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The growth and significance of scientific research into the origins of agriculture in China calls for fresh examination at scales large enough to facilitate explanation of cultural evolutionary processes. The Paleolithic to Neolithic transition (PNT) is not yet well-understood because most archaeological research on early agriculture cites data from the more conspicuous and common early Neolithic sites. In this, the first of two papers, we synthesize a broad range of early Neolithic archaeological data, including diagnostic artifacts, settlement patterns, site structure, and biological remains, to consider agriculture as a system-level adaptive phenomenon. Although farming by this period was already well-established in much of North China and the middle Yangtze River basin, echoes of the foraging past can be found in the persistence of hunting-related artifacts in North China’s Loess Plateau and aquatic-based intensification and vegiculture in South China. Our analysis of the growing body of Chinese data and projections using Binford’s hunting and gathering database indicate that agriculture was differentially developed, adopted, or resisted by foragers according to measurable, predictable initial conditions of habitat that influenced diet breadth. In a subsequent paper (*Journal of Anthropological Research* 73(3), 2017, doi:10.1086/692660), we will use these findings as a platform for a deeper consideration of the emerging archaeological record of the PNT, and to develop hypotheses for the last foraging and first farming adaptations in China.

Key words: origins of agriculture, Early Neolithic, diet breadth, China, hunter-gatherer, forager subsistence diversity

For the preceding century, research on China’s agricultural origins has centered on biological (e.g., Li 1984) and geographical (e.g., Ho 1969) studies, which later gradually incorporated archaeological data. As in the West, natural sciences such as paleoethnobotany and zooarchaeology were prominent, with contributions of Chinese archaeologists limited to the discovery and documentation of archaeological materials and biological remains, using culture-historical theories and methodologies to craft regional chronologies. However, we argue that the development of agriculture is a *cultural* phenomenon by which humans adapt to their environments through culturally developed and trans-

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mitted mechanisms. Therefore, although data from the natural sciences will always play an important role in reconstructing paleoenvironments, it is the task of archaeologists to infer changes in adaptive patterns—and, hence, cultural evolution—by analyzing data to test and refine explanations about the past.

In the case of China, this calls for reexamination of both existing data and explanations for agricultural origins. Neolithic culture traits (e.g., pottery, polished stone tools, sedentary villages, and domesticated animal and plant remains) are more archaeologically visible than those of foragers and easier to describe and categorize by attribute. Thus, Chinese research into the origins of agriculture has typically focused on fully Neolithic archaeological remains.

The problem of documenting agricultural origins also calls for cross-referencing between cultural evolutionary stages and research specialization. For example, early agriculture has its roots in late-stage Pleistocene foraging (sensu Binford 2001) and therefore falls within the research scope of Paleolithic archaeology. However, the “agriculture question” has aroused little interest among Paleolithic researchers who have an evolutionary research orientation and methods similar to those of natural scientists.

In addition, the political upheavals in China inhibited publication during the middle years of the twentieth century, so Western academic literature on the subject was based on research conducted by overseas Chinese scholars who (necessarily) worked with older, previously published data. The time lag for incorporating new archaeological data led to entrenchment of conclusions that call for serious reevaluation. One example is the view that rice agriculture originated in Yunnan and South Asia (Chang 1976), or that loess played a determining role in the development of Chinese agriculture (Ho 1969). The result of all this is a sizeable blind spot in Chinese archaeology: the critical transitional stage from the late Pleistocene to early Holocene has not yet been explored in depth by either Paleolithic or Neolithic archaeologists.

To frame the initial conditions of agriculture, we propose that clearer, more robust descriptions are needed for the archaeological signatures of intensification and early domestication from the period bracketed by the early Neolithic and the Terminal Paleolithic. This process is already underway. Beginning in the 1980s a new generation of researchers has been trained in bioarchaeology, related laboratories have been established, biological remains and samples from site excavations have accumulated in collections, and a new journal, *Agricultural Archaeology* (*Nongye Kaogu*), is dedicated to publishing research results.

Since China’s “great opening” in 1978, cooperative research between Chinese and Western archaeologists has increased dramatically.¹ Western scholars have participated in site excavations and studies of archaeological collections from Xianrendong (MacNeish and Libby 1995; MacNeish et al. 1998), Yuchanyan (Boaretto et al. 2009), Dadiwan (Barton et al. 2009; Bettinger et al. 2010; Zhang et al. 2010), and other sites. Western researchers have brought varied areas of research expertise, including the analysis of animal and plant remains (e.g., Cohen 1998; Crawford 2006, 2009; Pechenkina et al. 2005), paleoenvironment (Bar-Yosef 2011; Yasuda 2002, 2008), and cultural development

(Cohen 2003, 2011). Regional or synthetic studies have been authored by Western researchers (Bellwood 2006, 2011; Shelach 2000, 2006; Shelach and Teng 2013; Underhill 1997), Chinese archaeologists trained in the West (Chen 2004; Liu 2004; Liu and Chen 2012; Lu 1999; Qu et al. 2013), and other Chinese archaeologists who have published in English (e.g., Jiang 2013; Zhang and Huang 2013; Zhu 2013). Moreover, in the most recent decade, numerous works from associated fields such as paleoethnobotany (e.g., Fuller et al. 2009; Hunt et al. 2011; Yang et al. 2012), geoarchaeology (e.g., Atahan et al. 2008; Mao et al. 2008), and human-land interaction studies (e.g., Hu et al. 2013) have brought the neolithization of China into the limelight. At the same time, the sample of materials associated with the Upper Paleolithic to Neolithic transition and the early Neolithic is increasing, and modern methods of excavation and dating have enhanced the reliability and resolution of chronological control.

Our goal for this study is twofold: first, to define the better-known phenomenon—the Neolithic—as a means to the second goal, to work toward the lesser-known transition from Paleolithic to Neolithic (hereafter, the PNT). In this, the first of two papers, we summarize the Chinese Neolithic using a core suite of distinctive traits, such as ceramic vessels, polished stone tools, sedentary settlements, and domesticated plant and animal species. Since these traits did not appear simultaneously, there is some dispute in defining some of them as fully Neolithic. Nevertheless, taken as a group they are distinctive from preceding and later cultural adaptations and provide an archaeologically defensible early Neolithic cultural stage that begins at ca. 8,500 uncal BP. Our subsequent paper (Chen and Yu 2017) builds on this framework by bringing newly available data to bear on the more ambiguous PNT. The second paper examines the formational process of primordial agriculture in North China and the Yangtze Valley by addressing evolutionarily significant relationships between humans and environments. From this basis we will present a comprehensive model and archaeological implications for the origins of agriculture in China. Both papers feature the contributions of Chinese researchers, with some results presented in English for the first time.

THE “NEOLITHIC REVOLUTION” VIEWED FROM THE EARLIEST NEOLITHIC

Almost 100 years of archaeological fieldwork have generated a broad spatial and temporal framework for the Neolithic, especially in North China and the Yangtze Valley (Figure 1). Although new and sometimes major discoveries continue to surface, these data mostly supplement and refine the existing scheme rather than change it. The Neolithic culture stage has been partitioned repeatedly; currently, a basic division of early, middle, and late stages is largely accepted, although there is still argument about the starting time for each (IA-CASS 2010; Su 1999; Yan 1987; Zhao 2008). According to this scheme, the early Neolithic (ca. 8,500–7,000 uncal BP) shows a systematic representation of features that include the earliest agriculture. During the middle Neolithic, prehistoric agriculture took clear shape and began to diffuse culturally and geographically (e.g., Li et al. 2011; Nakamura 2010; Shu et al. 2010; Yu et al. 2012). With the growing complexity,

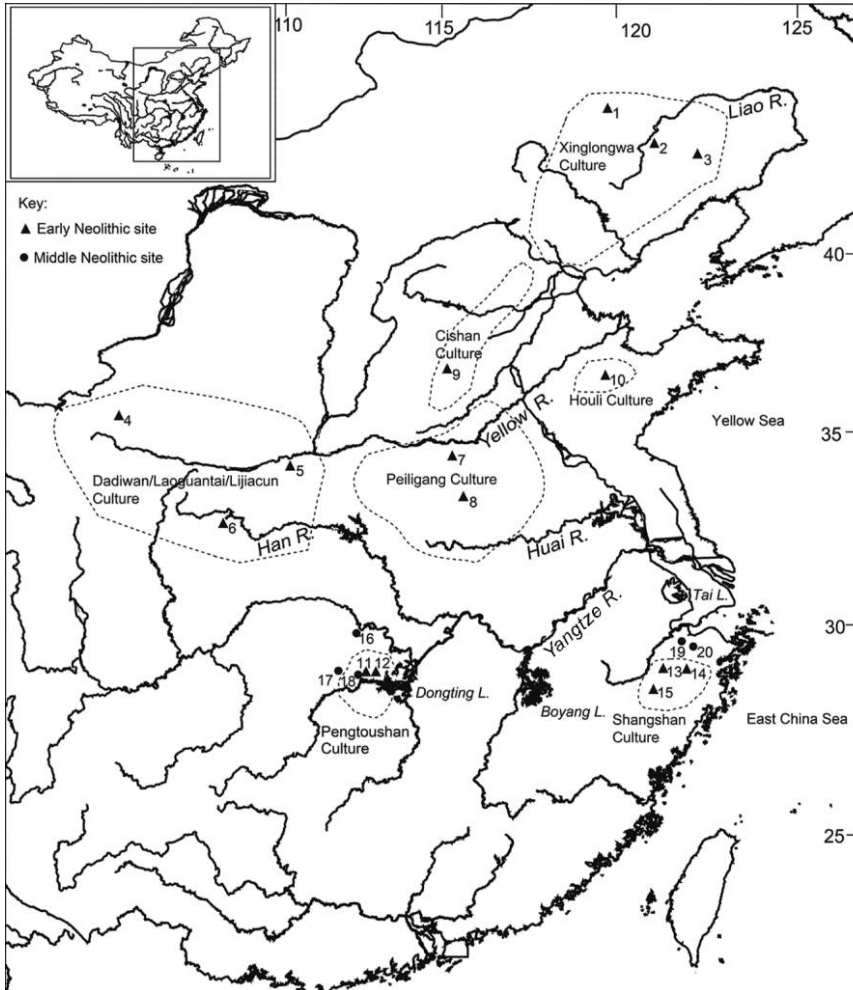


Figure 1. Major early Neolithic sites and cultural regions. Xinglongwa culture (1, Baiyinchanghan; 2, Xinglongwa; 3, Chahai); Dadiwan/Laoguantai/Lijiacun culture (4, Dadiwan; 5, Laoguantai; 6, Lijiacun); Peiligang culture (7, Peiligang; 8, Jiahu); 9, Cishan culture type site; 10, Houli culture type site; Pengtoushan culture (11, Pengtoushan; 12, Bashidang); Shangshan culture (13, Shangshan; 14, Xiaohuangshan; 15, Hehuashan); 16, Chengbeixi; 17, Zaoshi; 18, Hujiauwuchang; 19, Kuahuqiao; 20, Hemudu. The ranges of archaeological cultures marked by dashed lines are based on the current discoveries (IA-CASS 2010).

diversity, and competition of the late Neolithic, the stage became set for the next major shift: formation of the earliest state-level societies.

The early Neolithic of China is characterized by an avalanche of new features that spread rapidly. Sedentized settlements appeared on an unprecedented scale, organized

in a villagelike manner that exhibits house rows, numerous storage pits, graveyards, and surrounding ditches (used for defense, drainage, or both). The numbers of sites, depth of cultural deposits, and diversity of artifact assemblages all grew rapidly. The pace and scope of the early Neolithic raise major questions about evolutionary process: What were the relationships between early Neolithic societies and ancestral foraging groups? Which key factors would condition for the appearance of Neolithic forms of organization, as opposed to absence or delay? To establish a basis for these questions, we turn to the spatial-temporal framework that has been developed through numerous studies by leading Chinese archaeologists (Ren 1994; Su 1999; Yan 1987; Zhao 2008). The regions of North China and the Yangtze Valley are particularly well-studied. Table 1 summarizes seven early Neolithic cultural regions in these two biogeographic zones, along with dates.

