture. Therefore, the earliest intentional rice domestication is likely to be found in a relatively high-elevated area or terraces where rivers and creeks could help drain water after heavy rainfall and seasonal floods.

Based on this inference, it is not coincidental that the sites of the Pentoushan Culture, the earliest culture in which rice domestication became an important part of subsistence, is concentrated on the plains surrounding the Dongting Lake in Hunan Province and the terraces along the Yangtze River in the southwestern Hubei Province. The direct evidence of rice domestication includes a large quantity of rice remains and the identification of their status as domesticated. For example, in the site of Bashidang, approximately 15,000 grains of rice both with and without husks were found in an area of less than 100 m^2. The morphological analysis of the structure of bi-peak tubercles of rice lemma shows three characteristics of the Bashidang rice: the length-width is smaller than modern *indica* and *japonica*, indicating small-grain rice; it contains mixed characteristics of *indica*, *japonica* and common wild rice, suggesting it was before the *indica-japonica* differentiation; the L/W ratio shows a tendency of differentiation toward *indica*. The glume epidermal phytoliths of some of the grains share some similarities with those of cultivated *indica* rice. Therefore, the Bashidang rice was identified as proto-*indica* primitive domesticated rice (Zhang and Pei 1997: 40-1). Given the large quantity and the morphological identification, it is highly possible that they were intentionally domesticated.

The location of the Bashidang rice remains also supports the existence of cultivation. The main features of the site are walled fortresses, defensive ditches, and a starfish-shaped earthen ceremonial platform. House remains show structures with sunken floors, ground-level floors, and postholes. Over 200 postholes were found within an area of about 100 m^2 (Hunan Provincial Institute of Archaeology 1996, Pei 1998). All these features were found in the same stratum and constituted an ancient village. These remains demonstrate high-degree sedentism at the site. Not far from the village remains and also from the same stratum, the rice remains were recovered from mud on the edge of an ancient riverbed. There is no description of the unearthed location. Because of the high density of the rice remains, it is suggested they were stored by local villagers as seeds for planting (Pei 1998).

Rice was not the only species domesticated by the Bashidang farmers. In addition to rice, aquatic species such as water chestnut, lotus and gorgon fruit were recovered. For animal remains, domesticated species including ox, pig and chicken dominate the assemblage. Wild animals are limited in both quantity and species represented. Deer and muntjac are the only identified species. Fish bones were also found in large quantities (Hunan Provincial Institute of Archaeology 1996). Pei suggested that lotus and water chestnut were also cultivated. Both species can be easily planted and processed, and they often provide abundant nutritious food during most of the year. Lotus flower shaped pottery plates found in the site indicate the importance of the root-crop to humans (Pei 1998). Sauer (1952) suggested that root-crop cultivation was the beginning of farming, because its vegetative reproduction is simpler than seeding. Although this hypothesis was refuted by archaeological findings, the studies of the Zenpiyan plant remains in subtropical South China supports the existence of root-crop utilization before the introduction of rice farming in that area (Zhao 2006).

Judging from the composition of food resources in Bashidang, human subsistence was based on the domestication of a variety of plants and animals, and supplemented by hunting, gathering and fishing. Domesticated rice probably did not become the main staple, because root-crops like water chestnut and lotus root were abundant and available year-round. We do not know much about animal domestication in the site, but it seems to have appeared suddenly and was related to sedentism. In the Middle East, early domesticated animals such as sheep, goats, cattle and pigs appeared during the thousand-year period from 9,500 – 8,500 BP, which was soon after the beginning of plant cultivation (Bar-Yosef and Meadow 1995). Just as in the Middle East, we will not know the reason and process of animal domestication in China until we have secure evidence of their precursors.

The above analysis should be evaluated by looking at the tool assemblages found. So far, we only know a few pottery vessels, wooden spade blades, and unspecific tools of bone, wood, and bamboo were found in Bashidang (Hunan

Provincial Institute of Archaeology 1996). The apparent incomplete tool kits and lack of details make it difficult to analyze technological aspects of early domestication. This deficiency was made up for by the Pengtoushan assemblage. Pengtoushan is also located in the subtropical Liyang Plain and only 20 km from Bashidang. The two sites belong to the same ecological niche and same culture based on pottery comparisons. The combination of Pengtoushan and Bashidang assemblages can allow us to better understand rice domestication and related cultural development.

The remains of houses, graves and storage pits suggest increased sedentism of Pentoushan Culture. A large house and several small houses constitute a residential complex. Small houses often have an oven inside, whereas a large square house, 33.6 m^2 in size, did not have oven but its floor had been carefully prepared, as evident by a mixture of sand and clay covering the floor (Hunan Provincial Institute of Archaeology and Lixian Museum 1990). It seems that the variation in houses did not represent social differentiation, but reflected different functions within the community. Small houses appear to have been residences for individual families, whereas large houses were places for the community to gather. Burials were found at the site, but none were beneath houses (ibid). This evidence, along with the ceremonial platform in Bashidang, suggests ancestral worship could be the key factor to maintaining the community on various social and economic issues.

The lithic technology in Pentoushan is quite simple and basically the local tradition of the Early Neolithic. The development is reflected in a few ground stone artifacts, most of which are pendants and beads. The only ground stone tools are axes, however, the soft characteristics of the raw materials, their practical function is still uncertain. Since these polished stone artifacts required more investment and advanced technique, they are more valuable than chipped stone tools. A check of the Pengtoushan chipped stone tool inventory shows the absence of specific hunting tools like arrowheads or points. A plausible explanation is that trapping was the main strategy for capturing wild game and that hunting was less important overall. The pottery assemblage in Pengtoushan represents a development in technology. Although still primitive, the technology was more sophisticated than that of the Early Neolithic. Based on the shapes of pottery vessels, they are interpreted as being used for cooking and storage. Ceramic cooking pots are important for cooking rice, because rice was normally boiled in pots and eaten as a whole-grain food rather than ground into flour (Fujimoto 1983). The emergence of the earliest pottery vessels in Yuchanyan also suggests this function.

The Pengtoushan Culture fits most behavioral traits indicative of early farming communities based on ethnohistory and the archaeology of the Early Neolithic in the Middle East. The following summary is adapted from the study of Bar-Yosef and Meadow (1995).

1) The early farmers in both places employed a mixed subsistence strategy of cereal and root-crop cultivation, animal domestication and exploitation of wild resources by hunting, gathering and fishing.
2) Storage facilities were developed to preserve both subsistence and seed stocks.

3) The basic social unit was the extended family and the community was regulated by the elders on the basis of ancestral cult.
4) Communal activities were reflected in the building of a gathering house and sacred monuments.

In spite of these behavioral similarities and the approximate synchronization, tool assemblages in the Middle Neolithic Yangzi Valley and those in the early Neolithic Near East show a clear distinction: grinding and pounding tools were present in the Middle East but are absent in the Yangzi Valley, whereas pottery was common in the Yangzi Valley but not seen in the Middle East until after the PPNB (9,500-7,500 bp). Grinding slabs were found as early as 90,000 BP in Qafza Cave (Bar-Yosef and Kra 1994) and remained in PPNB sites such as Beidha (Wright 1991, 1993, 1994). Basalt mortars and pestles were found in Kebaran times and became common in the Natufian (ibid). The argument that these tools were used to process cereals was illustrated in a famous Kebaran site, Ohalo II, where basalt bowls and pestles were found with the remains of wild barley and wheat in them (Kislev et al. 1992). This discovery indicates a close relationship between grinding and pounding tools and wild cereal utilization. The presence of grinding and pounding tools from the Kebaran through the Natufian (Bar-Yosef 1990) supports the continuous exploitation of wild cereals. This could lead to cereal domestication.

Although evidence for the exploitation of wild rice has been found in Chinese sites since the Early Neolithic, grinding and pounding tools are absent from the tool inventory during the whole period. This phenomenon raises the question of how wild rice and early domesticated rice were processed by humans. The husk of rice is soft and can be dehusked by hand and foot or just through winnowing. This practice was common among Chinese rice farmers before the introduction of special dehusking machines. In addition, Australian aborigines were also recorded the similar rice dehusking methods (Cane 1984, Jones and Meehan 1989). When it comes to how rice grains were processed for human consumption, there are two possibilities. The first possibility is the use of organic grinding and pounding tools that were not preserved. Heavy duty pebble tools like choppers could have been used to cut wood or bamboo, both of which were abundant around those sites to make grinding tools. In two Late Neolithic sites – Hemudu (Liu and Yao 1993) and Honghuatao (Chen 1983), wooden pestles were found in association with rice remains. Considering archaeological evidence is always influenced by preservation and chance finding, we cannot rule out this possibility. The other possible explanation is related to the origins of pottery.

As early as 12,000 BP, a primitive pottery vessel form like the *fu* cooking pot was associated with several rice grains in Yuchanyan (Yuan 2000). Since then, pottery has been discovered in every Neolithic site with rice remains. Although rice can be pulverized to make deserts and snacks, people often cook it as whole grain in boiling water. The earliest direct evidence of such practice is found in Hemudu, where carbonized rice was found in a *fu* cooking pot (Liu and Yao 1993). Given the large quantity of rice and the absence of grinding/pounding tools in Pengtoushan Culture, it is reasonable to infer that rice was cooked as a whole grain in those cooking vessels. From this, can we further infer that the pottery found at Yuchanyan was invented for this purpose? Given the very limited rice remains and the apparently abundant wild food resources, it is difficult to argue that humans invests such time and resources to make pottery to cook a less important food item like rice. To date, the oldest pottery found comes from the Jamon Culture of Japan (Habu 2004). It is believed that pottery was invented there to cook aquatic/sea food like fish and shell to obtain "juicy" (moist) food (Yashuda 2002). Some nut and grass plants were probably also boiled before consumption. Boiled plants, fish, and even animal meat can be easily digested and can be tastier when cooked. For this benefit, it might be reasonable for the Yuchanyan inhabitants to invent pottery cooking vessels. The combination of pottery and rice harvesting could make rice exploitation more attractive, since boiling rice is less labor intensive when compared with grinding flour, and boiled rice became tastier and more nutritious than unboiled rice. This could be one of the reasons that rice finally became the main staple in East Asia. In the Middle East, wheat and barley have to be ground into flour before human consumption, which made grinding tools more important to cereal exploitation. Meanwhile, sheep and cattle can provide milk, which made juicy food less important than in East Asia. This could explain why at the beginning of agriculture pottery was not invented in the Middle East

As the successor of the Pengtoushan Culture, the Lower Zaoshi Culture had an expanded occupation area and showed improvement in settlement, technology and subsistence. We do not know the exact state of rice domestication during this period, because rice remains were all found in pottery temper and are therefore unidentifiable.

The gross quantity of rice remains in each assemblage was less than those in the Pengtoushan Culture and reduced gradually during throughout the cultural period. This, however, was a result of the change in pottery tempering techniques, not the decrease of rice exploitation (Pei 2000). Judging from animal remains, domesticated species such as ox, pig, and goat increased in proportion whereas numbers of wild animals decreased over time (ibid). This indicates that domestication changed the composition of human subsistence and farming became more important in the economy.

Similar house remains continued the Pengtoushan tradition but became more common, as they were found in higher numbers in every site of the culture. In addition, the floors of houses were often modified with clay and sand. A more apparent change is reflected in burials. In Fenshanbao, all burials were secondary and buried in living area. Pottery vessels were used as grave goods. This change shows the importance of the dead to the living, and could represent increased ancestral worship.

In lithic assemblages, ground stone tools improved in both quantity and quality. A total of 22 pieces of ground tools were found from an excavation area of 160 m^2 at Hujiawuchang. The tool types include axes, adzes, chisels and a knife (Hunan Provincial Institute of Archaeology 1993). Many of them are linked to rice harvesting and land clearing. In chipped stone tool kits, discoid choppers are common and often interpreted as a cutting tool used to make wood and bamboo tools (Yuan 1995).

Ceramics were better made. Their walls became thinner and decorations became more complex. They were about 2 mm thinner on average than those of the Pengtoushan Culture. Surface preparation included red slip coating, cord-marking, incision, stamping, punctuation, carving and perforation. The slow wheel had probably been invented, as some vessels were well formed and symmetrical. The slow wheel could also have been used in trimming of walls. In addition, many new shapes appeared: high necks, double ears, ring foot, sub-waist, etc. (Pei 2000).

As rice domestication flourished in the Middle Yangzi Valley, it also continued in Xianrendong and Diaotonghuan of the Lower Yangzi Valley. We do not have a good understanding of human subsistence there, since no plant remains were found. Phytolith analysis shows an increase in domesticated rice and the continuous existence of wild rice, and isotopic analysis of human skull fragments indicates rice consumption (MacNeish and Libby eds. 1995). However, the substantial number of wild animals and shells from this period demonstrate that hunting and fishing were still important food procurement strategies. The development of rice domestication was reflected in the tool technology. Ground stone tools increased and many types like adzes, hoes and weights were probably used in farming activities such as tilling and planting (ibid). The pottery technology was similar to its Middle Yangzi Valley counterparts. Based on the available data, we can only tell the process of rice domestication continued, but hunting and fishing were still important.

Kuahuqiao is another important site in the Lower Yangzi Valley. It is reported that over one thousand rice grains and husks were found, and their morphological characteristics indicate most of them are domesticated rice (Zhejiang Provinical Institute of Archaeology and Xiaoshan Museum 2004). As reflected in the fanual and floral remains from the site, the subsistence the site is a broad-sepctrum economy that consists of hunting, gathering, fishing, and primitive farming. The significance of Kuahuqiao rice discovery is that it provides clear evidence of rice domestication in the Lower Yangzi Valley, particularly the Yangzi Delta, that happened around 8,000 BP, about one thousand years earlier than the Hemudu rice agriculture. However, the cultural characteristics, as represented by pottery and house remains, are quite distinctive from the Hemudu remains. Although the two sites are located in the same area and not far from each other, it is still difficult to determine whether they have any cultural connection.

Jiahu (8,500 BP) in the Huai Valley is another important site related to the beginning of rice domestication. The rice remains include carbonized rice grains, husks, impressions of rice grains in pottery and a large quantity of rice phytoliths (Zhang et al. 1998). Rice morphological analysis indicates the following characteristics of the Jiahu rice. The length of the grains approaches that of *japonica*, the width approaches *indica*, and the L/W ratio approaches early *indica* and later *japonica*. The shape of rice phytoliths approaches *japonica*. The bi-peak tubercles on lemma were also proto-*japonica* (Zhang and Wang 1998). As a result, the Jiahu rice was identified as proto-*japonica* primitive domesticated rice with some traces of common wild rice and the *japonica*-*indica* differentiation has not reached (ibid).

Additionally, isotopic analysis of human bones indicates that the staple food of the Jiahu inhabitants was mainly C^3 plants, including rice (ibid).

The significance of the Jiahu rice remains lies in its location and cultural assignment. The latitude of the site is 33˚36' N, whereas the north limit of current common wild rice is 28˚14' N (National Wild Rice Resource Survey Group 1984). The existence of wild rice in Jiahu is probably related to the Holocene Optimum, a period when the average temperature was 4˚C higher than that of today (Shi et al. 1993). The composition of the animal remains also supports this. The environment of the site during human occupation was similar to that in the Lower Yangzi Valley today. The suitable environment affected the growth of wild rice progenitor and hence conditioned the emergence of rice domestication. In addition, the site is located on the river terrace of an alluvial plain. This fits the optimal condition of rice domestication as described earlier in this chapter.

Unlike sites in the Yangzi Valley, the Jiahu culture belongs to an important North China Middle Neolithic culture – the Peiligang Culture (Sun 1992). The settlements of this culture were characterized by multi-room houses, large cemeteries, hundreds of storage pits, and some kilns. This evidence suggests their social structure was based on family and grouped by kinship. Artifacts include eight shells with unidentified symbols and two bone flutes. These objects are unknown in any of the Yangzi assemblages and could represent certain level of social differentiation since they were buried with individuals. Both lithic and pottery technology were very sophisticated. Ground stone tools are common and a lot of the tool types are related to agricultural activities. Worth mentioning is the presence of grinding pestles and plates (Zhang et al. 1998). The pottery technology is suggested to be comparable to that of the Pengtoushan Culture (Chen 1999). The plant and animal remains show a mixed subsistence on domestication of rice, millet, pig, ox, dog, and chicken, as well as hunting, gathering, and fishing.

In addition to rice, millet and acorns were also utilized by the Jiahu inhabitants as they were found in the plant remains. Since there are no statistics on the quantities of each plant, it is unknown whether rice or millet was the main staple. We also have to notice that domesticated rice was not found again in the same region until the very end of prehistory when rice agriculture was widespread. This means that Jiahu rice domestication was not continued by its cultural successors. Two reasons could explain this. First, the growth of wild rice likely retreated from the area after the Holocene Optimum. At this time the temperature dropped and the environment gradually returned to the current warm temperate zone, which made the growth of wild rice impossible. The same effect could occur in domesticated rice, since primitive rice domestication was also conditioned by natural environment. The other reason is the cultural tradition. As we know that human behavior is conditioned by culture as well as nature. The Peiligang Culture, as well as most North China Neolithic farming cultures, was based on millet agriculture. Harvesting and grinding tools are typical in the Peiligang Culture and suitable to millet processing. At the end of the Jiahu occupation, the local environment turned to the warm temperate zone, which made it difficult for rice to survive. It is natural for local farmers to introduce millet agriculture from other culturally affiliated places.

6.4 The Establishment of Rice Farming Societies in the Late Neolithic

Beginning around 7,000 BP, rice agriculture had been established in the Middle Yangzi Valley and the Lower Yangzi Valley, as evidenced by abundant differentiated domesticated rice, sophisticated rice farming tools, paddy fields with irrigation systems, large scale permanent villages based on farming practices, and increasing social complexity. Although most of the evidence comes from the Hemudu site, other discoveries also supply very useful information.

The Hemudu rice has been recognized as a domesticated species since its discovery. You (1976) first identified it as *indica* based on average ratio of L/W and the even and regular distribution of hairs on fertile glumes. However, a reexamination by Zhou reached a different conclusion. Based on grain size, the distribution of hairs on lemma and palea, the slope degree on lemma shoulder, and the size/presence of awns, he found the majority (74.6%) of the rice sample belongs to the *indica* type, but *japonica* (21.8%) and intermediate types also existed. Besides, the average grain weight of Hemudu rice is estimated as 22 gram, which is in the range of current cultivars. Therefore, Hemudu rice is clearly domesticated rice including both *indica* (primarily) and *japonica* types (Zhou 1981).

The existence of full-scale rice agriculture is also reflected in agricultural tool kits. Bone spades were used as hoes, and some of them still had wooden handles attached at time of excavation. Wooden hoes, sticks and pestles were other tools related to farming. A type of very unique implement, made of stone, wood or bone and shaped like butterfly, has been interpreted as a field preparing tool (Yan 1989) although some think it was an ornament (Liu and Yao 1993). Rice could have been the main staple of the Hemudu people, but they also domesticated dogs and pigs. Although their subsistence depended on farming, hunting, gathering and fishing were also used to supplement the available food. This was based on the presence of wild plant and animal remains as well as hunting and fishing tools (ibid).

The inhabitants of Hemudu enjoyed a sedentary life: they built large pile-dwellings in their village. At least three buildings can be reconstructed in Stratum 4. The size of each house was about 23 m in length and 7 m in depth, and divided into many small rooms. A corridor or long balcony, about 1.3 m wide, ran along the length of each house (ibid). The architectural remains reflect the development of Hemudu society in several aspects.

First, it indicates an increased labor specialization. The manufacture of the wooden components, particularly various kinds of joinery and the construction of the whole pile-dwelling required skillful and specialized carpenters and builders. This would have been supported by other specializations including the manufacture of artistic objects such as sculptures and ornaments, and the production of loom textiles.

Second, it reflects changes in the social organization of communities. As with PPNB large house in the Middle East, the large pile-dwellings could accommodate more than a single biologically viable social unit. The assignment of resources and the organization of labor to conduct large scale building projects like house construction required leadership and reflects a social hierarchy.

Third, it represents more permanent sedentism. When compared with pile-dwellings and other house structures in the Middle Neolithic, the Hemudu houses were more complex in structure and required a larger labor investment. The extraordinarily large scale of these structures could also mean a considerable increase of population.

As described in Chapter 5, an important improvement in rice farming during the Late Neolithic was the use of paddy fields with irrigation systems such as those found at Caoxieshan (Zou et al. 2000) in the Lower Yangzi Valley and Chentoushan (Hunan Provincial Institute of Archaeology 1999) in the Middle Yangzi Valley. This means that rice agriculture became less constrained by the natural environment, particularly seasonal flooding.

Hemudu is the oldest Neolithic site in the Yangzi Delta, but its origins are still unknown. The highly developed rice based agricultural society at the site indicates it had an earlier stage of rice domestication. Xianrendong and Diaotonghuan are far from Hemudu and had distinctive ecological niche and cultural assemblages that bear no similarity to Hemudu's. Kuahuqiao is near Hemudu, and also has domesticated rice remains, but the cultural remains from the sites, in particular pottery and house remains, do not support cultural connections between them.

However, cultural comparisons between the Hemudu Culture and the Pengtoushan Culture could provide a clue on the origins of Hemudu. Pottery is often used to identify cultural relationships between different cultures. The *fu* cooking pot found in both cultures shows strong similarities in shape, surface preparation, temper and proportion in both pottery assemblages. Another cultural link is indicated by the pile-dwellings. In human subsistence, water caltrop and lotus root as well as domesticated pig were exploited by both cultures. The levels of rice domestication in both cultures suggest a continuous process of development. As mentioned earlier, the Pengtoushan rice was proto-*indica* primitive type before the *indica-japonica* differentiation, whereas the Hemudu rice was clearly domesticated species dominated by *indica* type. Therefore, I suggest that the early farmers of the Pengtoushan Culture diffused along the flat plains along the Yangzi River to the delta and settled in the Hemudu area because of its similar swampy environment and rich natural resources. They brought with them their primitive pottery construction techniques, rice farming experience and a preference for pile-dwellings. The diffusion of the Pengtoushan Culture is also supported by other sites. For example, Chen (1999) noted the presence of some pottery features in Jiahu of Peiligang Culture in North China. The possible link between Hemudu and Pengtoushan was also demonstrated in another study (Lu 1998).

6.5 Summary

The Early Neolithic adaptation in the Yangzi Valley was the beginning of the transition from hunting-gathering subsistence to the primitive rice domestication. The most significant changes were the appearance of the oldest primitive domesticated rice and the invention of pottery. However, subsistence was still dominated by hunting, gathering, and fishing. The lack of clear farming tools and the insignificant status of domesticated rice in food inventory suggest that domestication during this period was a result of intensive harvesting rather than intentional human cultivation. Since the availability of wild rice conditioned the harvesting, the primitive domestication of rice hit a dead end during the Younger Dryas episode when wild rice disappeared in the Yangzi Valley.

Although wild rice returned to the Yangzi Valley at the beginning of the Holocene, most of the evidence for early rice domestication sites was dated to after 9,000 BP. From then on primitive rice farming flourished in the Middle Yangzi Valley, with isolated sites in the Lower Yangzi Valley and the Huai Valley. The Lower Yangzi Valley assemblages came from the same sites discussed previously and only yielded information about the increased quantity of domesticated rice and the development of technology. We know little about the human society. As to the only domesticated rice site in the Huai Valley, the culture belongs to a North China tradition and the rice domestication lacked any successor in the region. Therefore, neither case appears to have contributed to the establishment of full blown rice agriculture in the Late Neolithic. In the Middle Yangzi Valley, the development of rice domestication was associated with the increased sedentism, social complexity, and population growth. During this period, rice agriculture was still developing. Along with rice domestication, some root-crops and a few animals were domesticated. It is clear that domestication and fishing were major subsistence strategies whereas hunting and gathering gradually became insignificant. Houses and village constructions indicate an increased sedentism and an organized farming society in which the extended family was the basic social unit. Primitive ancestor cults and labor specialization emerged, as suggested by in-site burials, ceremonial construction, and pottery manufacture. Although we don't know the population density due to limited data, it is clear that population increased continuously during the whole Neolithic period. This was reflected in the expansion of cultural areas and increasing number of sites.