EARLY NEOLITHIC IN NORTH CHINA

Settlement Patterns and Land Use

The abundant and broadly distributed archaeological record of North China signals an explosion in population, cultural adaptations, and evidence for complex social relationships in the early Neolithic. By this time, cultures apparently already had well-developed regional diagnostic styles. From north to south, Xinglongwa culture traits are manifest in the Liaoxi region, Cishan culture on the northern floodplain of North China, Peiligang culture in the middle, and a regional variant of Peiligang termed the Jiahu in the southern region (Figure 2). Further south, Xiaoshankou culture (Phase I) is found in the Huai River valley. From east to west are the Houli culture in Shandong Province, Peiligang culture in the middle, and Laoguantai culture in the west, probably including the variant of Lijiacun. Farther west, the Dadiwan culture in the Longdong region includes a regional variant, the lower Beishouling.

The geography of early Neolithic sites in North China is distinctive: whereas sites of the Late Upper Paleolithic had been located predominantly on the hilly flanks or margins of drainage basins, early Neolithic settlement focused on the ecotone between the mountains and floodplains (with middle and late Neolithic sites expanding onto fluvial plains and wetlands). This geographical pattern has been noted by several other researchers (e.g., Liu et al. 2009; Wagner et al. 2013; Yu et al. 2012). For example, the Houli culture sites found thus far are all located in the foothill zone of the Tai and Lu mountains; in the case of the Peiligang culture, more than 100 known sites are widely distributed in the transitional zone from the Taihang and Dabie mountains to the floodplains of North China (IA-CASS 2010; Zheng 2005). In the mountains of Liaoxi, Xinglongwa culture sites are generally located at higher elevations than later sites of the middle Neolithic Hongshan culture, which are down on the floodplain (Xia et al. 2000). A study in the Yiluo Valley (in Henan Province) draws a similar conclusion with a new quantitative land-use model (Yu et al. 2012).

Interestingly, the scant presence of early Neolithic sites on the Loess Plateau in Shanxi Province in east-central China (Zhang 2002) indicates that the first farmers in North

Table 1. The early Neolithic cultures and their dates in North China and the Yangtze Valley

Cultural region	Archaeological culture	Uncal BP	Cal BC	Date range (BC)
Zhongyuan	Cishan	7,355 ± 100 (ZK0439)	6,100 – 5,960	ca. 6,100 – 5,600
		-7,060 ± 100 (BK78029)	-5,820 – 5,630	
Guanzhong	Peiligang	7,455 ± 110 (ZK0754)	6,230 – 5,589	ca. 6,200 – 5,500
		-6,855 ± 110 (ZK0747)	-5,640 – 5,480	
Shandong	Houli	7,150 ± 90 (BK80025)	5,960 – 5,720	ca. 6,000 – 5,000
		-6,465 ± 120 (ZK0159)	-5,340 – 5,083	
Longdong	Dadiwan	7,675 ± 90 (BK91037)	6,384 – 6,179	ca. 6,300 – 5,600
		-6,966 ± 70 (BK91036)	-5,680 – 5,582	
Liaoxi	Xinglongwa ^b	6,725 ± 200 (ZK0632)	5,630 – 5,243	ca. 5,600 – 4,100
		-5,645 ± 140 (ZK0640)	-4,470 – 4,167	
		7,150 ± 90 (ZK2138)	5,960 – 5,720	ca. 5,900 – 5,000
		-6,245 ± 90 (ZK1267)	-5,203 – 4,864	
		6,925 ± 95 (BK80025)	5,712 – 5,530	ca. 6,000 – 5,300
		-5,660 ± 170 (ZK1389)	-4,510 – 4,159	

Lianghu	Pengtoushan	8,200 ± 200 (BK87050)	7,195 – 6548	ca. 7,200 ~ 6,200
		-7,745 ± 90 (BK89017)	-6,424 – 6219	
	Lower Zaoshi ^a	7,210 ± 110 (BK87046)	5,961 – 5,713	ca. 5,960 ~ 5,050
		-6,405 ± 90 (OXA2218)	-5,256 – 5,050	
	Chengbeixi	6,970 ± 127 (ZK2645)	5,740 – 5,540	ca. 5,740 ~ 5,400
		-6,800 ± 80 (BK84028)	-5,619 – 5,477	
Lower Yangtze	Shangshan ^c	9,610 ± 160 (BA02236)	9,220 – 8790	ca. 8,000 ~ 6,500
		-8,180 ± 35 (BA06137)	-7,190 – 7,070	
	Kuahuoqiao ^d	7,595 ± 242 (HL91002)	6,700 – 6,050	ca. 6,000 ~ 5,400
		-6,180 ± 90 (BK200170)	-5,480 – 5,230	

^a partly in the date range of the early Neolithic

^b located at the intersection of North China, Northeast China, and the Mongolian Plateau

^c The radiocarbon dates fall within the PNT, but cultural features resemble the early Neolithic, as discussed in the text.

BK/BA: Department of Archaeology/School of Archaeology and Museology, Peking University

ZK: Institute of Archaeology, Chinese Academy of Social Sciences

OXA: Department of Archaeology, Oxford University

HL: The Second Institute of National Bureau of Oceanography

BP: from AD 1950.

Half-life: Shangshan and Kuahuoqiao, 5,568 years; the rest, 5,730 years.

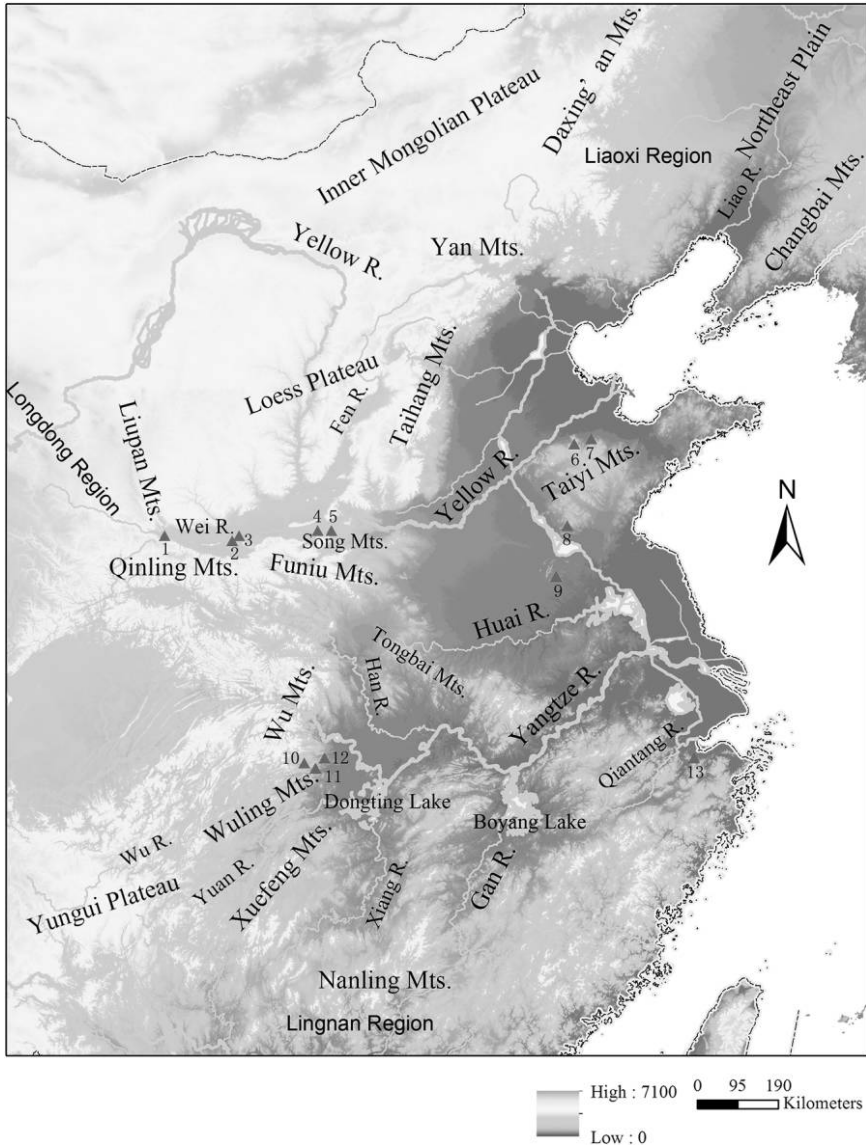


Figure 2. The geography of eastern China and additional sites mentioned in the text:
 1. Beishouling; 2. Jiangzai; 3. Baijia; 4. Yangshao; 5. Xipo; 6. Xiaojingshan; 7. Yuezhuang;
 8. Beixin; 9. Xiaoshankou; 10. Yan'er Cave; 11. Shiligang; 12. Chengtoushan; 13. Tianluoshan.

China likely did not prefer the higher, arid plateau. Low numbers of early Neolithic sites are not the result of inadequate fieldwork since a rich assemblage of Paleolithic sites and middle to late Neolithic remains have been found in Shanxi Province. Likewise, taphonomic conditions in loess environments are not a likely explanation for the lack of sites

as both eastern Gansu and Guanzhong on the Loess Plateau have abundant early Neolithic materials at Dadiwan (Phase I), Lijiacun, Baijia, and other early Neolithic cultures or variants. A more likely explanation is that agriculture was either not necessary or not adaptable for the Shanxi region in the central part of the Loess Plateau. The high frequency of Late Upper Paleolithic (LUP) microblade assemblages in Shanxi, such as Xiaochuan, Xueguan, Dingcun, and Shizitan, indicate that the onset of agriculture was delayed here relative to surrounding areas (excluding the northwest) because habitat and resource conditions on the Loess Plateau actually favored the persistence of foraging. The case of Shanxi appears to refute arguments that the earliest agriculture of North China should appear in more arid and marginal zones (Bettinger et al. 2007; Madson and Elston 2007). The most likely environmental types for agricultural experimentation are considered in detail in Chen and Yu (2017).

As early as the 1980s, Shi (1986) noted that the geographical pattern of pre-Yangshao cultural materials permits classification of sites into four types organized by North China ecosystems. The first category of sites is located on higher slopes of basin margins, up from river drainages, and frequently contains only one cultural layer. The second type is located in foothills on the gentle slope transitions to the floodplain, with closer access to drainages. The third consists of terrace sites with specific preference for the triangular zones formed by river confluences. The final category is riverside sites on the floodplain, similar to modern Chinese villages. Shi also notes that basin margin and footslope sites are generally earlier than the river confluence and floodplain categories. This pattern of site distribution implies that settlements during the early Neolithic were increasingly placed closer to the floodplains to access flatter, more fertile habitats suited to irrigation and transportation of harvests.

Dense, clay-rich floodplain soils and relatively lush wild vegetation would have required clearing and plowing; thus, farming on the floodplain would have been more labor intensive than on the loess soils of the footslopes. The pattern of stone tool assemblages illustrates a clear tendency for this in the case of the Liao Valley, where people did not begin to utilize the heavy soil of the floodplain until the Bronze Age (Chen et al. 2013, 2014). We expect that, concurrent with movement downslope to intensify agricultural production, growing population density and sedentized settlement created a ready labor force for field preparation and maintenance.

Using Shi's (1986) schematic, we can deduce a sequence of Chinese agricultural development using site locations. If most Neolithic sites in a region are located near river confluences or on the floodplain, the level of commitment to agriculture was likely high. Overall, the earliest farming groups settled in lower-elevation habitats that their foraging ancestors had only used seasonally; thus the move to committed floodplain agriculture represents a new lifeway and mode of production. Conversely, if Neolithic sites are located on the footslopes in a region it is reasonable to infer an earlier or less committed stage of agricultural development. Thus, while agriculture ultimately transformed the relationship between humans and environment, we argue that this change was *contingent and reversible* in certain situations.

Subsistence and Technology

The onset of agriculture changed humans physically, as is evident in genetic markers, bone morphology, and biochemical composition (Pinhasi and Stock 2011). Paleodietary investigations in China have included analysis of stable isotopes and trace elements in human and animal bones. Early research on stable isotope ^{13}C in human bone (Cai and Qiu 1984) suggests that diet composition during the Yangshao culture stage (ca. 5,000–3,000 cal BC) was about 48% C4 plants, such as foxtail and broomcorn millets (*Setaria italica* and *Panicum miliaceum*, respectively), grasses, sedges, and other seedy annuals. The proportion of C4 plants rises to 67% in the Taosi culture stage (ca. 3,000–2,000 cal BC). If we experimentally project a 1% increase per century in dependence on C4 plants, we can retrodict C4 diet contributions as low as 30% at 7,000 cal BC. This estimate may not be too far off the mark if we consider that agricultural development was likely gradual from the early to middle Neolithic. Recent paleodietary analyses of human bones from the Xiaojingshan site and animal bones from the Yuezhuang site (both representative of the early Neolithic Houli culture) suggest a C4 plant proportion of only 25% (Hu et al. 2008)—not far from our predicted values. This assumes that C4 plants per se are a reasonable proxy for domesticated seed crop species.

Isotope analysis of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of human and animal bone from the Dadiwan site suggests two stages of plant domestication. The first stage, at about 5,900–5,200 cal BC, is a less-intensified form of agriculture in which farmers emphasized broomcorn millet, consuming some and feeding the rest to domesticated dogs. In the second and more intensified stage around 3,900 cal BC, farmers diversified by adding foxtail millet and raising pigs as well as dogs (Barton et al. 2009). The earlier stage may reflect dryland farming, with subsequent intensified techniques possibly adapted from the Yangshao culture to the east. Isotope analyses from the Xinglongwa (Zhang 2003), Baijia (Atahan et al. 2011), and Jiahu (Hu et al. 2007) sites indicate a mixed economy of wild-plant-gathering, hunting, and fishing as well as farming. Later in this region, isotope analyses of human and animal bones from the Jiangzai and Xipo sites show that foxtail millet became the staple crop and was also used as fodder for pigs, dogs, and chickens (Pechenkina et al. 2005).

Plant microfossils (e.g., phytoliths) and macrofossils (e.g., seeds) have also been used to explore processes of domestication. Lu et al. (2009) reported their discovery of husk phytoliths and biomolecular components identifiable solely as broomcorn millet, dated to ca. 8,300–6,700 cal BC from newly excavated storage pits at the Cishan site, possibly the earliest known domesticated millet in China. Plant remains have been used to construct a regional sequence of domestication. Charred plant remains from 26 sites in the Yiuo Valley, along with 10 AMS dates, show that foxtail millet was predominant in the early Neolithic, broomcorn millet less important, and rice appeared by 3,000 cal BC (Lee et al. 2007). However, a new discovery suggests that rice had been cultivated in Shandong from the early Neolithic (Jin et al. 2014). Rice cultivation was established in the Jiahu culture of the Huai Valley in the early seventh millennium BC as a result of influence or migration from the Yangtze Valley (Zhang and Huang 2013). To date,

there is little evidence of root crops in the early Neolithic, although vegeculture (low-level, root-based cultivation) was likely an important form of food production in southern and eastern China. Evidence for vegeculture has been better studied for the Paleolithic to Neolithic transition and is discussed in Chen and Yu (2017).

With regard to animal husbandry, the claim of pig domestication by early Neolithic times is made based on morphometric analyses of molars from three sites, including Jiahu (Cucchi et al. 2011). At the Cishan site, domesticated pig and dog remains have also been found (Zhou 1981), both characterizing early Neolithic animal domestication. Pigs seem to be part of ritual in Xinglongwa, where two pigs (one male and one female) were found in a burial with human skeletons (Neimenggu 1985, 1997). Recent studies indicate that chicken domestication occurred later, even as late as the Bronze Age (Eda et al. 2016; Peters et al. 2016), although DNA analysis argues for an early Holocene domestication in North China (Xiang et al. 2014). At Baijia, isotopic analysis of bovid samples, probably water buffalo (*Bubalus* spp.), indicate some millet consumption by those animals, but no morphological evidence of domestication yet (Atahan et al. 2011). Interestingly, even in the middle Neolithic, the proportion of C4 plants such as millets in animal diets appears to have been greater than in the human diet (Pechenkina et al. 2005). Compared with domesticated animal inventories of West Asia, it is evident that domesticated animals in early Neolithic China were of less importance to subsistence.

Site Organization and Structure

Well-preserved archaeological sites such as Cishan (Hebei 1981) are an important source of original evidence. Cishan's three excavated areas total 2,579 m². Storage pits yielded ¹⁴C dates of ca. 7355–7235 cal BP in the 1981 report, and ca. 10,300 and 8,700 cal BP in later excavations (Lu et al. 2009). According to the archaeological report, 80 storage pits contained seed remains and plant ash deposits with depths of 0.3 to 2 m (with 10 pits deeper than 2 m). The seeds, mostly foxtail millet, were associated with macrobotanical remains of walnut, hazelnut, hackberry (*Celtis bungeana* Blume), and other species.

Cishan also yielded a large number of stone tools, with the proportion of polished stone tools relative to chipped stone increasing over time (direct radiocarbon dates are not available for these layers, but we can presume lower dates of no earlier than 10,300 cal BP and upper of c. 7,200 cal BP based on pit feature dates). When tools are displayed by functional categories (Table 2), an interesting distinction emerges: polished tools, such as stone spades used for planting or woodworking, show minor differences over time. However, tools for harvesting and seed-processing tell a different story. The lower layer contains no sickles, but the upper contains six sickles. Only four broken pestles and mortars were found in the lower layer, compared with 52 and 50 pieces, respectively, in the upper layer. These differences reflect a major increase in harvesting and grain-processing activities during the early Neolithic. A 2 × 3 chi-squared analysis (layers by counts of artifacts in each production mode group) suggests that the differences between the two layers are significant ($\chi^2 = 8.561$, $df = 2$, $p = 0.01383574$).

Table 2. Comparison of stone tools from two layers of the Cishan site (Hebei 1981)

Functional class	Upper Layer		Lower Layer	
	<i>N</i>	%	<i>N</i>	%
Spades	58	8.5	21	11.5
Axes	330	48.5	103	56.6
Knives	3	0.4	4	2.2
Whetstones	24	3.5	0	0.0
Scrapers	0	0.0	2	1.1
Chisels	20	2.9	8	4.4
Adzes	10	1.5	2	1.1
Vessel lids	5	0.7	0	0.0
Balls	111	16.3	27	14.8
Sickles	6	0.9	0	0.0
Hammers	10	1.5	3	1.6
Mortars	52	7.6	4	2.2
Pestles	50	7.3	4	2.2
Grinding Stones	2	0.3	0	0.0
Pellets	0	0.0	4	2.2
Total	681	100	182	100

Changing needs for stone tool technology are also evident at the Cishan site. In the lower layer, chipped stone tools represent about one third of the assemblage, with polished and mixed technologies making up the rest. In the upper layer, this shifts to one fifth chipped stone with the remainder being polished plus mixed technology. The advantages of polished stone tools are longer use-life and resistance to breakage, and the disadvantages are weight and manufacturing effort. This indicates decreasing mobility for forager-farmers. Polishing the cutting edges of chipped stone tools decreases sharpness but increases durability of the edge by adding resistance to fracture. Overall, the increase in polished stone reflects more planing, chopping, crushing, and grinding functions relative to slicing, scraping, and chopping for chipped stone tools. This implies a shift from animal processing to woodworking and plant food processing.

An interesting but unexplored aspect of the Cishan site is the process of abandonment. Why are food and artifact remains unusually abundant at the site? Forty-five kits of intact implements (pestles, mortars, “yu” artifacts similar to flat-bottomed jars, and accompanying stands) were found in storage pits. These artifacts are apparently *de facto* refuse (*sensu* Schiffer 1987)—in other words, probably placed intentionally. This could mean that ancient residents of Cishan planned to return. The presence of intact food storage pits further supports this argument, as we would not expect agriculturists to abandon stored foods permanently. Only two of the pits at Cishan have been iden-

tified as house pits. The Jiahu site is similar; only a few pits are recognizable as houses (Henan 1999). This suggests semisedentism in the early Neolithic, in which people periodically left villages to forage for seasonal wild resources.

Many early Neolithic houses appear to be temporary surface structures rather than semisubterranean houses, and the intact pottery vessels and stone implements frequently found in early Neolithic sites are rare in later Neolithic sites. This pattern could also reflect that later Neolithic sites were abandoned in a slow and planned manner or were revisited to retrieve food, tools, or architectural materials (*sensu* Tomka et al. 1993). In contrast, early Neolithic sites were occupied sporadically, with a cycle of rapid abandonment and reoccupation which indicates that these early agriculturalists retained their mobility options. This abandonment pattern with abundant *de facto* refuse can also be seen in early Neolithic sites of the Liao Valley, such as Baiyinchanghan (Neimenggu 2004), Chahai (Liaoning 2012), and Xinglongwa (Neimenggu 1985, 1997). In the Middle East, a similar pattern of seasonal abandonment and reoccupation of semisedentary sites has been argued for the Natufian period late in the Epipaleolithic (Boyd 2006). We may never know exactly why Cishan was abandoned rather than re-occupied, but this early Neolithic pattern of North China offers a view of distinctive settlement patterns and a point of contrast with year-round sedentism in later periods.

THE EARLY NEOLITHIC MIDDLE AND LOWER YANGTZE VALLEY

Settlement Patterns and Land Use

The early Neolithic of the middle and lower Yangtze Valley is more complex than in North China, and the signals are more ambiguous. Two cultural regions—the middle and lower Yangtze Valley—have been defined by the areas around Dongting Lake and Tai Lake. They are linked by the intermediary region around Boyang Lake (Yan 2000) and are believed to have experienced different formation processes of the agricultural landscape (Makibayashi 2014). The area around Boyang Lake is sometimes combined with the Dongting Lake area and is termed the Two-Lake region, forming an axis of Neolithic occupation of Southeast China that extends to the Zhujiang Delta (Su 1999). In recent years, the early Neolithic spatial-temporal framework has been clarified by the discovery of Shangshan culture sites in the lower Yangtze Valley (Zhejiang 2007). Thus we assert that there are at least two secondary Neolithic centers in the middle and lower Yangtze Valley: the Dongting Lake region and the Tai Lake region, both forming regional centers of subsequent complex societies. The Boyang Lake region is possibly a transitional zone between the two regions.

Early Neolithic remains are abundant and diverse in the Dongting Lake region, including the Pengtoushan (ca. 7,000–5,600 cal BC), lower Zaoshi (ca. 5,500–5,000 cal BC), and Chengbeixi (ca. 6,500–5,000 cal BC) cultures. The Pengtoushan culture is represented by two major sites, Pengtoushan and Bashidang (Hunan 1990a, 2006), where rich cultural remains include a large sample of rice grains. Twenty-nine radiocarbon dates for Pengtoushan come from three laboratories, including the Research Labora-

tory for Archaeology and the History of Art at Oxford University (Chen and Hedges 1994). Thirteen are conventional dates, 14 are AMS dates, and two are from the Mossbauer method. Researchers noted that coarse matrix carbon in the pottery temper produces artificially old dates; thus most of the accepted dates are from rice grain and straw. Given the multiple dating methods used, the absolute date range of Pengtoushan culture is relatively reliable.