During the Late Neolithic, we see an established rice agriculture and a complex farming society in the Hemudu site in the Yangzi Delta. The sophistication of rice agriculture is reflected by large quantities of clearly domesticated rice remains and a set of clear-cut farming tools. The development of social complexity was represented by increased labor specialization, the rise of leadership, and evidence for a social hierarchy. Population growth, increased sedentism and increased social complexity are all correlated to the development of rice agriculture. Cultural comparison and rice domestication levels suggest a link between the Pengtoushan Culture and the Hemudu Culture.

Chapter 7

A New Theoretical Perspective on the Origins of Rice Agriculture

Based on the synthetic analysis of the related environmental and archaeological data in Chapter 6, I am able to present a new theoretical model to answer the key issues related to the origins of rice agriculture.

First, the general process of the origins of rice agriculture can be defined by different characteristics of cultural development during the Early, Middle and Late Neolithic periods and can be divided into three developmental stages: incidental domestication, specialized domestication, and rice agriculture, which correspond to the cultures of the three periods respectively.

Second, *incidental domestication*, which was not intentional domestication, of wild rice appeared in Early Neolithic sites of Yuchanyan, Xianrendong and Diaotonghuan. But it ended due to environmental shift between 11,000 and 10,000 BP and had little influence on the subsequent development of rice domestication.

Third, intentional, *specialized domestication*, started in three independent centers at the Middle Yangzi Valley, the Lower Yangzi Valley, and the Huai Valley around 9,000 BP. Increase of population density and environment amelioration led to increased sedentism. All three factors caused the origins of rice domestication.

Fourth, established rice agriculture emerged in the Middle Yangzi Valley and the Lower Yangzi Valley by the Late Neolithic (7,000 BP), as a result of continuous development of rice domestication. Increasing population and sedentism during this process led to increased social complexity. Rice became a prestige item and called for an increase of its production. The social demand of rice caused the establishment of rice agriculture in the Late Neolithic cultures such as Hemudu and Daxi. Rice domestication in the Huai Valley did not developed into rice agriculture, because the ecology changed and were not suitable to the growth of rice during this period.

7.1 The "Where" Question – one or multiple centers?

So far, archaeological data seems to indicate that rice domestication started in the Middle Yangzi Valley and the Lower Yangzi Valley, as evidenced by the oldest domesticated rice remains found in Yuchanyan, Xianrendong, Diaotonghuan, and Shangshan. However, we have to ask if these limited data can represent the center of the emergence of rice domestication. Based on my analysis, the answer is a cautious "no".

First of all, I argue that the appearance of primitive traces of domesticated rice in those oldest rice remains resulted from rice harvesting, not intentional rice domestication. In Yuchanyan, a total of fewer than ten grains of rice husks were found, compared to the considerably abundant wild animal and plant remains in the same assemblage. In the tool kits, no clear-cut evidence is related to cultivation activities such as land preparation, seed storage, sowing, and planting. The so called "hoe-shaped" implement alone is not enough to demonstrate the existence of human intentional domestication. In Xianrendong and Diaotonghuan, the evidence of the oldest domesticated rice was questionable, for it came from statistical analysis of phytolith identifications rather than concrete rice remains. The error possibility of this method has been addressed by some researchers (Lu et al. 1997). Besides, some perforated shell tools in the tool assemblages only supported the harvesting of wild rice.

In addition, at least two independent phytolith analyses, one in Xianrendong and Diaotonghuan (Zhao 1998) and one in the paleo-estuary of Yangzi River (Lu et al. 2002), demonstrated that the growth of rice disappeared in the Yangzi Valley during the Younger Dryas episode. The deteriorated environment between 11,000 and 10,000 BP made it difficult for wild rice to survive. Early domesticated rice would have suffered the same fate as its wild relatives. As indicated in Chang's study (1976), domesticated rice can interbreed with their wild relatives such as common wild rice. This means domesticated rice can easily return to wild rice without human intervention. Therefore, at the beginning of the Holocene, when environmental conditions allowed rice to grow in the Yangzi Valley again, only wild rice is evident. Rice cultivation before the Younger Dryas period was not sustainable and hence played little role in the development of rice domestication after the Younger Dryas.

The phytolith analysis of the Diaotonghuan assemblage indicates the return of wild rice in the Yangzi Valley at the beginning of the Holocene and the continuous growth of rice, including domesticated rice, since that time. However, reliable evidence of farming tools used for tilling and planting appeared only after 9,000 BP in the same assemblage. Interestingly, the appearance of rice domestication in the Pengtoushan Culture of the Middle Yangzi Valley happened around the same time. Although no specific farming tool kits were found at those sites, the large quantities of domesticated rice remains, as well as the domestication of other plant and animal species, suggest the existence of intentional human domestication. About 500 years later, rice domestication appeared in Jiahu north of the Huai River. The domesticated rice remains and tools for various farming activities demonstrate that the Jiahu inhabitants conducted intentional domestication of various species including rice.

The domestication of multiple species, the manufacture of ground stone tools and pottery vessels, as well as the building of sedentary villages all indicate that there should be an earlier development stage of both Pengtoushan and Jiahu cultures. Researchers have suggested some connections between the pottery technology of the Pengtoushan and Jiahu cultures (Chen 1999) and claimed that Jiahu rice domestication was influenced by the Pengtoushan Culture (Lu 1998). However, there is little resemblance between them in terms of settlement patterns, lithic technology and the major pottery types. More importantly, the Pengtoushan rice was identified as proto-*indica* type whereas the Jiahu rice was proto-*japonica* type. Judging from the complete assemblages of the two cultures, I suggest they represent two independently developed cultures. Meanwhile, the Xianrendong and Diaotonghuan assemblages represent a third independent culture of rice domestication, as they continue a local tradition and bear no similarity to Pengtoushan and Jiahu. Considering the availability of the wild progenitor of domesticated rice in all the areas after the beginning of the Holocene, I suggest that there existed a period of intensive harvesting of wild rice in all the cases before the emergence of intentional rice domestication. The details of this theory will be addressed in the discussion of the process related to the beginning of rice domestication.

In conclusion, I argue that rice domestication began in three independent areas: 1) the Middle Yangzi Valley, 2) the Lower Yangzi Valley and 3) the Huai Valley. This answer of the "where" question allows me to answer the "when" question, for the latter is contingent on the former.

7.2 The "When" Question – one-time or multiple-times event?

As mentioned earlier, the only concrete evidence of rice domestication before the Younger Dryas episode was found in Yuchanyan. The rice domestication, despite its questionable status, ended with the disappearance of wild rice in the region. About 3,000 years later, rice domestication appeared again in Liyang Plain of distant north of Yuchanyan. Is it possible that the descendents of the Yuchanyan inhabitants developed rice domestication in Pengtoushan? The chronologic gap is too wide to provide a clear-cut answer. Pei argued that Yuchanyan belonged to the "basin model" of cultural development that is typical of South China, whereas Pengtoushan represented a typical "plain model" of the Middle-Lower Yangzi Valley that benefited the development of rice domestication (Pei 2006). Pei also cited some unpublished new discoveries from the Liyang Plain where the Pengtoushan Culture is found to build a cultural connection between the late Paleolithic cultures like the Wuyashan and Yangerdong complexes and the Pengtoushan Culture (Pei 2000). However, the lack of absolute dating made it difficult to determine if these pre-Pengtoushan assemblages were earlier than or contemporaneous with the Yuchanyan assemblage. Although the Yuchanyan lithic assemblage contains more pebble tools than those in the Liyang Plain, the pottery technology of Yuchanyan and Pengtoushan exhibits some connections in terms of common vessel type, forming technique, and surface decoration. Since I cannot rule out the possible cultural connection between Yuchanyan and Pengtoushan, I consider the earliest incipient rice domestication in Yuchanyan as an event that occurred around 12,000 BP.

At the beginning of the Holocene, a second wave of rice domestication began in three independent areas. The rice domestication at this time is the beginning of a long process that led to the origins of full rice agriculture. In the Middle Yangzi Valley, rice domestication emerged at least during the Pengtoushan period. Since there is no data of pre-Pengtoushan rice remains in the area, I conclude that rice domestication began in the Middle Yangzi Valley by 9,000 BP. In the Huai Valley, Jiahu is the only site with clear evidence of rice domestication before the spread of rice agriculture in the Late Neolithic. Based on the radiocarbon dating of the site, I suggest that rice domestication in the Huai Valley emerged by 8,500 BP. As to the Lower Yangzi Valley, I can only depend on the evidence from Xianrendong and

Diaotonghuan to draw a conclusion. We should note that the chronology was built upon the combination of absolute dating and cultural comparison, and that there are no macro-remains of domesticated rice found. According to the estimated dating of the stratum in which evident farming tools were found, we cautiously propose that rice domestication began at around 9,000 BP in the Lower Yangzi Valley. In the Yangzi Delta, at least by 8,000 BP, rice domestication occurred in archaeological site such as Kuahuqiao.

In conclusion, I suggest that there were two waves of rice domestication. The first wave happened before the Younger Dryas episode. It is represented by the Yuchanyan assemblage and dates to about 12,000 BP. At the beginning of the Holocene, the second wave of rice domestication emerged in three areas: in the Middle Yangzi Valley and the Lower Yangzi Valley the event happened at around 9,000 BP; in the Huai Valley, it had occurred by 8,500 BP, which is considered roughly contemporaneous with the beginning in the other regions.

7.3 The "How" Question – the origins of rice agriculture

Considering the current consensus on the concepts related to the origins of agriculture (Price and Gebauer 1995), I feel that Rindos' three types of domestication (1984) provides the best theoretical model to recognize the process of the origins of rice agriculture. This model has been applied in the study of agricultural origins in the New World and has demonstrated its strength (Pearsall 1995). This theory was summarized in Chapter 2. In the following discussion, I point out the archaeological evidence that reflects each type of domestication and then compare the expected evidence with our database of archaeological evidence related to the origins of rice agriculture. Due to the overemphasis of the controversial "naturalness" of the coevolution of domestication, Rindos' domestication model did not consider the changes of human society during this process. In my discussion, I add the related cultural changes in conjunction with the domestication of rice.

Incidental domestication refers to the relationship between a nonagricultural society and some of the plants upon which it feeds. Based on the basic characteristics of this type of domestication, I expect the following evidence of incidental domestication of rice in archaeological assemblages:

- The subsistence strategy could be any nonagricultural means, including hunting, gathering, and fishing.
- Either wild or domesticated species could be found in human food inventory, but they were only resulted from harvesting. Therefore, no farming tools except for harvesting tools were invented.
- The growth of rice was conditioned by environment, not humans.
- The rate of change of rice under incidental domestication tends to be very slow, so it should be closer to its wild progenitor than the fully domesticated rice.

Based on these expectations, I argue that the Yuchanyan assemblage and the assemblages from Zone G and Zone E of Diaotonghuan represent the incipient domestication of rice. In both cases, we see the dominance of hunter-gatherer subsistence strategies as evident by the tool kits and food remains. Both rice remains and associated tools in these assemblages can only substantiate the harvesting of wild rice. The rice remains from the Yuchanyan also indicate that they were a very primitive type of domesticated rice. The rice phytoliths from Diaotonghuan suggest that only wild rice was found in the assemblage of Zone G and primitive domesticated rice appeared later in Zone E. Given harvesting tools found with these rice remains in both cases, these tools indicate that harvesting could cause the appearance of domesticated rice. Experimental studies of wild wheat and barley also demonstrate that harvesting can lead to the development of domesticated crops (Hillman and Davis 1990).