Pengtoushan culture sites are located in the transitional zone between the Wuling Mountains and the Dongting Lake basin (Hunan 2006). Most of these sites have been found on the northern bank of the Lishui River (in Hunan Province), possibly due to erosion of the southern bank (Gu 1991). Alternatively, early Neolithic people may have chosen to live on the northern bank to avoid impacts from seasonal floods, which are greater on the southern bank. During the subsequent lower Zaoshi culture stage, sites extend toward the margin of Dongting Lake. Dongting Lake is a recent feature, formed no earlier than ca. 2,500 uncal BP (Fang 1991). Prior to this, the Dongting landscape was seasonally inundated floodplains dotted by small ponds. Pollen analysis at the Pengtoushan site indicates an assemblage dominated by fir as well as spores of ferns that prefer hygric habitats. The scarcity of aquatic plants reflects a forest-grassland landscape mainly with warm coniferous species (Hunan 1990b). During the middle Neolithic, Daxi culture sites expanded throughout the Dongting floodplain and exhibit continuously decreasing evidence of paddy field weed species (Nasu et al. 2012).

Throughout the Neolithic sequence, the middle to lower Yangtze Valley shows a clear preference for settlement in the floodplain. In contrast, the Late Upper Paleolithic sites of Yan'er cave, Shiligang, and Zhuma in the Dongting Lake region are located in the wide Lishui River valley and adjacent hilly flanks. This was an optimal habitat type for Paleolithic hunter-gatherers, with suitable gravels for manufacturing choppers and chopping tools, clean water, fuel, and game. In general these resources were not as easy to procure in the upper valley, where the landform is narrow and rugged, or in the lower valley, where lithic raw materials are scarce or too small to produce choppers. In comparison, the optimal habitat for Yangtze agriculturalists is the floodplain, similar to the situation in North China. Therefore, although the earliest agriculture began in optimal habitats for hunter-gatherers, the only place it could become well-established was in the floodplain: the optimal zone for agriculturalists.

Subsistence and Technology

Rice has different ecological requirements from millet in terms of water and growing season, but in the Yangtze Valley rice is comparable to the millet of North China as a major Neolithic hallmark. Rice remains constitute an important discovery in Pengtoushan culture sites (c. 7,500–6,100 cal BC), although questions about the scale of cultivation and its economic significance remain. Rice remains are typically found in pottery sherds and burnt clay, but not in stratified contexts. The rice husks in pottery sherds were probably added intentionally as temper, leaving visible imprints of rice stems and leaves on the burnt clay.

The Bashidang site has yielded more than 15,000 rice grains (listed as 9,800 in the site report), numerous animal bones, bone tools, and many other organic artifacts (Hunan 2006). This suggests that early Neolithic peoples lived close to water, and their subsistence included hunting, fishing, and aquatic plants such as lotus, water chestnut, and gorgon fruit (*Euryale ferox*) in addition to rice cultivation. Aquatic food plants are easily harvested, high-yielding, and storable: lotus roots remain edible for eleven months, and lotus seeds can be dried, ground into flour, and stored for several months. Thus, rice planting and collecting of wild aquatic plants could have been equally important during the Pengtoushan culture (Zhang et al. 2003). If Pengtoushan societies had the same degree of dependence on seed crop agriculture as, say, the Houli culture of North China, we would expect the proportion of rice in the diet to be 25% or less. Therefore the lack of extensive rice remains in the Pengtoushan site is not surprising.

Only two faunal categories are represented at Pengtoushan: bovid (five tooth fragments) and avifauna (two bone fragments). Faunal remains are more abundant at the Bashidang site, where more than 1,000 specimens of mammal, bird, fish, and other aquatic animals have been identified. Mammals include buffalo (19 specimens) and pig (three specimens), as well as deer and black rat. All specimens are fragmented (Hunan 2006). There is no evidence that buffalo or pig were domesticated. The utilization of small animals such as birds and aquatic animals indicates subsistence intensification associated with growing sedentism, as these animals can be hunted in the vicinity of the settlement.

In the subsequent lower Zaoshi culture, evidence for hunting persists along with an emphasis on aquatic resources. At the Zaoshi site, abundant faunal remains consist mainly of low-utility elements (teeth and vertebrae) representing a diverse faunal assemblage (spotted deer, barking deer, buffalo, pig, goat, porcupine, and turtle [Hunan 1986]). Although teeth of deer, pig, and buffalo predominate, it is still not known if the latter two were domesticated. At the Hujiauwuchang site of the Zaoshi culture (Hunan 1993), excavators note that animal bones are richer in the lower layers, and a high degree of fragmentation could reflect processing to extract grease. The excavators infer that pigs, buffalo, and even goats could have been intentionally bred based on the abundance of faunal remains. However, unambiguous evidence of animal domestication does not appear until the middle Neolithic. Thus, even if animal domestication had begun during the Pengtoushan culture, the contribution to subsistence was probably minimal.

Early Neolithic stone tool assemblages also reflect adaptive changes in the Yangtze Valley. The lithic sample from the Pengtoushan site (Figure 3) consists of stone tools and associated debitage ($N=1,406$) and ornaments ($N=62$). About one quarter of the lithic specimens are chert, usually 2–5 cm long, and include scrapers, awls, and burins. Polished stone tools—axes (11), adzes (7), spades (2), a chisel (1), and grinding stones (4)—make up only about 2% of the stone tool assemblage. The remainder ($N=81$) consists of choppers and chopping tools made from gravels. The ornaments

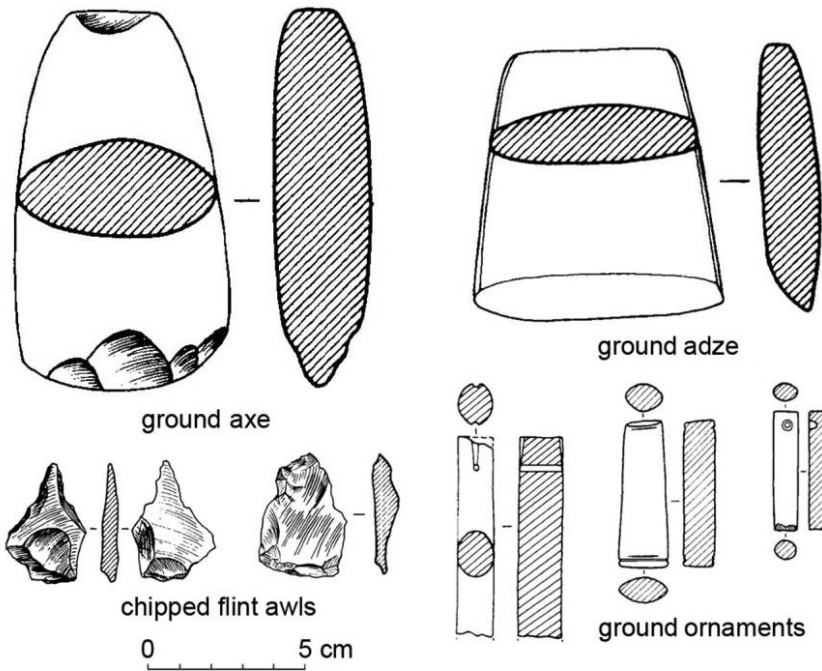


Figure 3. Stone tools from the Pengtoushan site (after Hunan 2006).

from Pengtoushan include 47 finished specimens that are delicately polished. These characteristics are also seen in the assemblage from the Bashidang site, where 2,070 lithic artifacts and 167 finely polished ornaments have been found. The proportion of chert artifacts at Bashidang is 23%, and polished stone tools still represent less than 2%. The similar lithic assemblages from Pengtoushan and Bashidang suggest that polished woodworking tools, such as axes, adzes, and chisels, are associated with the wood components found in situ.

Chipped stone tools constitute 89.8% of the lower (earlier) Zaoshi culture assemblage at the Hujiauwuchang site; however, polished stone tools increase significantly to about 30% of the assemblage in the later stages. This corresponds with increasing sedentism through time. Evidence of mortise and tenon construction and planks worked by polished tools further suggest that these societies were investing increasing amounts of labor in the construction of sedentary facilities. Polishing techniques used for heavy-duty stone tools were adapted for use in making ritual or personal ornamentation, suggesting growth of craft specialization and expertise.

Site Organization and Structure

Four types of early Neolithic structures were found at the Bashidang site: semisubterranean, surface, railing-frame, and hathpace (containing a landing at the junction of

two flights of stairs that make a 180° turn) (Hunan 1996). The soil under the hathpace structure was sterile and lacked inclusions, and it seems to have been intentionally transported from nearby. The huge investment of labor at Bashidang is best observed in the construction of a ditch and wall that enclose an area of about 16,500 m². The wall is still 0.5 to 1 m. in height today, with a base about 6 m wide. This ditch was dredged at least three times during its use-life and probably functioned for flood control and drainage rather than as a defense facility.

Compared with late Neolithic sites such as Chengtoushan, Bashidang is much smaller and simpler with no evident plan. Since the amount of labor invested in the ditch and wall construction would not be economical if the site was used only once for a few months, we can conclude that a sedentary lifeway existed in the Yangtze Valley as early as the Pengtoushan culture stage.

THE SHANGSHAN CULTURE: A CASE STUDY IN PRE-NEOLITHIC VERSUS EARLY NEOLITHIC

As mentioned above, the early Neolithic as a distinctive “archaeological culture” is characterized by the emergence of traits defined by assemblages of artifacts and other features, within a bounded spatial and temporal range. By this standard, the Shangshan culture of the lower Yangtze Valley is barely recognizable as Neolithic, with only three sites—Xiaohuangshan (Zhang et al. 2005), Shangshan (Zhejiang 2007), and the newly excavated Hehuashan—discovered to date. The Shangshan culture has been dated to as early as 9,600 cal BC, quite early compared with the PNT sites of Yuchanyan and Xianrendong. Yet Shangshan looks much more sophisticated, especially in terms of pottery production. Below, we evaluate the status of Shangshan as an anomalous transitional site or a typical early Neolithic site in order to highlight diagnostic characteristics of both culture stages.

Disagreement over the Shangshan time range complicates this exercise (Huang and Jiang 2006). The radiocarbon anomalies of the Yangtze Delta are attributed to the intensive erosion and redeposition of organic materials at the time (Long et al. 2016). However, this environmental process mostly influenced the catchment of the southern Yangtze Delta. It is still unclear if these radiocarbon anomalies occurred in the Shangshan site. A recent Bayesian analysis (Long and Taylor 2015) considers spans (start and end) of cultural phases and set the age range of Shangshan at ca. 8,800–6,600 cal BC. Therefore, the Shangshan culture dates overlap with those of early Pengtoushan. Shangshan archaeobotanical remains (carbonized rice grains, phytoliths, and rice husks used as ceramic temper) indicate that rice was certainly cultivated in or near settlements, but the level of domestication is uncertain (Wu et al. 2014; Zhao 2010, 2011). In fact, the uncertainty in rice morphology is not resolved until 5,000 cal BC (the Hemudu period; Wu et al. 2014). Remains of wild plant and animal foods at Shangshan are common enough that the subsistence pattern is interpreted as “low-level” agriculture, still mixed substantially with foraging, which also characterizes the subsistence of cultures along the southeast coast of China (Jiao 2007, 2013).