Specialized domestication involves an intensification of incidental domesticates and a change of human behavior from opportunistic to intentional and finally to obligate. As reflected in archaeological assemblages, I expect the following changes.

- The morphological changes of rice moved closer to but not yet reached fully domesticated status.
- The quantity of rice remains increased as an indication of increased productivity.
- Domestication alone was not productive enough to support human subsistence, so species diversity remains high but the ratio of wild to domesticate taxa declined over time.

- Tools and facilities associated with storing, planting and land preparation appeared in archaeological assemblages.
- Population growth and increased sedentism resulted from this process.

Specialized rice domestication was found in archaeological assemblages of the Middle Neolithic cultures of the Middle Yangzi Valley, the Lower Yangzi Valley and the Huai Valley. An important morphological change in domesticated rice remains from those assemblages was a clear tendency toward the differentiation of *indica* and *japonica*. Although none of the rice remains during this period were fully domesticated, rice remains found in Bashidang were identified as proto-*indica* primitive domesticated rice, while those in Jiahu were proto-*japonica* type. Also in these two sites, large quantities of rice remains were found, indicating increased productivity of rice due to domestication. In the Xianrendong and Diaotonghuan assemblages, the ratio of domesticated to wild rice increased over time. In all the assemblages with rich food remains, rice domestication was found to be occurring along with the domestication of other plant and animal species,while wild animals and plants were also being exploited to supplement the domesticates. The incomplete database does not allow me to compare the ratio of wild and domesticates during this period, but the trend of decreasing wild species and increasing domesticates can be observed if we compare the food inventories from sites before and after this period. The tools for planting rice and land preparation are not clearly reflected in archaeological assemblages from this time. However, some stone axes, adzes and choppers could have been used for land clearing and storing facilities and equipment were common, in the form of storage pits and pottery vessels found dating to this period. The increase of population and sedentism are more easily seen in the Middle Yangzi Valley assemblages. From the Pengtoushan Culture to the Lower Zaoshi Culture, we see the expansion of occupation areas by the cultures, the development of technology in the manufacture of lithic and pottery and an increase of house and burial remains found in sites.

Agricultural domestication is the culmination of the process of specialized domestication, marked by the establishment of agroecology. Archaeologically, it is characterized by established domestication of rice and increasing evidence of agricultural activities. Judging from the evidence of Hemudu and other Late Neolithic sites in the Middle Yangzi Valley and the Lower Yangzi Valley, the agricultural domestication of rice appeared in these assemblages. The Hemudu rice remains exhibit a clear differentiation of *indica* and *japonica* domesticated rice. The large quantity of Hemudu rice also indicates an increased productivity associated with the establishment of rice agriculture. In addition, agricultural tools like hoes, digging sticks and pestles made of stone, bone and wood were found in Hemudu. Later in this period, paddy fields with irrigation systems were found in both the Middle and Lower Yangzi Valleys. According to the Hemudu food inventory, rice became the main staple and the human subsistence was dependent on the agriculture of rice and a few plant and animal species. Along with the establishment of agricultural domestication, population continued to increase and human societies became more complex. In permanent farming villages like Hemudu, we see increased labor/craft specialization, the rise of leadership, and the presence of social hierarchy.

In sum, incidental domestication appeared in the Early Neolithic, represented by Yuchanyan and Zones G and E of Diaotonghuan. The rice domestication of this stage was the result of rice harvesting. Specialized domestication was indicated by the Middle Neolithic assemblages with rice remains. This rice moved morphologically closer to but did not reach fully domesticated status. Hunter-gatherers became the early farmers who intentionally cultivated rice and other species and invented tools and facilities to store domesticates. Meanwhile, population increased, technology changed and human societies became complex and more sedentary. In the Late Neolithic, rice agriculture became established in sites such as Hemudu. Not only was rice fully domesticated, but it also became the main food staple. Human subsistence became dependent on rice agriculture, which includes the domestication of rice and other plants and animals. The appearance of various agricultural tools and paddy fields with irrigation system indicates that humans had complete control of the growth of rice. As a result, human settlement became permanent and human society became ever more complex.

Based on above analysis, the developmental process of the origins of rice agriculture in three independent centers can be presented as follows:

In the Middle Yangzi Valley, the emergence patterns are as follows:

- The Yuchanyan assemblage represents incidental domestication of rice.

- The Pengtoushan Culture and the Lower Zaoshi Culture represent specialized domestication.
- The Daxi Culture represents the establishment of agricultural domestication.

Pengtoushan, Lower Zaoshi and Daxi represent a continuously cultural sequence in the circum-Lake Dongting area of the Middle Yangzi Valley, but the relationship between Yuchanyan and Pengtoushan is unclear.

In the Lower Yangzi Valley, the Xianrendong and Diaotonghuan assemblages represent the stages of incidental and specialized domestication. The beginning of agricultural domestication of rice in the area is represented by the Hemudu assemblage of the Yangzi Delta. However, no evidence indicates the cultural connection between the two earlier stages of rice domestication and any other assemblage related to the origins of rice domestication, including Hemudu, and the Xianrendong – Diaotonghuan assemblages. Therefore, the Xianrendong–Diaotonghuan rice domestication also did not contribute to the origins of rice agriculture.

In the Huai Valley, only the Jiahu assemblage represents specialized domestication. And there is no evidence of the two other types of rice domestication in the area. There is also no convincing connection between Jiahu and any early rice domestication assemblages in the Yangzi Valley. Therefore I conclude the Jiahu rice domestication did not lead to the origins of rice agriculture. It was an early, but unsuccessful start.

Based on the above analysis, we can make a hypothesis of the developmental process of origins of rice agriculture. By about 12,000 BP, incidental domestication emerged in the sites of Yuchanyan, Xianrendong and Diaotonghuan. Between 11,000 and 10,000 BP, rice domestication disappeared due to the effect of the Younger Dryas. At the beginning of the Holocene, incidental domestication of rice returned to Xianrendong and Diaotonghuan and developed into specialized domestication during the Middle Neolithic. Although there is no evidence yet, it is possible that incidental domestication also existed in pre-Pengtoushan and pre-Jiahu assemblages. Between 9,000 and 7,000 BP, specialized domestication developed in the Pengtoushan and Lower Zaoshi Cultures of the circum-Lake Dongting area of the Middle Yangzi Valley. From 8,500 to 7,500 BP, specialized domestication also occurred in Jiahu of the Huai Valley. After 7,000 BP, agricultural domestication appeared in both the Daxi Culture of the circum-Lake Dongting area and the Hemudu Culture of the Yangzi Delta. Both Daxi and Hemudu appear to have their origins in Pengtoushan. Daxi was developed from Pengtoushan through Lower Zaoshi, whereas Hemudu—as argued previously—was built by the migrants from Pengtoushan.

7.4 The "Why" Question – rice domestication and rice agriculture

As discussed earlier, although Rindos' coevolutionary model is useful to explain the process of agricultural origins, his insistence on the "naturalness" of the mechanism of this process caused many scholars to reject his theory as a whole. As

Watson (1995) pointed out, human initiative and self-conscious action did play an important role in this process, but this aspect have often been neglected due to the emphasis of "unintentional" mechanism in Rindos' argument. Judging from the developmental process of rice agriculture origins, it is clear that even at the incidental domestication stage, the intentional selection of wild rice by foragers played an important role in the emergence of incidental domestication of rice. Considering the three distinctive but related stages of domestication process, it is necessary to discuss the reasons for the emergence of each type of domestication.

Most of current models on the subject focus on either incidental domestication (e.g., Yan 1998) or specialized domestication (e.g., Zhao 1996, Lu 1998), depending on how they define the beginning of rice domestication. In the following discussion, I will discuss a variety of factors suggested by those theoretical models reviewed in Chapter 2 and evaluate their roles in the origins of three types of domestication.

The "Why" of Incidential Domestication

As noted above, incidental domestication represents conscious selection but unconscious domestication by hunter-gatherer societies. The incidental domestication of rice emerged and persisted in the late hunter-gatherer societies of the Middle and Lower Yangzi Valleys during the Early Neolithic. There is no clear evidence to substantiate the existence of population pressure or social complexity such as leadership. Therefore, the only plausible explanation lies in the environment.

As mentioned in Chapter 4, the environment of the Middle and Lower Yangzi Valleys was generally warm and moist at the time of the emergence of rice domestication. Judging from the floral and fauna composition of those assemblages, the micro-ecology of those sites featured rich natural resources. In such a rich environment, what caused local foragers to harvest rice? The existence of wild rice in local ecological niche alone can not lead to the harvesting. Considering the ecology and distribution of wild rice, tropical/subtropical South China is more suitable to the growth of wild rice and could provide more abundant wild rice resources to local inhabitants. But archaeological evidence in South China indicates that rice was not utilized there until the introduction of rice agriculture after 6,000 BP, and root-crop plants were preferred by local foragers and early farmers (Zhao 2006).

To answer this question, we have to consider what kind of advantage wild rice could have over other food resources. The basic merits of wild rice as a food item include the following aspects.

First, the processing of wild rice is relatively easy and less labor intensive. As mentioned earlier, rice can be cooked in boiled water as a whole grain and dehusking is also an easy task. Second, cooked wild rice tastes good and is nutritious. In fact, a study shows that wild rice tastes even better than domesticated rice (Han and Qu 1991). Third, rice can be stored for a relatively long time, so it can provide security during lean seasons (Kelly 1995). Fourth, the reproductive ability of wild rice is higher than other food plants such as nuts and fruits. This means that wild rice has a more predictable availability.

In terms of the specific environment, although the long term conditions were amicable, the climate was characterized by seasonality and fluctuations. In Yuchanyan, the plant remains can be categorized as two types: grass seeds such as rice, and fruits like Chinese gooseberry, wild grape, hackberry and plum (Yuan 2000). Apparently, the merits of wild rice, particularly the third and fourth listed above, had a clear advantage over those fruits considering the seasonal and fluctuated environment. We argue that under a mild but fluctuating environment wild rice was incidentally collected as one of many edible plant resources of foragers conducting a broad-spectrum subsistence. It was the consciousness of selecting more storable and reliable plant food that led the foragers in Yuchanyan and Diaotonghuan to keep wild rice harvesting as part of their subsistence strategy. This marked the emergence of the incidental domestication of rice.

The "Why" of Specialized Domestication

Specialized domestication represents the transition from hunter-gatherers to early farmers. The specialized domestication of rice, when humans not only harvested wild rice but also intentionally stored and planted seeds for a more productive return, represents a significant change in human behavior, culture, and social structure and is often considered as the "real" beginning of rice domestication. Various factors, based on both archaeological evidence and ethnological studies, have been introduced to explore the motivation/mechanism of the transition from hunting-gathering to farming.

1. Adaptive disadvantages and advantages of farming

As a subsistence strategy, farming has long been thought as less labor efficient than foraging. Harlan (1967) demonstrated in his experimental harvesting of wild wheat in the Near East that collecting wild grain is more productive and efficient than farming. Ethnographic observations of various contemporary hunter-gatherer groups also indicate that foragers spent less time gathering food and had more leisure time than farmers (Lee 1968, Kelly 1995, Sackett 1996). By measuring the return rate of calories/work hour, behavioral ecologists also showed that farming is less labor efficient than foraging (Kramer and Boone 2002, Barlow 2006). The disadvantages of farming over foraging formed the theoretical basis for the "pressure" models, which argued foragers were forced to become farmers as they faced food crisis resulted from environmental and/or demographic factors.

On the other hand, farming, as the means of food procurement, is more secure and less risky both physically and psychologically than hunting and gathering (Woodburn 1968). Hunting is a physically dangerous activity. The availability of wild plants and animals is often unpredictable due to environmental variability. As a result, foragers sometimes suffered hunger and malnutrition (Kelly 1995). In the long term adaptation of hunter-gatherers, humans' desire to increase food security had always been a driving force of human cultural evolution. In addition, farming can provide food resources to support uncontrolled population growth, since carrying capacity can be increased significantly through farming (Hayden 1972).

2. Environment factors

The environment conditioned how hunter-gatherers lived primarily through the availability of their food resources. Most of environmental models for the origins of agriculture, as mentioned in Chapters 2 and 3, focused on the long-term effects of environmental changes, among which are the post-LGM amelioration, the Younger Dryas deterioration, and the Holocene amelioration. Based on analyses of environmental changes and the evolutionary process of rice domestication, I found these environmental events did not play a determinative role in the transition. In particular, the incidental domestication of rice occurred both before and after the Younger Dryas, and the environmental conditions were generally similar at the beginning of both incidental domestication and specialized domestication. Although I believe long term environmental effects were closely related to the emergence of rice domestication, I feel that seasonality and short term environmental fluctuations could be more important to the process, and that the emergence of specialized domestication was mainly caused by other factors.

3. Population pressure

Since Boserup, many models, either based on population alone or in conjunction with other factors, have been proposed to explain the origins of agriculture. The fundamental relationship of population to agriculture is that when humans occupied every ecological niche at the end of the Pleistocene and population increase exceed the carrying capacity of a given niche, a food crisis would develop and force hunter-gatherers to become farmers. I admit that from a worldwide perspective, humans occupied almost every ecological niche before the emergence of specialized domestication, and also agree that population pressure could play an important role in the origins of farming. The only question is how to substantiate this in the archaeological data.

4. Sedentism

As hunter-gatherers reduced their mobility, sedentism increased accordingly. In our analysis of hunter-gatherer assemblages in the Middle and Lower Yangzi Valleys, sedentism only began at the end of the Late Paleolithic when the subsistence strategy changed from a forager type to a collector type and the increasing abundance of cultural remains was found in individual assemblages. As reflected in the database, increased sedentism since the end of the Late Paleolithic was correlated to technological changes and the appearance of storage facilities. The emergence of sedentism is considered a signal of the recognition of a rigid territorial system among hunter-gatherer groups and often related to population growth (Rosenberg 1990, 1998). Increased sedentism means more people stayed longer in a given environment. Its immediate effect was an intensified exploitation of natural resources, the reduction of the available range and quantity of high-quality resources, and local resource depletion in some cases, which often caused periodic food shortages (ibid). In the long run, however, it benefited the emergence of specialized domestication, since the hunter-gatherers would have both desire and pressure to domesticate wild plants. On the one hand, they could inherit the past experience in incidental domestication, and become more familiar with those potential domesticates. On the other hand, the food shortages could force them to make the transition to specialized domestication.

5. Social competition

Evidence on social competition is basically uncertain in the assemblages related to the emergence of specialized domestication. Along with population growth and increased sedentism, a certain level of social complexity could occur in hunter-gatherer societies, however, whether this complexity led to social competition and the rise of leadership is unsubstantiated by the available data. This situation is clear from later time when rice agriculture was established in the Late Neolithic.

It is clear that the recognition of the merits of wild rice was inherited by the forgers who started specialized domestication of rice, as evidenced by the continuous occupation of Diaotonghuan since the emergence of incidental domestication at about 12,000 BP. It is hard to demonstrate a direct connection between Yuchanyan and Pengtoushan. But it is reasonable to infer that there could have been a pre-Pengtoushan incidental domestication period, developed either locally or by migrants from other places, including Yuchanyan. The same inference could be made in the Jiahu case. In either case, the primitive farmers had some recognition of wild rice when they began specialized domestication. Unlike the emergence of incidental domestication, the beginning of specialized domestication represented a big leap in terms of human cultural evolution and is often considered by many as the emergence of real rice domestication (Zhao 1996, Lu 1998).

Based on the above analysis, I suggest that population growth and increased sedentism could be the plausible reasons of the emergence of specialized domestication. Given the different landscape and cultural development, the change in population and sedentism was presented in two different patterns in the three independent areas.

In the Dayuan Basin where Xianrendong and Diaotonghuan belong, the change was probably a result of the loss of land mass due to the rise of sea level. As mentioned in Chapter 4, the sea level rose at an average speed of 5.4 mm/year (Yang and Xie 1984), which led to the inundation of low-lying areas near major rivers. The Dayuan Basin is only 50 km southwest of the Lake Poyang, a major water reservoir of the Yangzi River, and was inevitably affected by the change of water level. The effect was two-fold: population density increased due to population concentration and possible migration, and mobility decreased as ground water habitats extended and landmass reduced. The increased population density and sedentism are reflected in the cultural remains dated from 10,000 to 8,000 BP in Xianrendong. Not only was the quantity of artifacts increased dramatically from the preceding period, but there also appeared the first pottery, fire places, garbage pits and possible burials (Jiangxi Cultural Relics Administration 1963, Jiangxi Museum 1976; MacNeish and Libby eds. 1995). Chang (1986) even suggested that the Xianrendong cave represented a permanent home during this period.

In the circum – Lake Dongtin area where the Pengtoushan Culture belongs and the Northern Huai Valley where Jiahu belongs, the assemblages dated to the millennium before the beginning of specialized domestication are unknown. However, based on the assemblages of the early part of the Middle Neolithic, I can make a reasonable inference of what happened during that time. Whether to local inhabitants or immigrants, the environmental amelioration since the beginning of the Holocene provided an increasingly amicable habitat before the emergence of specialized domestication. In a landscape which features flat alluvial plain and rich water systems, environmental amelioration means increasing the carrying capacity of the ecological niche. As a result, the hunter-gatherers tend to move less and the population could grow even though the subsistence strategy was unchanged. This has been demonstrated by the studies of contemporary hunter-gatherers (Cane 1984, Kelly 1995). Although there is no evidence that dates to the time to support this inference, the construction of sedentary villages and the diversified cultural remains in both Pengtoushan and Jiahu were clearly the results of increasing population and sedentism during the preceding period in those areas.

As population and sedentism increased in all the three areas, there were some changes in the composition of their food inventory. In Xianrendong and Diaotonghuan, deer was the predominant animal species beginning the Early Neolithic. From 11,000 to 9,000 BP, there was a clear decrease in their body size along with a considerable increase in the number of deer found in the faunal remains (Redding 1995). This change is linked to the changing environment, but it also indicates an increasingly intensified hunting of local animal resources during the period of increasing population and sedentism. In Jiahu, deer is the only territorial animal with clear evidence of human utilization. The identification of all other mammal species was only based on their coprolites, which can only demonstrate the presence of these species in the area during the time of human occupation. Comparing with the relatively small proportion of territorial animal remains, aquatic resources including turtles, fish and shells were found in large quantities (Zhang et al. 1998). In Bashidang, wild animals were also very limited in both species and quantity, and aquatic resource utilization was represented by a large number of fish bones (Pei 2000). The Jiahu and Bashidang wild animal remains were used as indirect evidence to support the decrease of wild animal resources as humans became more sedentary. Although the limited data do not allow us to recognize the changing pattern of plant resources during this period, we can argue that the reduction of the wild animal species, the decrease of large animals hunted, and the increase of aquatic resources all indicate an intensified exploitation of natural food resources in these areas during the period of increasing population and sedentism.

The persistence of intensified exploitation of natural resources in a given area could deplete the natural resources, particularly wild ungulates that have very low reproductive abilities. As the population and sedentism continued to increase, the balance between hunter-gatherers and their natural resources could be broken – and a food crisis would occur at this point. The traditional “buffering mechanisms” of hunter-gatherers facing the risk and uncertainty of food resources include: mobility, diversification, storage and exchange (Halstead and O’Shea 1989). Increasing mobility and diversification cannot solve the problem in our cases: on the one hand, the rigid territory system and the high population density made it difficult to increase mobility; on the other hand, increasing foraging frequency and diet breadth could accelerate the depletion of natural resources. Storage and exchange were not viable under the existing subsistence strategy: they depended on the abundance of certain resources that were conditioned by environmental variations and the reproductive abilities. Ultimately, the food crisis can only be solved by introducing a new subsistence strategy – intentional domestication also called specialized domestication in the coevolutionary model.

It is clear that the last hunter-gatherers in the three areas experimented with domesticating a few plant and animal species. In Bashidang, water caltrop, lotus, ox, pig and chicken were domesticated along with rice domestication. In Xianrendong and Diaotonghuan, rice and chicken were domesticated. In Jiahu, the domesticated species include rice, ox, pig and dog. As indicated in the study of the Middle East, the reasons for animal domestication are still unclear (Bar-Yosef and Meadow 1995). The domestication of aquatic plants like water caltrop and lotus can be explained by their high reproductive ability, year long availability, and their ability to be stored. Their domestication is also easy and less labor intensive (Pei 2000).

As mentioned in the beginning of incidental domestication, wild rice was harvested by hunter-gatherers for a few reasons, the most important of which are its high reproductive ability, its return rate, and its storability. These merits were likely very attractive to hunter-gatherers, because they fit the desire for food security among hunter-gatherers. However, the gathering of wild rice could not meet the increased demand which resulted from increased population and sedentism. Common wild rice is regenerated by vegetative reproduction, which only produces a certain quantity of seeds each year. Most of the seeds are consumed by birds and animals, so very few were able to survive in field. In disturbed habitats such as hunter-gatherer niches, the mortality rate of wild rice is high (Oka 1975). I argue that the contradiction between the demand of more rice and the restricted yield of wild rice led the last foragers in the three areas to start investing more labor and time into the domestication of wild rice.

The "Why" of Agricultural Domestication

As specialized domestication represents the beginning of domestication, agricultural domestication indicates the establishment of an agricultural society. Many models for agricultural origins in general (e.g., those reviewed in Chapter 2) or specifically for the origins of rice agriculture (e.g., those in Chapter 3) often focus on the emergence of domestication and imply that agricultural societies are the natural outcome of domestication. It now seems clear, based on the developmental process of the origins of rice agriculture, that the development of domestication does not guarantee the establishment of an agricultural society. Rice domestication emerged in three independent centers of China, but only led to the origins of rice agriculture in one center. I argue that the development of social complexity due to population growth, increased sedentism, and a new subsistence strategy led to the origins of rice agriculture.

Of the three centers with the earliest rice domestication, Jiahu had the earliest development of social complexity. However, this development did not lead to rice agriculture. As this area was occupied by inhabitants affiliated with the Peiligang Culture and its successors, there rice domestication was replaced by an agriculture based on millet (Chang 1986, Zhang and Wei 2004). As discussed earlier, the disappearance of rice domestication after the Jiahu period was resulted from environmental change and cultural tradition that made rice domestication unviable both ecologically and culturally.

In the case of Xianrendong and Diaotonghuan, however, rice domestication continued in the area through the end of the Middle Neolithic. Unlike both the Yangzi Delta and the circum-Lake Dongting area, where rice agriculture appeared in the beginning of the Late Neolithic, the area did not witness the origins of rice agriculture. Instead, it was abandoned by humans, and was not reoccupied until after 5,000 BP. As indicated by the assemblages dated between 9,000 and 7,000 BP, human culture had a continuous development from the preceding period: technological improvement was reflected in lithic, pottery and bone artifacts; increased population and sedentism were represented by the abundance of cultural and food remains as well as hearths, storage pits and other unidentified features; the development of domestication was indicated in the increase of the proportion of domesticated rice in the rice phytoliths and the domestication of chicken (Jiangxi Cultural Relics Administration 1963, Huang and Ji 1963, MacNeish and Libby eds. 1995).

Why did this development not lead to the origins of rice agriculture? The answer should come from comparing it with the Middle Neolithic cultures in the Middle Yangzi Valley which demonstrated a continuous development of domestication that led to the origins of rice agriculture in the Late Neolithic. In addition to the continuous development of the specialized domestication of multiple species, the improvement of technology (e.g., ground stone tools and pottery), and the increased sedentism and population growth, the Pengtoushan and Lower Zaoshi Cultures had the following characteristics that are different from those in contemporaneous Xianrendong and Diaotonghuan assemblages.