Shangshan material culture is consistent with the early Neolithic culture traits of Pengtoushan. The Shangshan ceramic assemblage is characterized by large wide-mouth pots, double-ear jars, large flat-bottom plates, and perforated round-foot plates. Most sherds contain carbon-based tempers, with frequency of sand-tempered sherds increasing over time. Sherd thickness of 20 mm is not uncommon, and firing temperature is estimated to be as low as 800° C, with an uneven degree of surface heating. Some sherds display sheetlike bedding in cross-section and embedded rice grains. Although the manufacturing technology of Shangshan pottery appears primitive, containers occur in various functional types possibly used as cooking utensils, water containers, and storage vessels. Within each functional type there are morphological variants, such as round bottom, round foot, and flat bottom. Other Shangshan ceramic features, such as necks, ears, and round feet, set them apart from the generic shapes of earlier vessels. Ceramics of PNT sites such as Xianrendong and Yuchanyan are usually characterized by round-bottom jars and pots and small numbers of sherds (Hoopes and Barnett 1995).

Shangshan culture sites are complex: the type site encompasses 20,000 m², and the Xiaohuangshan site is 50,000 m². This is markedly larger than PNT sites, which often cover only several hundred square meters. Shangshan culture sites are characterized by Neolithic features such as hearths, graves, and ditches. The type site has a house foundation or pit that measures 14 × 6 m and is oriented northwest to southeast. Three rows of postholes are apparent (Figure 4). In longitudinal section, the postholes exhibit rounded bottoms and vertical walls, with diameters ranging from 27 to 50 cm and depths of 70 to 90 cm. Some have small rocks at the base, probably used as padstones.

Based on the size of the postholes, the structure at the Shangshan site is argued to be a house with a railing frame (Sheng et al. 2006), a form now common in tropical Asian regions. Similar discoveries were also made at the contemporary Hehuashan site, as well as middle Neolithic sites such as Hemudu (Zhejiang 2003). Architecture of this size and technological style has not been found at any PNT site.

Features at the Shangshan type site include three types of pits. The first type contains complete pottery vessels that researchers consider to be results of ritual activities. The second pit type is more than 70 cm deep, usually with vertical walls and a flat bottom, and contains sherds, stone tools, bone and carbon fragments, and other debris. This type is thought to serve for storage. The third pit type (of undesignated function) is irregularly shaped, and some of them contain rich artifact assemblages.

Pits at the Xiaohuangshan site are square or circular in plan view, about 1 m in diameter or width, and have vertical walls and flat bottoms. One large pit is 1.9 m in diameter and 1 m deep, with a few regular post holes around it. This is probably a storage pit that was covered by a shed. Some storage pits have mortars and pestles at the bottom, and others even have steps carved into the wall to help people deposit and retrieve their goods. As mentioned above, early Neolithic sites frequently have well-preserved storage facilities and more de facto refuse, which suggests retention of at least some mobility by early agriculturalists. Prior to leaving on seasonal foraging trips, inhabitants could store implements and vessels that were not easily portable,

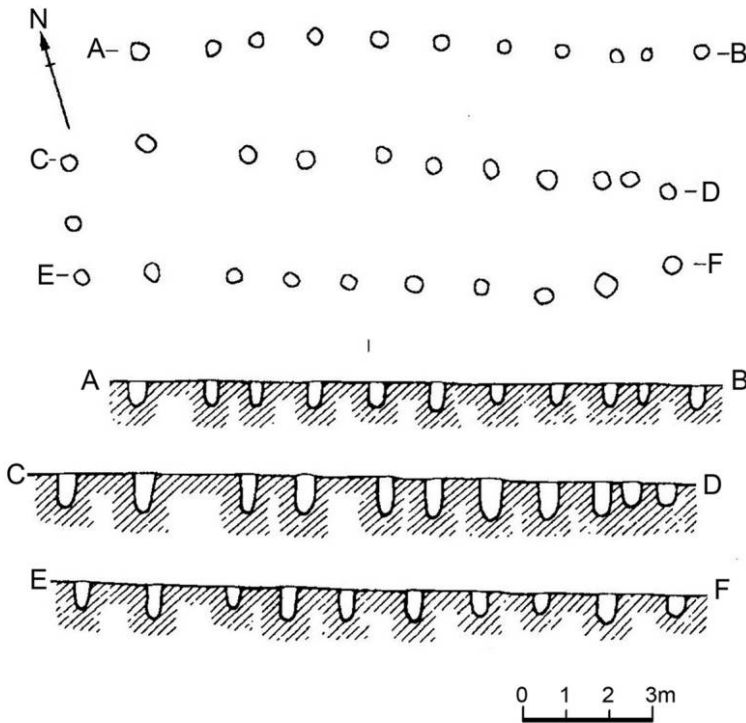


Figure 4. Plan and profile view of postholes unearthed in the Shangshan site (after Zhejiang 2007).

as well as certain foods (such as at the Cishan site). All pit types found at Shangshan and Xiaohuangshan could have been used for storage.

The Shangshan culture stone tool assemblage is simple relative to its diversified pottery. Lithics are primarily ground stone, including mortars, pestles, bolas, and perforated artifacts as well as a few finely polished adzes and chisels. The mortars are generally larger than at other early Neolithic sites. There is little retouch except on concave grinding surfaces. Pestles with multiple grinding surfaces are frequently found in fragments. Another type of grinding tool is derived from pebbles with bottoms flattened into use-wear facets. The Shangshan type site also contains numerous rounded stone bolas. Overall, the Shangshan stone toolkit is characterized by sizeable grinding and pounding tools possibly used in food processing, and some fine woodworking tools such as adzes and chisels. Cutting and scraping tools related to hunting are lacking. There are no reports of the small chert flake tools characteristic of LUP sites of the middle Yangtze Valley, and many Shangshan lithic tools are made of silt sandstone, which is not suitable for the type of cutting activities typical of choppers and chopping tools (Chen and Chen 2012). In comparison, few grinding tools were found in the stone tool assemblage at Pengtoushan, and only a few wooden pestles at Bashidang.

Food-processing tools seem to vary by region, which may indicate cultural variability in local manufacturing customs but is more likely related to the nature of the resources being processed. In general, the size and strength of food-processing tools is proportional to the hardness of objects to be processed and the scale of processing tasks. For example, grinding tools for maize processing in the American Southwest are heavier than millet processing tools such as those from the Cishan site because corn kernels are larger and harder than millet seeds. Wooden mortars and pestles, less likely to be preserved in archaeological contexts, work well for milling rice grains. Thus the heavy food-processing tools of the Shangshan culture suggest processing of large, tough seeds such as nuts, indicative of intensified foraging rather than seed-crop processing.

The late-stage early Neolithic Kuahuqiao culture (6,200–5,000 cal BC) serves as an interesting comparison with Shangshan culture sites. Kuahuqiao stone tools are mostly polished and include adzes, axes, chisels, and projectile points (Jiang 2013; Zhejiang 2004). Bone tools include spades, awls, arrow points, needles, and spoons, possibly used in farming, hunting, fishing, and household tasks. Ceramics are thinner and more uniform, showing growing sophistication in the craft of production although firing temperatures are still low (750° to 850° C, similar to those at Shangshan). Evidence for wild edible fruits at the Kuahuqiao site includes water chestnut, gorgon fruit (*Euryale* spp.), walnut, peach, plum, apricot, pinecone, and jujube (*Zizyphus* spp.). A starch grain analysis from pottery vessels recovered eight genera of plants (Yang and Jiang 2010), consistent with the above data. Notably, pits filled with acorns have been found at this site (similar to Hemudu). This tree nut has a hard kernel and is ideal for storage. Further, oak trees are adapted to the local habitat; require no sowing, fertilization, or pest control; and consumption by humans is compatible with the mobility needed by forager-horticulturalists to maintain access to other wild foods (Yu 2015). Subsistence labor is “back-loaded”: ethnographies show that acorns require extensive processing before they can be eaten by humans (hulling, grinding into flour, leaching, filtering, and precipitating; Basgall 1987; Liu et al. 2010a, 2010b). This method, which requires time, labor, and a heavy, multicomponent toolkit, is also used to process gorgon fruit and lotus root.

The large wide-mouthed pots from Shangshan culture sites (Figure 5) may have been used for acorn processing. This vessel type is not suitable for cooking, and no soot has been found on the surfaces. Some researchers have proposed they were used for stone-boiling, but no associated fire-modified rock is mentioned in the archaeological record. The most likely function of wide-mouthed Shangshan vessels is filtration and precipitation for nuts and seeds. The multiple corners along the rim could serve to drain after leaching, and the discovery of nut fruits at Shangshan supports this scenario. Starch grain analysis of sherds and grinding slabs from the Xiaohuangshan site suggests that acorns were probably cooked whole in the vessels before they were shelled or ground on the grinding slabs (Liu et al. 2010c; Yao et al. 2016).

Concurrent with consumption of nuts, dietary intake of rice significantly increased during the Shangshan culture stage (Zheng and Jiang 2007). At the waterlogged Kuahu-

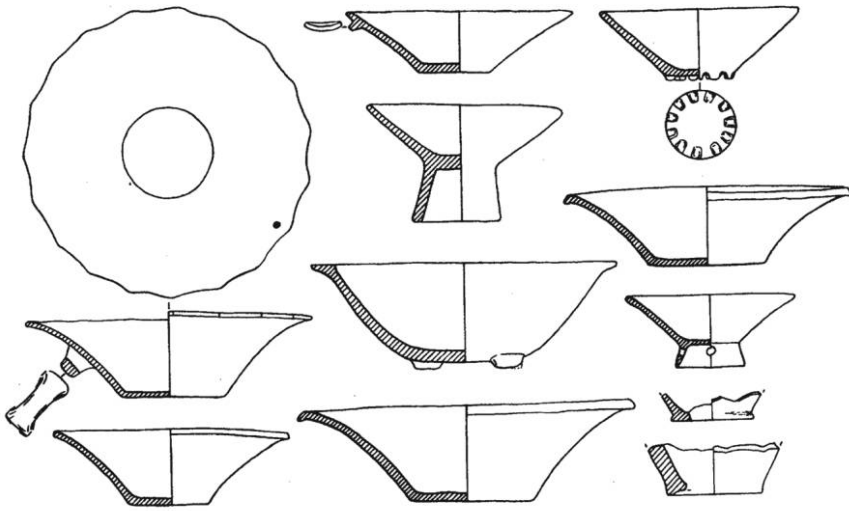


Figure 5. Wide-mouthed pots of the Shangshan culture (after Zhejiang 2007).

qiao site, good organic preservation facilitated the discovery of nearly 1,000 rice grains and a rich assemblage of farming tools, including spades of bone and wood. Food-processing tools, such as wooden pestles, and the remains of domesticated pigs are among the earliest found yet in the Yangtze Valley and Lingnan region, indicating that early seed-crop processing was accompanied by animal husbandry. Faunal remains of marine foods indicate a broad-spectrum early Neolithic diet that combined wild and cultivated foods. Kuahuqiao and other Neolithic communities may have modified lowland swamps for rice cultivation and settlement by using fire to reduce tree cover (Hu et al. 2013; Zong et al. 2007). Interestingly, other studies have a different viewpoint: up until the later Hemudu stage, no evidence of slash-and-burn agriculture was found in the well-preserved Tianluoshan site (Li et al. 2012), nor any evidence of weeding or irrigation (Zheng et al. 2009). The findings at Kuahuqiao are consistent with the Bashidang site, which represents a later stage of the Pengtoushan culture. If sedentization was already taking place, the transport costs of seed crops would have been reduced. This would render acorns, with their extensive processing requirements and smaller yields, a significantly less adaptive food.

Shangshan cannot be designated as a PNT site because of doubts regarding chronological control and the Neolithic-like site structure, features, artifacts, and subsistence; yet the same concerns regarding chronology disallow designation of Shangshan as an anomalously early Neolithic site. We therefore agree with Jiao (2013) that the Shangshan culture represents a distinctive early Neolithic phenomenon of food production alongside echoes of the preceding PNT lifeway: seasonal foraging, intensification of use of aquatic resources, bulk processing and storage, and protodomestication of

certain wild plants. Smith's "low-level food production" concept (2001) seems appropriate for the Shangshan culture.