First, there appeared settlements of different sizes, larger ones with ceremonial architecture. In the Liyang Plain, the core area of the Pengtoushan and Lower Zaoshi cultures, the sites of the same period formed two large groups. In each group there were a certain number of small groups, often consisting of 2-3 sites. This pattern was consistent through the Late Neolithic when two large settlements (also called "ancient cities" in Chinese archaeology) developed in the areas of the two groups. During each period, there was one large settlement that was two to three times larger than the other settlements. As discussed in Chapter 6, the basic social structure during the Middle Neolithic was the extended family. The formation of two levels of settlement groups indicates different level of alliance among these social groups. The two large settlements were important as social groups. Their importance is demonstrated by the considerable amount of labor and time needed for their construction. Additionally, several ceremonial buildings were found in Bashidang, the largest settlement of the Pengtoushan Period. An example of one of these is a platform with a central posthole under which ox mandibles were buried—suggesting the structure was used for ceremonial activities, such as sacrifices.

Second, burials show the differentiation of social status. Burials during this period did not form clear cemeteries, and the preservation was often not good. Most of them were secondary burials distributed around the residential area. The grave goods were often broken implements and potsherds, presumably used by the dead in their lifetime. However, there is a particular burial at the Pengtoushan site, which could be associated with a high-ranked person. This is one of the very few primary burials at the site. The body is a female, and the grave goods include stone tubes found near her waist and hips. Since early social structure was often matriarchic, and the burial and grave goods were clearly better treated, it is reasonable to infer that this burial could be of a high-ranked person in the Pengtoushan society.

Third, a certain level of inter-group labor specialization could appear. There is no clear indication of labor/craft specialization within individual sites. However, the comparison of assemblage compositions among the sites indicates the possibility. The lower part of Bashidang and Pengtoushan belonged to the same site group. The lower Bashidang assemblage is dominated by the large quantity of rice grains, along with a few tools linked to planting and harvesting. Very few ceramics were found in the stratum of rice remains. In the Pengtoushan assemblage, pottery was the predominant remain. In an area of only 400 m^2, the unearthed potsherds weigh several tons, filling a full mid-size truck. Considering that Bashidang was the largest settlement of the group, it is highly possible that the Pengtoushan residents were more specialized in pottery manufacture, and they provided some potteries to the Bashidang settlement through alliance and/or exchange. This specialization was not complete, as the pottery making was probably not a full time occupation. Ethnographic studies of modern Chinese minorities indicate that the part-time potters could still make sufficient pottery for intra-group trade and exchange, and that cooperation between part-time potter and those who did not make pots was the way for those who did not make pots of the community to obtain pots (Li 1998).

Fourth, rice could emerge as a representation of wealth and social status. Among the plants domesticated by people of the Pengtoushan Culture, rice domestication required the most labor and time. Perhaps it is not a coincidence that Bashidang was both the largest settlement of the Pengtoushan Period and yielded the largest quantity of rice remains. Maybe the level of rice domestication was linked to the social status of the settlement. The possibility that rice was initially domesticated to produce alcohol, an important feasting object, was introduced by Hayden (2003) to explain the origins of rice domestication. Recent chemical analyses of organics in the Jiahu pottery jars suggest that they were probably used to contain rice wine (McGovern et al. 2004). This result supports Hayden’s argument and indicates that rice could be used as a prestigious item in the beginning of its domestication. As indirect evidence, the Late Neolithic site of Chentoushan had visible defensive enclosure consisting of high a wall and deep ditch. Considering the intensive social competition during this period, the defensive facility was clearly used to protect those with wealth and high social status. However, more than one decade of continuous excavations at the site only yielded a few precious jade objects in the burials (Hunan Provincial Institute of Archaeology and Li 1999). Considering the appearance of paddy fields and irrigation systems at the site, and the large amount of food required to construct such a large size city, it is reasonable to infer that rice was the wealth they were protecting. Also, as an indication that rice was a valuable item, the motif of rice was found on the surface decoration of some pottery vessels in Hemudu (Liu and Yao 1993).

Fifth, the ecological niche of the settlements was relatively spacious. As Pei (2006b) measured, the minimum niche size was about 50 km^2 during the Pengtoushan Period and 35 km^2 during the Lower Zaoshi Period. Meanwhile, the slow accumulation of cultural deposits during this period indicates a relatively slow growth of population when compared to the Late Neolithic. As mentioned before, the Middle Neolithic subsistence strategy was multiple species domestication along with hunting, fishing and gathering. Given the rich and diversified ecology of the Pengtoushan and Lower Zaoshi Cultures, there does not appear to have been any pressure from population or environment which caused the transition to full-scale rice agriculture.

Based on the above cultural characteristics of the Middle Neolithic cultures with rice domestication, it is plausible to argue a social explanation of the origins of rice agriculture. During the Middle Neolithic period, along with the development of rice domestication and the increased sedentism, the social structure became complex. Extended families constituted lower-level social groups, which formed higher-level societies. Within the societies there emerged high-ranking persons – perhaps senior women and certain level of inter-group labor specializations. The social groups would have been connected through marriage, alliance and reciprocal exchange. Rice became a valuable item, and probably the representation of wealth and social status. This point was demonstrated in Hayden's cross-cultural comparison and analysis of cultural characteristics of rice (2003). As a prestige item, rice could be used in all those inter-group activities, and also be pursued by the leaders to demonstrate and reinforce their status. As a result, the non-subsistence demand of rice could lead to the increase of rice production. Meanwhile, the emergence of leadership in an increasingly complex society could help solve all kinds of social problems related to the sedentary lifestyle, encourage technological innovations, and channel resources to facilitate the development of rice domestication. It is the development of social complexity that generated and channeled the increased production of rice, which finally led to the origins of rice agriculture.

In conclusion, I argue that three different types of mechanism caused the emergence of three types of rice domestication. The beginning of incidental domestication of rice was resulted from hunter-gatherer's conscious harvesting of wild rice in suitable ecological niches. The emergence of specialized domestication of rice was an inevitable choice when hunter-gatherers with incidental rice domestication faced the pressures from increased population and sedentism. The origins of rice agriculture were caused by the development of social complexity in societies with specialized rice domestication.

7.5 Summary

Presented in this chapter is the first theoretical model that provides systematic answers to major questions concerning the origins of rice agriculture. This model differs from all existing models on the origins of rice agriculture in several aspects.

First, it views the origins of agriculture as an evolutionary process. Instead of looking for a turning point of rice domestication, such as the earliest domesticated rice or farming tools, it proposed a three-stage process of domestication to understand changes of both rice and humans under domestication. As indicated in this model, the appearance of domesticated rice alone can not demonstrate the presence of rice domestication. Also, specialized rice domestication did not always lead to rice agriculture, as indicated in Jiahu. From the appearance of the first domesticated rice to established rice agriculture, it took several thousands of years.

Second, it represents the first application of evolutionary and social theories to explore the origins of rice agriculture. As I discussed in Chapter 3, environmental factors, demographic factors, and their combination have been used by different models to explain the origins of rice agriculture and none of those models provided satisfactory answers to the issues of the origins of rice agriculture. By introducing evolutionary theory into the study, this model explains the origins of rice agriculture in three evolutionary stages. Social theory provided the most acceptable explanation of the establishment of rice agriculture.

Third, it demonstrates the importance of the synthetic methodology used in building the database and formulating the theoretical model. Although the data of this model almost all came from published materials, careful collation and analysis made the database the most comprehensive and reliable basis to build a theoretical model. As demonstrated by this model, the synthetic application of theories in Western archaeology is particular helpful to understand the origins of rice agriculture.

Although this model addressed all major issues concerning the origins of rice agriculture, it still has some questions unanswered, mainly due to the restriction of related evidence. The issue I want to address is my unconscious emphasis of the Middle Yangzi Valley, particularly the Pengtoushan Culture in this model. I suggested the Middle Yangzi Valley as one of the three centers of rice domestication. Comparing with the Lower Yangzi Valley and the Huai Valley, the Middle Yangzi Valley has the most complete cultural sequence from incidental domestication to full agriculture. This is related to the discoveries of related sites in different regions. The Pengtoushan Culture has been emphasized, because of its possible linkages to its contemporary site of Jiahu and the later site of Hemudu. However, all postulations of these relationships require more evidence.

Chapter 8

Conclusion

This dissertation presents a new theoretical model to understand the origins of rice agriculture. The study is based in part on a critical review of existing theories on the origins of rice agriculture. The new model is also built on a synthetic analysis of comprehensive and updated data of archaeological cultures and related environments by applying theories of the origins of agriculture in Western archaeology. In this chapter, I want to briefly recapitulate the main points of my model and discuss some related issues.

8.1 Recapitulation

Concerning the center of the origins, the most popular current view is the Middle and Lower Yangzi Valleys where the oldest domesticated rice remains and the earliest human society with established rice agriculture are found. However, there are gaps in both chronological sequences of regional assemblages and knowledge of relationships among these assemblages. Furthermore, the Huai Valley should be included as a third region, for it has similarly old rice remains in a cultural tradition different from those of the Yangzi Valley.

The theories of the origins of rice agriculture are important to my study and they form the direct basis for further exploration. The existing models can be classified to two types based on causal factors: demographic pressure and environmental changes. Yan (1998) considers population pressure in the particular ecological niche of the Yangzi Valley as the impetus of the beginning of rice domestication. His argument is based on the ecological and cultural comparisons between the Yangzi Valley and South China. Other models focus on environmental changes. Both Higham (1995) and Zhao (1996) see environmental deterioration as the impetus of the origins, but they differ on the specific environmental event. Another environmental explanation is suggested by Yashuda (2002), who argues that environmental amelioration after the LGM encouraged hunter-gatherers to utilize wild rice that led to rice domestication. The common problem all these models have is the lack of support from empirical evidence.

The changes of human cultures related to the origins of rice agriculture can be divided to four archaeological periods. The late Paleolithic, roughly from the LGM to 12,000 BP, witnessed the lithic technology change from pebble chopping tools to small flake tools made of exotic high quality raw materials and an increased sedentism of hunter-gatherers as shown by the quantity of artifacts and indicators for long-term site occupation. Hunting became more important in human subsistence, as the food procurement model changed from forager type to collector type. The Early Neolithic (12,000 – 9,000 BP) is characterized by the appearance of wild rice harvesting and the invention of pottery. The harvesting of wild rice halted during the Younger Dryas episode when wild rice may have disappeared from the Yangzi Valley. The sites are all caves within restricted basins, which could correlate to the fluctuated and deteriorated environment. Human subsistence during this period depended on hunting, fishing and gathering. The Middle Neolithic (9,000 – 7,000 BP) saw the expansion of rice domestication to the Huai Valley. The development of technology is represented by the appearance of ground stone tools and the increasing diversity of ceramic technology. Domesticated rice increased its importance in human subsistence during the Middle Neolithic. Root-crops such as water caltrop, lotus root and a few animals including ox, pig and chicken were probably also domesticated in this period. Hunting and gathering became less important in human subsistence. The site patterns show an apparent shift to alluvial plains, probably to accommodate rice farming. Farming villages probably appeared, as is suggested by house remains, storage pits, burials and protective constructions. In the Late Neolithic (7,000 – 5,000 BP), rice agriculture became established and rice was fully domesticated. In terms of technology, ground stone tools became more sophisticated and a slow wheel was used to make fine pottery vessels. Rice agriculture became the dominant subsistence strategy. Large quantities of rice remains, a set of farming tools and paddy fields with irrigation systems are all found dating to this period. Meanwhile, human societies become more complex, as reflected by clear craft/labor specialization, the building of large scale houses, and the differentiation of grave goods.

Based on the analysis of various aspects of cultural changes during the four periods, along with the consideration of environmental effects, I propose a newly theoretical model to answer the "where, when, how and why" questions of the origins of rice agriculture. Following Rindos' coevolutionary model, I argue that there existed three developmental stages of rice agriculture. By 12,000 BP, incidental domestication of rice appeared in Yuchanyan, Xianrendong and Diaotonghuan sites. This consisted only of the harvesting and processing of wild rice. The mechanism of this domestication is environment conditioned human consciousness among hunter-gatherers. Between 9,000 and 8,500 BP, specialized domestication probably emerged independently in Pengtoushan, Xianrendong and Diaotonghuan, as well as Jiahu of the Huai Valley. Increased population density and sedentism were the impetus for this change. To maintain their food security, hunter-gatherers who had experience with incidental domestication began to intentionally domesticate rice and other plants and animals to increase their yield. Not all the domestications finally led to the established agriculture. I argue that only the Pengtoushan rice domestication was developed to rice agriculture in the circum-Lake Dongtin area and the Yangzi Delta area during the Late Neolithic. At 7,000 BP, full rice agriculture was established in these two areas, represented by the Daxi Culture and the Hemudu Culture, respectively. The impetus of the origins of rice agriculture was the development of social complexity in a society in which rice was linked to wealth and social status.

8.2 Pottery, Sedentism and Rice Agriculture

For a long time, pottery, sedetism, agriculture and ground stone tools were considered the signs of the beginning of the Neolithic in Chinese archaeology. Now this concept should change as archaeological evidence has shown that these traits emerge at different times for many cultures. Even so, there is no doubt that they are closely related technologies in the origins of rice agriculture. In this section, I discuss the emergence of pottery technology and sedentism in the context of the origins of rice agriculture.

According to the chronology used in this dissertation, the oldest pottery in China emerged in Yuchanyan, dated to 12,000 BP. At 10,000 BP, pottery appeared in Xianrendong and Diaotonghuan. From 9,000 BP on, pottery technology continuously developed in conjunction with rice domestication. Pottery was invented by hunter-gatherers at the end of the Pleistocene. Based on the shape of the reconstructed pottery vessel in Yuchanyan, the original researcher (Yuan 2000) suggested it represented a cooking vessel *fu*, a common pottery type in ancient China. Considering the presence of a hearth and the absence of grinding tools for rice processing, I suggest one of the functions of the Yuchanyan pottery was to cook rice in boiled water. Meanwhile, we cannot rule out other possible usages of the pottery, such as to store collected plant seeds or other food items, and to cook other plants, aquatic food or even animal food.

Yuchanyan pottery was invented at roughly the same time as pottery in the Jomon Culture of Japan, which was considered the oldest pottery in the world (Aikens 1995). The earliest Jomon pottery emerged in a cultural context which featured a broad-spectrum hunting, fishing and gathering subsistence and seasonal sedentism (Habu 2004). The general subsistence strategy and level of sedentism between Yuchanyan and the incipient Jomon sites are roughly comparable. Based on the cultural context of pottery invention in both cases, I argue that the reason for pottery invention and its relationship with sedentism and agriculture are consistent with the general principles concluded by the studies of the earliest potteries in various parts of the world (Hoopes and Barnett 1995). Pottery was invented to process a wide range of food items in broad-spectrum hunter-gatherer societies. Through soaking and cooking in boiled water, many plants, including rice, become more palatable and nutritious. Also, cooking in pottery can provide “juicy” (moist) food, which is important in the absence of milk. Pottery was invented later in the Near East, where grinding tools can facilitate food processing and milk obtained from sheep and cattle made juicy food less critical to human diets. As indicated in all three cases, however, pottery invention was associated with some level of sedentism. It is notable that although pottery invention could occur in seasonally sedentary hunter-gatherer societies, the use of pottery is only viable in a sedentary context (ibid).

As indicated in my analysis of human cultures earlier in this study, the appearance of sedentism occurred during the end of the Paleolithic Period in the Yangzi Valley. This is based on the disappearance of site clusters, the considerable increase in the quantity of cultural deposits in individual sites, and the long term repeated occupation of sites like Diaotonghuan. The level of sedentism increased dramatically with the emergence of specialized domestication, as evidenced by storage facilities and permanent house and village remains. Reasons for the appearance of sedentim are related to the changing subsistence strategy during the late phase of the Paleolithic in the Yangzi Valley. Human adaptation after the LGM changed subsistence from a forager strategy to a collector strategy (following Binford's term), which featured increased logistical mobility in expanded territory but limited mobility within an individual niche. This situation matches the definition of sedentism proposed in Western archaeology (e.g., Rafferty 1985). The significance of sedentism to the emergence of intentional domestication lies in two aspects. On one hand, it increased the population density in a given ecological niche, which became a driving force of the emergence of domestication. This point is consistent with the Near East (Bar-Yosef and Meadow 1995, Bar-Yosef 1998) and ethnographic data of contemporary hunter-gatherers (Kelly 1995). On the other hand, seasonal sedentism allowed hunter-gatherers to become familiar with their niche and the associated food resources and hence encourage their intensive exploitation of a wide range of natural food resources, including some food items never used before.

In conclusion, I argue that sedentism preceded both pottery invention and rice domestication in the Yangzi Valley, and pottery was invented to facilitate the processing of food items including but not restricted to wild rice.

8.3 Remaining Questions and Directions for Future Research

One of the biggest challenges in the study of origins of rice agriculture is the estimation of population density since the late Paleolithic. As indicated in studies of the subject in other parts of the world, the population of hunter-gatherer societies is measured by the density of settlements in a given territory with reference to modern hunter-gatherers (e.g., Binford 2001), or based on the settlement size, the density of deposit and number of burials (e.g., Bar-Yosef and Meadow 1995). In my case, the related archaeological data are very meager. The problem is reflected in two ways. On one hand, the number of sites discovered is limited, and there is no clear information about the site distribution in specific regions during the late Paleolithic and Early Neolithic. On the other hand, many sites during this transitional period lack absolute dating. Most of the dates were based on the geological stratigraphy or faunal comparisons. This situation makes it difficult to place known sites in a chronological order for use in calculation and comparison. Since population density is a key factor affecting the origins of rice agriculture and social complexity, I argue that regional surveys of site distribution and increased absolute dating of sites belonging to the transitional period should be emphasized in future research.

Another question remaining is the cultural relationship between Yuchanyan and Pengtoushan, and that between Pengtoushan and Hemudu. The Yuchanyan assemblage represents the beginning of incidental domestication in the Middle Yangzi Valley. Given the available dating, it was occupied for a period of time around 12,000 BP. The next earliest cultural assemblage in that area is Pengtoushan, which is dated to 9,000 BP. Yuchanyan is a cave on the north edge of the Nanling Mountain Chain, whereas Pengtoushan is near the Yangzi Valley. There is a significant chronological and spatial gap between the two assemblages. Although some scholars argued for indigenous development of the Pengtoushan Culture (Pei 2000), there has been no clearly dated pre-Pentoushan remains of the Pengtoushan area that are contemporaneous to or later than the Yuchanyan assemblage. Meanwhile, the invention of pottery and the domestication of rice in Yuchanyan suggest some possible links with Pengtoushan. To solve this issue, finding the cultural precursor of Pengtoushan is critical. Until we establish a local development sequence from late Paleolithic assemblages to the Pengtoushan Culture, it is still possible that there exists links between Yuchanyan and Pengtoushan. The same problem exists in the suggested link between Pengtoushan and Hemudu. The proposed linkage of them is based on pottery comparisons and similar house structures. However, it is necessary to fill in the chronological and spatial gaps between the two cultures. To settle this issue, attention should be paid to the archaeological discoveries that may relate the Pengtoushan Culture to the Hemudu Culture. As pottery is one of the most important cultural aspects of the Neolithic societies, it is necessary to pay particular attention to ceramic similarities and variability.

Finally, I want to address the identification of ancient rice remains. In my final arguments, I relied on the morphological identification of those related rice remains to establish the evolutionary relationship between them. The main sequence of the development of rice agriculture is from Pengtoushan through Lower Zaoshi to Daxi in the Middle Yangzi Valley, and from Pengtoushan to Hemudu in the Lower Yangzi Valley. This is supported by cultural comparison as well as the evolution of domesticated rice in which pro-*indica* Pengtoushan rice evolved to *indica* rice in both regions at the beginning of the Late Neolithic. However, DNA studies indicate that all existing ancient rice remains in the Yangzi Valley belong to the *japonica* type (Sato

2002). Since morphological identification has some inevitable errors (Ahn 1992) and DNA analysis is the latest technique in this study, the existing identification of ancient rice remains is still uncertain. In this study, I follow the convention and the majority of the studies, but am aware of the debate on this issue. Although the model suggested in this dissertation can stand no matter what result the debate might come to, it is still important to have clearly identified ancient rice remains. In this, both botanists and geneticists play a critical role.

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Site	Lab Number	Sample	Dating Method	Uncalibrated years bp	Calibrated year BP	Reference
Yuchanyan	BK?	Acid in pottery	AMS	12320±120	N/A	Yuan 1999
Yuchanyan	BK?	Charcoal in pottery	AMS	14810±230	N/A	Yuan 1999
Yuchanyan	BK?	Wood charcoal	AMS	14490±230	N/A	Yuan 1999
Yuchanyan	BK?	Animal bone	AMS	12060±120	N/A	Yuan 1999
Diaotonghuan	UCR3441	Charcoal	^{14}C	17640±60	N/A	MacNeish and Taylor 1995
Diaotonghuan	BA-93180	Charcoal	^{14}C	17040±270	19895-19155	MacNeish and Taylor 1995
Diaotonghuan	BA-93179	Charcoal	^{14}C	19770±360	N/A	MacNeish and Taylor 1995
Diaotonghuan	BA-95137	Charcoal	^{14}C	24540±430	N/A	MacNeish and Taylor 1995
Xianrendong	BA-93181	Charcoal	^{14}C	14610±290	17366-16670	MacNeish and Taylor 1995
Xianrendong	BA-95145	Charcoal	^{14}C	12530±140	N/A	MacNeish and Taylor 1995
Xianrendong	UCR-3440	Charcoal	^{14}C	14160±140	N/A	MacNeish and Taylor 1995
Xianrendong	AA-15008	Floatation	^{14}C	17420±128	20973-20447	MacNeish and Taylor 1995
Xianrendong	UCR-3438	Charcoal	^{14}C	16730±130	N/A	MacNeish and Taylor 1995
Xianrendong	BA-93182	Charcoal	^{14}C	18110±270	21342-20524	MacNeish and Taylor 1995
Xianrendong	UCR-3439	Charcoal	^{14}C	16720±130	N/A	MacNeish and Taylor 1995
Xianrendong	UCR-3300	Human bone	^{14}C	15080±90	18238-17977	MacNeish and Taylor 1995
Shangshan	BA-02236	Charcoal in pottery	^{14}C	9610±160	N/A	Zhejiang and Pushang 2007
Shangshan	BA-02235	Charcoal in pottery	^{14}C	8740±110	N/A	Zhejiang and Pushang 2007
Shangshan	BA-02237	Charcoal in pottery	^{14}C	8620±160	N/A	Zhejiang and Pushang 2007
Shangshan	BA-02238	Charcoal in pottery	^{14}C	8050±110	N/A	Zhejiang and Pushang 2007
Shangshan	BA-06136	Charcoal	^{14}C	8855±40	N/A	Zhejiang and Pushang 2007
Shangshan	BA-06137	Charcoal	^{14}C	8180±35	N/A	Zhejiang and Pushang 2007
Pengtoushan	BK89017	Charcoal	^{14}C	7770±110	8490-8172	Chen and Hedges 1994
Pengtoushan	BK89019	Charcoal	^{14}C	7770±110	9442-9057	Chen and Hedges 1994
Pengtoushan	BK89020	Charcoal	^{14}C	7945±100	8980-8557	Chen and Hedges 1994
Pengtoushan	BK89021	Charcoal	^{14}C	8380±115	9244-8955	Chen and Hedges 1994
Pengtoushan	BK89022	Charcoal	^{14}C	8135±90	8951-8547	Chen and Hedges 1994
Pengtoushan	OXA1275	Acid in pottery	AMS	7930±80	8548-8370	Chen and Hedges 1994
Pengtoushan	OXA1277	Acid in pottery	AMS	6552±110	7145-6793	Chen and Hedges 1994
Pengtoushan	OXA1280	Acid in pottery	AMS	9785±180	10946-10301	Chen and Hedges 1994
Pengtoushan	OXA1281	Charcoal in pottery	AMS	7890±90	8494-8361	Chen and Hedges 1994
Pengtoushan	OXA2215	Acid in pottery	AMS	7610±80	8340-8019	Chen and Hedges 1994