NEOLITHIC ECHOES OF A FORAGING PAST

The archaeological evidence at Shangshan and other early Neolithic sites points to a phased or "quiet" revolution: stable isotope analyses show that domesticated plant foods constituted only about one quarter of the early Neolithic diet, and a significant proportion of lithic tool types (e.g., microblade tools at Xinglongwa and small chert flake tools at Pengtoushan) continued to reflect mobile activities. This pattern suggests that despite the apparent cascade of new material traits, foraging continued to be an important part of early Neolithic subsistence. The settlement shift in preferred habitats from river valley and basin to hilly flanks, piedmonts, and, increasingly, the floodplain was a major change in human-environment relationships, yet the onset of the Neolithic was not uniform. Archaeological evidence of subsistence and technology has revealed delays in the cold north and hedging tactics in areas where intensification based on aquatic resources was possible.

Variability in the tempo and mode of the early Neolithic onset is therefore predictable according to the ways in which evolutionary responses were conditioned (as was the preceding foraging lifeway) by local habitat and resources. All other things being equal, we expect the Neolithic transition was more gradual in habitats where diverse ecotones provided more opportunities to expand foraging diet breadth (*sensu* Winterhalder 1980). To evaluate this expectation, we turn to Lewis R. Binford's (2001) projections for hunter-gatherer behaviors based on environmental and climate characteristics (Binford and Johnson 2014). Binford characterized resource structure and subsistence for ethnographically documented foraging groups and then used weather station and key habitat data (length of the growing season, annual moisture, known vegetation types, etc.) to project subsistence and other characteristics for locations where foragers no longer reside. These projections are not the same as predictions, but they do facilitate hypothesis development for large-scale phenomena. Using detailed climate data from 36 weather stations, the percentage of expected foraging dependence on terrestrial hunting, terrestrial plant gathering, and aquatic-based subsistence was calculated by Binford for a variety of Chinese habitats (Binford and Johnson 2014). Projections were calculated for "unpacked" conditions (e.g., environment influences mobility and subsistence more than presence [or absence] of neighbors) and "packed" conditions (a threshold estimated as ca. 9.1 persons/km² [Binford 2001], in which the influence of neighbors becomes significant).

To estimate the capacity of the environment to support increasing diet breadth, we used Simpson's Diversity Index ($D = \sum [n/N]^2$), where D = diversity index and n/N = Binford's expected percentage of dependence on hunting, gathering, and fishing. Values that approach 0 represent infinite diversity and values that approach 1, zero diversity. In other words, the higher the value of D , the lower the expected subsistence diversity. Binford's projections for "unpacked" conditions show two habitat areas of

China with subsistence diversity in a range we consider conducive to agricultural innovations: low enough to encourage niche expansion through cultivation, but not so low as to disallow it. These areas include the middle Yangtze River basin around Dongting Lake, home of the Pengtoushan culture, and North China, north of the Xinglongwa culture area (Figure 6). Therefore, under less-packed foraging conditions, environments of moderate to low subsistence diversity (e.g., landlocked; moderate productivity; high seasonality) would likely encourage the development of food production.

We now turn to Binford’s projected expected subsistence emphasis for “packed” foragers, which extrapolates from ethnographically known hunter-gatherer groups under the assumption that the influence of neighbors is offsetting local environmental influences. We calculated the foraging subsistence diversity index in the same manner as above. Under packed conditions, the areas of lowest expected subsistence diversity shift: northward to cool, arid plateau/grasslands north of Shanxi Province, and eastward to the coast (Figure 7). In comparison with the prior graph, this projection suggests that foraging diet breadth expansion has reached its limits, and specialization (e.g., hunting in the north, fishing/shellfish in the east) is required to maintain subsistence based on wild resources.

The two projections indicate different phases of the same phenomenon: since early Neolithic farmers were no longer competing with foragers for wild resources, the “unpacked” foraging projection based on environmental data is a good predictor of early Neolithic settlement. Low subsistence diversity in this case means less environmental

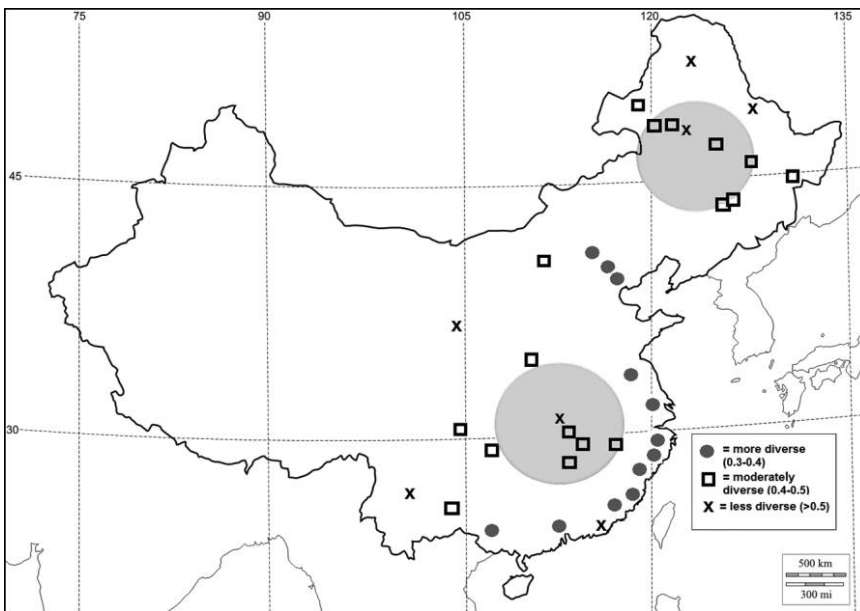


Figure 6. Projection of Binford’s expected forager subsistence diversity under “unpacked” conditions in which environmental and climate are the major predictive variables.

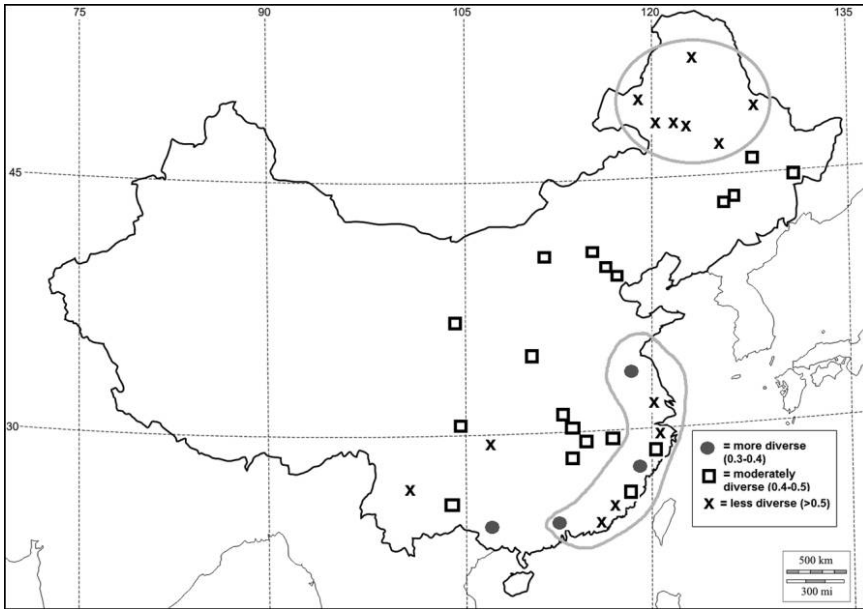


Figure 7. Projection of Binford's expected forager subsistence diversity under "packed" conditions, from ethnographically derived data in which proximity of neighbors is a major predictive variable.

potential to expand foraging diet breadth and higher incentives to sedentize and farm. However, the "packed" forager projection is a better predictor of Late Upper Paleolithic foraging specialization; here, low subsistence diversity signifies either (a) higher capacity of the environment to support aquatic-focused foraging (coast/rivers) or (b) lower capacity of the environment to support food production (north). The PNT lies between these two projections—where intensified foraging has reached its limit, and the earliest sedentism and experimentation with domesticated crops began.

CONCLUSION

Although the archaeological record of China indicates that agriculture replaced foraging variably, we can expect rapid diversification of Neolithic cultures in habitats where farming appears first: in other words, dramatic increases in site size and numbers, changes in preferred habitat types, systematically organized sites and features (e.g., structure, ditch, dam, storage pit, graveyard), proliferation of pottery types, and a numerous and diverse polished stone tool assemblage indicative of woodworking. The suite of early Neolithic culture traits is distinct from that of the Late Upper Paleolithic, yet it does not represent the full-fledged agriculture that is apparent in the middle Neolithic. We propose "low-level mixed agriculture" as an empirically valid evolutionary developmental stage that played out predictably according to properties of habitats and resource structure in North China and the middle to lower Yangtze Valley.

This provides a firm foundation for exploring cultural conditions prior to the early Neolithic: the Paleolithic to Neolithic Transition. In Chen and Yu (2017) we summarize emerging archaeological data for this complex and subtle cultural phase in China and develop hypotheses to explain key changes in relationships between people and environments that foreshadowed the Neolithic period.

NOTES

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1. Pinyin spelling is used throughout the paper except in direct quotations and references.

REFERENCES CITED

- Atahan, P., J. Dodson, X. Li, X. Zhou, S. Hu, L. Chen, F. Bertuch, and K. Grice. 2011. Early Neolithic diets at Baijia, Wei River Valley, China: Stable carbon and nitrogen isotope analysis of human and faunal remains. *Journal of Archaeological Science* 38:2811–17.
- Atahan, P., F. Itzstein-Davey, D. Taylor, J. Dodson, J. Qin, H. Zheng, and A. Brooks. 2008. Holocene-aged sedimentary records of environmental changes and early agriculture in the lower Yangtze, China. *Quaternary Sciences Reviews* 27:556–70.
- Bar-Yosef, O. 2011. Climatic fluctuations and early farming in West and East Asia. *Current Anthropology* 52(S4):175–93.
- Barton, L., S. D. Newsome, F. Chen, H. Wang, T. P. Guilderson, and R. L. Bettinger. 2009. Agricultural origins and the isotopic identity of domestication in northern China. *Proceedings of the National Academy of Sciences (USA)* 106:5523–28.
- Basgall, M. 1987. Resource intensification among hunter-gatherers: Acorn economies in prehistoric California. *Research in Economic Anthropology* 9:21–52.
- Bellwood, P. 2006. “Asian farming diasporas? Agriculture, language, and genes in China and Southeast Asia,” in *Archaeology of China*. Edited by M. T. Stark, pp. 96–118. Oxford: Blackwell.
- . 2011. The checkered prehistory of rice movement southwards as a domesticated cereal—from the Yangtze to the equator. *Rice* 4:93–103.
- Bettinger, R. L., L. Barton, and C. Morgan. 2010. The origins of food production in North China: A different kind of agricultural revolution. *Evolutionary Anthropology* 19:9–21.
- Bettinger, R. L., L. Barton, P. J. Richerson, R. Boyd, H. Wang, and W. Choi. 2007. “The transition to agriculture in northwestern China,” in *Late Quaternary climate change in Quaternary sciences*. Edited by D. B. Madsen, F. Chen, and X. Gao, pp. 83–101. Amsterdam: Elsevier.

- Binford, L. R. 2001. *Constructing frames of reference: An analytical method for archaeological theory building using ethnographic and environmental data sets*. Berkeley: University of California Press.
- Binford, L. R., and A. L. Johnson. 2014. Program for calculating environmental and hunter-gatherer frames of reference (ENVCALC2.1). Updated Java version, August 2014. <<http://ajohnson.sites.truman.edu/data-and-program/>>, accessed 22 November 2015.
- Boaretto, E., X. Wu, J. Yuan, O. Bar-Yosef, V. Chu, Y. Pan, K. Liu, D. Cohen, T. Jiao, S. Li, H. Gu, P. Goldberg, S. Weiner, and B. D. Smith. 2009. Radiocarbon dating of charcoal and bone collagen associated with early pottery at Yuchanyan Cave, Hunan Province, China. *Proceedings of the National Academy of Sciences (USA)* 106:9595–9600.
- Boyd, B. 2006. On “sedentism” in the Later Epipalaeolithic (Natufian) Levant. *World Archaeology* 38(2):164–78.
- Cai, L., and S. Qiu. 1984. Carbon 13 measurement and paleodiet breadth research (in Chinese). *Kaogu* 1984(10):945–55.
- Chang, T. T. 1976. The rice cultures. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 275:143–55.
- Chen, H., and S. Chen. 2012. An experimental study of choppers from the Yuzui Paleolithic locality 2, Yunxian, Hubei Province (in Chinese). *Acta Anthropologica Sinica* 31:1–10.
- Chen, S. 2004. *Adaptive changes of prehistoric hunter-gatherers during the Pleistocene-Holocene transition in China*. PhD dissertation, Southern Methodist University, Dallas TX.
- Chen, S., and P-L Yu. 2017. Intensified foraging and the roots of farming in China. *Journal of Anthropological Research* 73(3), doi:10.1086/692660.
- Chen, S., K. Yang, H. Chen, Z. Dong, and L. Wang. 2013. A functional study on the stone spades of Lower Xiajiadian culture from the Dashanqian site (in Chinese). *Kaogu* 2013(6):50–61.
- Chen, S., K. Yang, Z. Dong, and L. Wang. 2014. Explaining the function of stone hoes unearthed at the Dashanqian site, Kalaqin, Inner Mongolia. *Acta Anthropologica Sinica* 33:522–33.
- Chen, T., and R. E. M. Hedges. 1994. AMS radiocarbon dating of pottery from Pengtoushan and Hujiaowuchang sites and the earliest rice remains in China (in Chinese). *Wenwu* 1994(3):88–94.
- Cohen, D. J. 1998. The origins of domesticated cereals and Pleistocene-Holocene transition in East Asia. *Review of Archaeology* 19:22–30.
- . 2003. Microblades, pottery, and the nature and chronology of the Paleolithic-Neolithic transition in China. *Review of Archaeology* 24:21–36.
- . 2011. The beginnings of agriculture in China: A multiregional view. *Current Anthropology* 52:273–93.
- Crawford, G. 2006. “East Asian plant domestication,” in *Archaeology of Asia*. Edited by M. T. Stark, pp. 77–95. Oxford: Blackwell.
- . 2009. Agricultural origins in North China pushed back to the Pleistocene-Holocene boundary. *Proceedings of the National Academy of Sciences (USA)* 106:7271–72.
- Cucchi, T., A. Hulme-Geaman, J. Yuan, and K. Dobney. 2011. Early Neolithic pig domestication at Jiahu, Henan Province, China: Clues from molar shape analyses using geometric morphometric approaches. *Journal of Archaeological Science* 38:11–22.
- Eda, M., P. Lu, H. Kikuchi, Z. Li, F. Li, and J. Yuan. 2016. Reevaluation of Early Holocene chicken domestication in northern China. *Journal of Archaeological Science* 67:25–31.

- Fang, J. 1991. Influence of sea level rise on the middle and lower reaches of the Yangtze River since 12,100 BP. *Quaternary Science Reviews* 10:527–36.
- Fuller, D. Q., L. Qin, Y. Zheng, Z. Zhao, X. Chen, L. A. Hosoya, and G. Su. 2009. The domestication process and domestication rate in rice: Spikelet bases from the Lower Yangtze. *Science* 323:1607–10.
- Gu, H. 1991. “The Quaternary palaeoenvironment of Dongting Lake and its impacts upon human activities” (in Chinese), in *Environmental archaeology*, vol. 1. Edited by K. Zhou, pp. 173–78. Beijing: Science Press.
- Hebei [Hebei Wenwu Guanlichu, Handan Shi Wenwu Baoguansuo]. 1981. The site of Cishan at Wu’an, Hebei Province (in Chinese). *Kaogu Xuebao* 1981(3):303–38.
- Henan [Henan Sheng Wenwu Kaogu Yanjiusuo]. 1999. *Wuyang Xiahu* (in Chinese). Beijing: Science Press.
- Ho, P. T. 1969. *The loess and origins of agriculture in China* (in Chinese). Hong Kong: Hong Kong Chinese University Press.
- Hoopes, J., and W. Barnett. 1995. “The shape of early pottery studies,” in *The emergence of pottery*. Edited by W. Barnett and J. Hoopes, pp. 1–10. Washington, DC: Smithsonian Institution Press.
- Hu, L., Z. Chao, M. Gu, F. Li, L. Chen, B. Liu, X. Li, Z. Huang, Y. Li, B. Xing, and J. Dai. 2013. Evidence for a Neolithic age fire-irrigation paddy cultivation system in the lower Yangtze River delta, China. *Journal of Archaeological Science* 40:72–78.
- Hu, Y., S. H. Ambrose, and C. Wang. 2007. Stable isotope analysis of humans from Jiahu site. *Science in China (D)* 37:94–101.
- Hu, Y., S. Wang, F. Luan, C. Wang, and M. P. Richards. 2008. Stable isotope analysis of humans from Xiaojingshan site: Implications for understanding the origin of millet agriculture in China. *Journal of Archaeological Science* 35:2960–65.
- Huang, Q., and L. Jiang. 2006. Shangshan site and Shangshan culture (in Chinese). *Chinese Cultural Relics News*, Dec. 29.
- Hunan [Hunan Sheng Bowuguan]. 1986. The Neolithic remains of Zaoshi lower layer, Shimen County, Hunan (in Chinese). *Kaogu* 1986(1):1–11.
- Hunan [Hunan Sheng Wenwu Kaogu Yanjiusuo]. 1990a. The excavations at the early Neolithic site of Pengtoushan, Lixian, Hunan (in Chinese). *Wenwu* 1990(8):17–29.
- Hunan [Hunan Sheng Wenwu Kaogu Yanjiusuo Baofeng Fenxi Shiyanshi]. 1990b. The pollen analysis of Pengtoushan site, Li County, Hunan Province, and a discussion on the paleoenvironment (in Chinese). *Wenwu* 1990(8):30–32, 69.
- Hunan [Hunan Sheng Wenwu Kaogu Yanjiusuo]. 1993. The Neolithic Hujiawuchang site of Linli County, Hunan (in Chinese). *Kaogu Xuebao* 1993(2):171–206.
- . 1996. Preliminary report on excavations at the early Neolithic site of Bashidang at Mengxi, Lixian, Hunan (in Chinese). *Wenwu* 1996(12):26–39.
- . 2006. *Pengtoushan and Bashidang* (in Chinese). Beijing: Science Press.
- Hunt, H. V., M. G. Campana, M. C., Lawes, Y. Park, M. A. Bower, C. J. Howe, and M. K. Jones. 2011. Genetic diversity and phylogeography of broomcorn millet (*Panicummiliaceum* L.) across Eurasia. *Molecular Ecology* 20:4756–71.
- IA-CASS [Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo]. 2010. *Chinese archaeology: Neolithic archaeology* (in Chinese). Beijing: Chinese Social Sciences Press.

- Jiang, L. 2013. "The Kuahuqiao site and culture," in *A companion to Chinese archaeology*. Edited by A. P. Underhill, pp. 537–54. Oxford: Blackwell.
- Jiao, T. 2007. *The Neolithic of Southeast China: Cultural transformation and regional interaction on the coast*. Youngstown: Cambria Press.
- . 2013. "An economic perspective of Southeast China's prehistory—in memory of Professor Kwang-Chih Chang," in *Rethinking East Asian archaeology: Memorial essay collection for the tenth anniversary of Kwang-Chih Chang's death*. Edited by K. T. Chen, pp. 21–36. Taipei: Institute of History and Philology, Academia Sinica.
- Jin, G., W. Wu, K. Zhang, Z. Wang, and X. Wu. 2014. 8000-year old rice remains from the north edge of the Shandong highlands, east China. *Journal of Archaeological Science* 51: 34–42.
- Lee, G., G. W. Crawford, L. Liu, and X. Chen. 2007. Plants and people from the Early Neolithic to Shang periods in North China. *Proceedings of the National Academy of Sciences (USA)* 104:1087–92.
- Li, C., Y. Zheng, S. Yu, Y. Li, and H. Shen. 2012. Understanding the ecological background of rice agriculture on the Ningshao Plain during the Neolithic Age: Pollen evidence from a buried paddy field at the Tianluoshan cultural site. *Quaternary Science Reviews* 35:131–38.
- Li, F. 1984. *The history of domestic plants in China* (in Chinese). Beijing: Science Press.
- Li, Y., Q. Xu, H. Duan, and M. J. Bunting. 2011. Environmental context of a Neolithic site at Beifudi, northwest Hebei Province, China. *Journal of Archaeological Science* 38:2502–8.
- Liaoning [Liaoning Wenwu Kaogu Yanjiusuo]. 2012. *Fuxin Chabai: An excavation report on the Neolithic settlement*. Beijing: Cultural Relics Publishing House.
- Liu, L. 2004. *The Chinese Neolithic: Trajectories to early states*. Cambridge: Cambridge University Press.
- Liu, L., and X. Chen. 2012. *The archaeology of China: From the Late Paleolithic to the Early Bronze Age*. Cambridge: Cambridge University Press.
- Liu, L., J. Field, R. Fullagar, C. Zhao, X. Chen, and J. Yu. 2010a. A functional analysis of grinding stones from an early Holocene site at Donghulin, North China. *Journal of Archaeological Science* 37:2630–39.
- Liu, L., J. Field, R. Fullagar, S. Bestel, X. Ma, and X. Chen. 2010b. What did grinding stones grind? New light on Early Neolithic subsistence economy in the Middle Yellow River Valley, China. *Antiquity* 84:816–33.
- Liu, L., J. Field, A. Weisskopf, J. Webb, L. Jiang, H. Wang, and X. Chen. 2010c. The exploitation of acorn and rice in early Holocene Lower Yangtze River, China (in Chinese). *Acta Anthropologica Sinica* 29:13–32.
- Liu, X., H. V. Hunt, and M. K. Jones. 2009. River valleys and foothills: Changing archaeological perceptions of North China's earliest farms. *Antiquity* 83:82–95.
- Long, T., and D. Taylor. 2015. A revised chronology for the archaeology for the Lower Yangtze, China, based on Bayesian statistical modeling. *Journal of Archaeological Science* 63:115–21.
- Long, T., C. O. Hunt, and D. Taylor. 2016. Radiocarbon anomalies suggest late onset of agricultural intensification in the catchment of the southern part of the Yangtze Delta, China. *Catena* 147:586–94.
- Liu, H., J. Zhang, K. Liu, N. Wu, Y. Li, K. Zhou, M. Ye, T. Zhang, H. Zhang, X. Yang, L. Shen, D. Xu, and Q. Lia. 2009. Earliest domestication of common millet (*Panicum miliaceum*) in