Site	Lab Number	Sample	Dating Method	Uncalibrated years bp	Calibrated year BP	Reference
Pengtoushan	OXA2216	Charcoal in pottery	AMS	8290±80	8995-8727	Chen and Hedges 1994
Pengtoushan	OXA2217	Charcoal in pottery	AMS	8490±80	9372-9000	Chen and Hedges 1994
Pengtoushan	OXA2220	Charcoal in pottery	AMS	7590±80	N/A	Chen and Hedges 1994
Pengtoushan	OXA2221	Charcoal in pottery	AMS	11190±100	N/A	Chen and Hedges 1994
Pengtoushan	OXA2224	Charcoal in pottery	AMS	7385±80	N/A	Chen and Hedges 1994
Pengtoushan	OXA2225	Charcoal in pottery	AMS	11020±100	N/A	Chen and Hedges 1994
Pengtoushan	BK87002	Pottery	^{14}C	9100±120	9972-9652	Chen and Hedges 1994
Pengtoushan	BK87050	Wood charcoal	^{14}C	8200±120	9973-9653	Chen and Hedges 1994
Pengtoushan	BK89016	Wood charcoal	^{14}C	7815±100	8416-8213	Chen and Hedges 1994
Pengtoushan	BK89018	Bamboo charcoal	^{14}C	7945±170	8599-8334	Chen and Hedges 1994
Pengtoushan	OXA1273	Charcoal in pottery	AMS	9065±300	10036-9459	Chen and Hedges 1994
Pengtoushan	OXA1274	Ester in pottery	AMS	7055±100	7719-7549	Chen and Hedges 1994
Pengtoushan	OXA1282	Charcoal in pottery	AMS	8455±90	9365-8992	Chen and Hedges 1994
Pengtoushan	OXA2210	Rice in pottery	AMS	7775±90	8405-8187	Chen and Hedges 1994
Pengtoushan	OXA2211	Acid in pottery	AMS	7520±90	8137-7960	Chen and Hedges 1994
Pengtoushan	OXA2212	Charcoal in pottery	AMS	8550±80	9427-9058	Chen and Hedges 1994
Pengtoushan	OXA2213	Charcoal in pottery	AMS	9220±80	9997-9897	Chen and Hedges 1994
Pengtoushan	OXA2214	Rice in pottery	AMS	7250±140	7944-7670	Chen and Hedges 1994
Chengbeixi	BK84028	Animal bone	AMS	6800±80	7530-7390	Institute of Archaeology, CASS 1993
Chengbeixi	ZK2643	pottery	AMS	8220±250	9215-8435	Institute of Archaeology, CASS 1993
Chengbeixi	ZK2644	pottery	AMS	8274±234	9251-8546	Institute of Archaeology, CASS 1993
Fenshanbao	N/A	N/A	^{14}C	6800±80	N/A	He 1995
Fenshanbao	N/A	N/A	^{14}C	8220±250	N/A	He 1995
Fenshanbao	N/A	N/A	^{14}C	8274±234	N/A	He 1995
Hujiawuchang	BK87045	Wood charcoal	AMS	7190±140	7916-7633	Institute of Archaeology, CASS 1991
Hujiawuchang	BK87046	Wood charcoal	AMS	7210±110	7912-7664	Institute of Archaeology, CASS 1991
Hujiawuchang	BK87047	Wood charcoal	AMS	6960±100	7644-7478	Institute of Archaeology, CASS 1991
Hujiawuchang	OXA2218	Carbonized straw	AMS	6395±90	7208-7002	Chen and Hedges 1994
Hujiawuchang	OXA2219	Acid in pottery	AMS	6695+80	7431-7280	Chen and Hedges 1994
Hujiawuchang	OXA2220	Charcoal in pottery	AMS	7590±80	8240-8008	Chen and Hedges 1994
Hujiawuchang	OXA2221	Charcoal in pottery	AMS	11190±100	12906-12689	Chen and Hedges 1994
Hujiawuchang	OXA2222	Carbonized straw	AMS	6500±100	7281-7092	Chen and Hedges 1994

Site	Lab Number	Sample	Dating Method	Uncalibrated years bp	Calibrated year BP	Reference
Hujiawuchang	OXA2223	Acid in pottery	AMS	6715±80	7471-7292	Chen and Hedges 1994
Hujiawuchang	OXA2224	Charcoal in pottery	AMS	7385±80	8058-7904	Chen and Hedges 1994
Hujiawuchang	OXA2225	Charcoal in pottery	AMS	11020±100	12750-12520	Chen and Hedges 1994
Hujiawuchang	OXA2733	Charcoal in pottery	AMS	6540±242	7389-7029	Chen and Hedges 1994
Kuahuqiao	HL91002	Wood	^{14}C	7595±155	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	HL91001	Acorn	^{14}C	7076±170	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BA9906	Acorn	^{14}C	6800±100	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK200166	Wood	^{14}C	6970±90	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK200165	Wood	^{14}C	6585±155	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK2003006	Wood	^{14}C	7070±90	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK2003007	Wood	^{14}C	7055±50	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	ZK3173	Wood	^{14}C	6991±210	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	HL91026	Wood	^{14}C	6870±110	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK200168	Wood	^{14}C	6615±90	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK200167	Wood	^{14}C	6450±90	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK200169	Wood	^{14}C	6180±176	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	HL91023	Wood	^{14}C	6500±120	N/A	Zhejiang and Xiaoshan 2004
Kuahuqiao	BK200170	Wood	^{14}C	6375±170	N/A	Zhejiang and Xiaoshan 2004
Jiahu	WB8360	Wood charcoal	^{14}C	7920±150	8620-8360	Zhang ed. 1989
Jiahu	DY-K0185	Grass ash	^{14}C	7561±125	8280-8020	Zhang ed. 1989
Jiahu	DK-K0186	Grass ash	^{14}C	7105±120	7840-7630	Zhang ed. 1989
Jiahu	DK-K0188	Grass ash	^{14}C	7017±130	7750-7520	Zhang ed. 1989
Jiahu	DK-K0189	Grass ash	^{14}C	7137±130	7930-7650	Zhang ed. 1989
Jiahu	BK91007	Nut	^{14}C	7960±60	8530-8430	Zhang ed. 1989
Jiahu	BK94126	Wood charcoal	^{14}C	8285±100	9060-8990	Zhang ed. 1989
Jiahu	BK94127	Wood charcoal	^{14}C	7450±80	8160-7980	Zhang ed. 1989
Jiahu	BK94172	Grass ash	^{14}C	7415±80	8120-7970	Zhang ed. 1989
Jiahu	BK94173	Wood charcoal	^{14}C	8190±75	9040-8650	Zhang ed. 1989
Jiahu	BK94174	Wood charcoal	^{14}C	7825±80	8460-8350	Zhang ed. 1989
Jiahu	BK94175	Wood charcoal	^{14}C	7510±90	8180-7990	Zhang ed. 1989
Jiahu	BK94176	Wood charcoal	^{14}C	7650±70	8320-8180	Zhang ed. 1989
Jiahu	BK94177	Wood charcoal	^{14}C	8090±110	9000-8500	Zhang ed. 1989

Site	**Lab Number**	**Sample**	**Dating Method**	**Uncalibrated years bp**	**Calibrated year BP**	**Reference**
Jiahu	BK94178	Wood charcoal	^{14}C	8225±70	9040-8800	Zhang ed. 1989
Jiahu	BK95013	Human bone	^{14}C	7050±80	7750-7620	Zhang ed. 1989
Jiahu	BK95014	Human bone	^{14}C	7240±70	7940-7760	Zhang ed. 1989
Jiahu	BK95017	Human bone	^{14}C	7035±70	7720-7620	Zhang ed. 1989
Jiahu	BK95018	Human bone	^{14}C	8000±100	8630-8440	Zhang ed. 1989
Hemudu	BK75057	Wood charcoal	^{14}C	6310±100	7167-6878	Institute of Archaeology, CASS 1991
Hemudu	BK75058	Wood charcoal	^{14}C	5050±100	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78101	Wood charcoal	^{14}C	6060±100	6852-6574	Institute of Archaeology, CASS 1991
Hemudu	BK78102	Wood charcoal	^{14}C	6040±100	6738-6484	Institute of Archaeology, CASS 1991
Hemudu	BK78103	Grass	^{14}C	5910±90	6666-6416	Institute of Archaeology, CASS 1991
Hemudu	BK78104	Acorn	^{14}C	6310±170	7206-6787	Institute of Archaeology, CASS 1991
Hemudu	BK78105	Wood charcoal	^{14}C	5560±80	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78106	Wood charcoal	^{14}C	5610±80	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78109	Wood charcoal	^{14}C	6260±200	7197-6724	Institute of Archaeology, CASS 1991
Hemudu	BK78110	Wood charcoal	^{14}C	5310±100	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78111	Wood charcoal	^{14}C	6050±100	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78113	Wood charcoal	^{14}C	5610±80	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78114	Rice husk	^{14}C	6240±100	7018-6787	Institute of Archaeology, CASS 1991
Hemudu	BK78115	Wood charcoal	^{14}C	5940±85	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78116	Wood charcoal	^{14}C	6200±85	6986-6753	Institute of Archaeology, CASS 1991
Hemudu	BK78117	Wood charcoal	^{14}C	5270±90	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78118	Wood charcoal	^{14}C	5210±100	N/A	Institute of Archaeology, CASS 1991
Hemudu	BK78119	Wood charcoal	^{14}C	6200±100	N/A	Institute of Archaeology, CASS 1991
Hemudu	PV-0028	Wood charcoal	^{14}C	5320±100	6024-5762	Institute of Archaeology, CASS 1991
Hemudu	PV-0047	Acorn	^{14}C	6260±130	7160-6782	Institute of Archaeology, CASS 1991
Hemudu	WB77-01	Wood charcoal	^{14}C	5975±100	6738-6484	Institute of Archaeology, CASS 1991
Hemudu	ZK-0263	Acorn	^{14}C	6065±120	6859-6559	Institute of Archaeology, CASS 1991
Hemudu	ZK-0263(2)	Rice husk	^{14}C	6085±100	6859-6646	Institute of Archaeology, CASS 1991
Hemudu	ZK-0589	Wood charcoal	^{14}C	5370±95		Institute of Archaeology, CASS 1991
Hemudu	ZK-0590	Wood charcoal	^{14}C	6200±85	6986-6753	Institute of Archaeology, CASS 1991
Caoxieshan (paddy field)	N/A	N/A	^{14}C	5270±100	5905±125	Zou et al. 2000

Site	Lab Number	Sample	Dating Method	Uncalibrated years bp	Calibrated year BP	Reference
Caoxieshan (paddy field)	N/A	N/A	^{14}C	5565±60	6220±60	Zou et al. 2000

Appendix I: Radiocarbon dates of archaeological sites in this dissertation

English Name	**Chinese Name**
Jigongshan	鸡公山
Zhangnaodong	樟脑洞
Wuyashan	乌鸦山
Yanerdong	燕儿洞
Shiligang	十里岗
Diaotonghuan	吊桶环
Xianrendong (Hsien-jen-tung)	仙人洞
Sanshandao	三山岛
Yuchanyan	玉蟾岩
Shangshan	上山
Pengtoushan	彭头山
Zaoshi	皂市
Bashidang	八十档
Chengbeixi	城背溪
Fenshanbao	坟山堡
Hujiawuchang	胡家屋场
Kuahuqiao	跨湖桥
Jiahu	贾湖
Hemudu (Ho-mu-tu)	河姆渡
Daxi	大溪
Chengtoushan	城头山
Caoxieshan	草鞋山

Appendix II: Translation of Chinese names of sites in this dissertation