- East Asia extended to 10,000 years ago. *Proceedings of the National Academy of Sciences (USA)* 106:7367–72.
- Lu, T. L. 1999. *The transition from foraging to farming and the origin of agriculture in China*. British Archaeological Reports 774. Oxford: Archaeopress.
- MacNeish, R. S., and J. Libby, eds. 1995. *Origins of rice agriculture: The preliminary report of the Sino-American Jiangxi (PRC) Project SAJOR*. Publications in Anthropology 13. El Paso: Centennial Museum, University of Texas at El Paso.
- MacNeish, R. S., G. Cunnar, Z. Zhao, and J. G. Libby. 1998. *Re-revised second annual report of the Sino-American Jiangxi (PRC) Origin of Rice Project SAJOR*. Andover, MA: Andover Foundation for Archaeological Research.
- Madson, D. B., and R. E. Elston. 2007. “Variations in Late Quaternary central Asian climate and the nature of human response,” in *Late Quaternary climate change in Quaternary sciences*. Edited by D. B. Madsen, F. Chen, and X. Gao, pp. 69–82. Amsterdam: Elsevier.
- Makibayashi, K. 2014. The transformation of farming cultural landscapes in the Neolithic Yangtze area, China. *Journal of World Prehistory* 27:295–307.
- Mao, L., D. Mo, L. Jiang, Y. Jia, X. Liu, M. Li, K. Zhou, and C. Shi. 2008. Environmental change since mid-Pleistocene recorded in Shangshan archaeological site of Zhejiang. *Journal of Geographical Sciences* 18:247–56.
- Nakamura, S. 2010. The origin of rice cultivation in the Lower Yangtze region, China. *Archaeological and Anthropological Sciences* 2:107–13.
- Nasu, H., H. Gu, A. Momohara, and Y. Yasuda. 2012. Land-use change for rice and foxtail millet cultivation in the Chengtoushan site, central China, reconstructed from weed seed assemblage. *Archaeological and Anthropological Sciences* 4:1–14.
- Neimenggu [Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Neimenggu Dui]. 1985. A brief report on the excavation of the Xinglongwa site, Aohanqi, Inner Mongolia (in Chinese). *Kaogu* 1985(10):865–74.
- . 1997. A brief report of the Xinglongwa settlement in 1992, Aohanqi, Inner Mongolia (in Chinese). *Kaogu* 1997(1):1–26.
- Neimenggu [Neimenggu Zizhiqu Wenwu Kaogu Yanjiusuo]. 2004. *Baiyinchanghan: An excavation report on the Neolithic site* (in Chinese). Beijing: Science Press.
- Pechenkina, E. A., S. H. Ambrose, X. Mao, and R. A. Benfer Jr. 2005. Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. *Journal of Archaeological Science* 32:1176–89.
- Peters, J., O. Lebrasseur, H. Deng, and G. Larson. 2016. Holocene cultural history of red jungle fowl (*Gallus gallus*) and its domestic descendant in East Asia. *Quaternary Science Reviews* 142:102–19.
- Pinhasi, R., and J. T. Stock, eds. 2011. *Human bioarchaeology of the transition to agriculture*. Chichester: Wiley-Blackwell.
- Qu, T., O. Bar-Yosef, Y. Wang, and X. Wu. 2013. The Chinese Upper Paleolithic: Geography, chronology, and techno-typology. *Journal of Archaeological Research* 21:1–73.
- Ren, S. 1994. The discovery and significance of the Xinglongwa culture (in Chinese). *Kaogu* 1994(8):710–18.
- Schiffer, M. B. 1987. *Formation processes of the archaeological record*. Salt Lake City: University of Utah Press.

- Shelach, G. 2000. The earliest Neolithic cultures of Northeast China: Recent discoveries and new perspectives on the beginning of agriculture. *Journal of World Prehistory* 14:363–413.
- . 2006. Economic adaptation, community structure, and sharing strategies of households at early sedentary communities in Northeast China. *Journal of Anthropological Archaeology* 25:318–45.
- Shelach, G., and M. Teng. 2013. “Earlier Neolithic economic and social systems of the Liao River region, Northeast China,” in *A companion to Chinese archaeology*. Edited by A. P. Underhill, pp. 37–54. Oxford: Blackwell.
- Sheng, L., Y. Zheng, and L. Jiang. 2006. The Early Neolithic Shangshan site, Pujiang County, Zhejiang Province (in Chinese). *Nongye Kaogu* 2006(1):30–32.
- Shi, X. 1986. “The discovery and significance of the pre-Yangshao culture,” in *A collection of the research articles on archaeology in China, in memory of Xia Nai on his fiftieth anniversary in archaeology* (in Chinese). Edited by the Editorial Board, pp. 1–23. Xian: San Qin Press.
- Shu, J., W. Wang, L. Jiang, and H. Takahara. 2010. Holocene vegetation dynamics and human impact, I: Agricultural activities and rice cultivation in East Asia. *Quaternary International* 227:10–21.
- Smith, B. D. 2001. Low-level food production. *Journal of Archaeological Research* 9:1–43.
- Su, B. 1999. *New explorations on the origin of Chinese civilization* (in Chinese). Beijing: Sanlian Bookstore.
- Tomka, S. A. 1993. “Site abandonment behavior among transhumant agro-pastoralists: The effects of delayed curation on assemblage composition,” in *Abandonment of settlements and regions: Ethnoarchaeological and archaeological approaches*. Edited by C. M. Cameron and S. A. Tomka, pp. 11–24. Cambridge: Cambridge University Press.
- Underhill, A. P. 1997. Current issues in Chinese Neolithic archaeology. *Journal of World Prehistory* 11:103–60.
- Wagner, M., P. Trasov, D. Hosner, A. Fleck, R. Ehrich, X. Chen, and C. Leipe. 2013. Mapping of the spatial and temporal distribution of archaeological sites of northern China during the Neolithic and Bronze Age. *Quaternary International* 290–291:344–57.
- Winterhalder, B. 1980. “Optimal foraging strategies and hunter-gatherer research in anthropology: Theory and models,” in *Hunter-gatherer foraging strategies: Ethnographic and archeological analyses*. Edited by B. Winterhalder and E. Smith, pp. 13–35. Chicago: University of Chicago Press.
- Wu, Y., L. Jiang, Y. Zheng, C. Wang, and Z. Zhao. 2014. Morphological trend analysis of rice phytolith during the early Neolithic in the Lower Yangtze. *Journal of Archaeological Science* 49:326–31.
- Xia, Z., H. Deng, and H. Wu. 2000. Geomorphologic background of the prehistoric cultural evolution in the Xar Moron River Basin, Inner Mongolia (in Chinese). *Acta Geographica Sinica* 55:329–36.
- Xiang, H., J. Gao, B. Yu, H. Zhou, D. Cai, Y. Zhang, X. Chen, X. Wang, M. Hofreiter, and X. Zhao. 2014. Early Holocene chicken domestication in northern China. *Proceedings of the National Academy of Sciences (USA)* 111:17564–69.
- Yan, W. 1987. The unity and diversity of prehistoric cultures in China (in Chinese). *Wenwu* 1987(3):38–48.
- . 2000. *The origins of agriculture and the rise of civilization* (in Chinese). Beijing: Science Press.

- Yang, X., and L. Jiang. 2010. Starch grain analysis reveals ancient diet at Kuaahuqiao site, Zhejiang Province. *Chinese Science Bulletin* 55:1150–56.
- Yang, X., Z. Wan, L. Perry, H. Lu, Q. Wang, C. Zhao, J. Li, F. Xie, J. Yu, T. Cui, T. Wang, M. Li, and Q. Ge. 2012. Early millet use in northern China. *Proceedings of the National Academy of Sciences (USA)* 109:3726–30.
- Yao, L., Y. Yang, Y. Sun, Q. Cui, J. Zhang, and H. Wang. 2016. Early Neolithic human exploitation and processing of plant foods in the Lower Yangtze River, China. *Quaternary International*. DOI: 10.1016/j.quaint.2016.03.009
- Yasuda, Y. 2002. “Origins of pottery and agriculture in East Asia,” in *The origins of pottery and agriculture*. Edited by Y. Yoshinori, pp. 119–42. New Delhi: Roli Books.
- . 2008. Climate change and the origin and development of rice cultivation in the Yangtze River basin, China. *Ambio*, special report no. 14:502–6.
- Yu, P. L. 2015. Ethnoarchaeology of foraging and the case of the vanishing agriculturalists in the Amazon Basin. *Journal of Anthropological Archaeology* 38:59–66.
- Yu, Y., Z. Guo, H. Wu, and P. Finke. 2012. Reconstructing prehistoric land use change from archaeological data: Validation and application of a new model in Yiluo Valley, north China. *Agriculture, Ecosystems and Environment* 156:99–107.
- Zhang, C., and H. Huang. 2013. Jiahu 1: Earliest farmers beyond the Yangtze River. *Antiquity* 87:46–63.
- Zhang, D., F. Chen, R. L. Bettinger, L. Barton, D. Ji, C. Morgan, H. Wang, X. Chen, G. Dong, T. P. Guilderson, and H. Zhao. 2010. Archaeological records of Dadiwan in the past 60 ka and the origin of millet agriculture. *Chinese Science Bulletin* 55, doi: 10.1007/s11434-010-0097-3, accessed September 2014.
- Zhang, H., H. Wang, and W. Yang. 2005. Early Neolithic remains are discovered in Xiaohuangshan site, Zhejiang Province (in Chinese). *Zhongguo Wenwu Bao*, Sept. 30.
- Zhang, Q. 2002. Archaeological retrospect and prospect in Shanxi at the millennium (in Chinese). *Kaogu* 2002(4):3–13.
- Zhang, W., A. Pei, and T. Mao. 2003. Studies on the printings of bi-peaked tubercles on lemmas of rice kernels in broken pottery pieces unearthed from Pengtoushan excavation site in Li County, Hunan (in Chinese). *Acta Agronomica Sinica* 29:263–67.
- Zhang, X. 2003. Study on the diet of ancient people by analyzing bone elements and isotopes (in Chinese). *Acta Anthropologica Sinica* 22:75–84.
- Zhao, H. 2008. “A study on the developmental system of Neolithic cultures in China” (in Chinese), in *A century’s retrospect on the study of Chinese archaeology*. Edited by W. Yan, pp. 19–34. Beijing: Science Press.
- Zhao, Z. 2010. New data and new issues for the study of origin of rice agriculture in China. *Archaeological and Anthropological Sciences* 2:99–105.
- . 2011. New archaeological data for the study of the origins of agriculture in China. *Current Anthropology* 52:s295–s306.
- Zhejiang [Zhejiang Sheng Wenwu Kaogu Yanjiusuo]. 2003. *Hemudu: A Neolithic site and its archaeological excavations* (in Chinese). Beijing: Cultural Relics Publishing House.
- Zhejiang [Zhejiang Sheng Wenwu Kaogu Yanjiusuo, Xiaoshan Bowuguan]. 2004. *Kuahuqiao* (in Chinese). Beijing: Cultural Relics Publishing House.
- Zhejiang [Zhejiang Sheng Wenwu Kaogu Yanjiusuo, Pujiang Bowuguan]. 2007. A brief report of Shangshan site, Pujiang County, Zhejiang Province (in Chinese). *Kaogu* 2007(9):7–18.

- Zheng, J. 2005. *Neolithic cultures and the civilization of Xia Dynasty* (in Chinese). Nanjing: Jiangsu Education Press.
- Zheng, Y., and L. Jiang. 2007. The ancient rice remains unearthed from Shangshan site and its significance (in Chinese). *Kaogu* 2007(9):19–25.
- Zheng, Y., G. Sun, L. Qin, C. Li, X. Wu, and X. Chen. 2009. Rice fields and modes of rice cultivation between 5000 and 2500 BC in east China. *Journal of Archaeological Science* 36: 2609–16.
- Zhou, B. 1981. Animal bones from the Cishan site at Wuan, Hebei. *Kaogu Xuebao* 1981(3): 339–47.
- Zhu, Y. 2013. “The early Neolithic in the central Yellow River valley c. 7000–4000 BC,” in *A companion to Chinese archaeology*. Edited by A. P. Underhill, pp. 171–93. Oxford: Blackwell.
- Zong, Y., Z. Chen, J. Innes, C. Chen, Z. Wang, and H. Wang. 2007. Fire and flood management of coastal swamp enabled first rice paddy cultivation in east China. *Nature* 449: 459–62.