STRUCTURE AND EVOLUTION OF ECONOMIC NETWORKS IN NEOLITHIC WALLED TOWNS OF THE JIANGHAN PLAIN:
A Geochemical Perspective

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STRUCTURE AND EVOLUTION OF ECONOMIC NETWORKS IN NEOLITHIC WALLED TOWNS OF THE JIANGHAN PLAIN:
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This research examines development of early complex societies in the middle Yangzi River valley of China during the late Neolithic (c. 3100 – 2000 BCE). The most conspicuous marker of these societies are large and densely-populated walled settlements that emerged across the region in the late fourth millennium BCE. Settlement survey of a region encompassing two such walled towns, Taojiahu and Xiaocheng, has shown that for over a thousand years, nearly all inhabitants of the region lived together in tightly nucleated communities within the walled enclosures. This distinctive settlement pattern highlights the presence of strong and persistent sociopolitical forces that drew together and integrated these communities.

This dissertation investigates the degree to which controlling, managing, or profiting from the production and distribution of basic goods contributed to the ability of aspiring leaders at Taojiahu and Xiaocheng to project their political authority. More specifically, it examines how changes in utilitarian economic networks corresponds with the centralization and decentralization of these walled towns. Geochemical analysis of 1,150 pottery sherds collected during the Taojiahu-Xiaocheng regional settlement survey were used to reconstruct the organization of ceramic exchange networks during the Qujialing (3100 – 2500 BCE) and Shijiahe (2500 – 2000 BCE) periods.

Results of this analysis indicate that late Neolithic pottery was made by several distinct producer groups based out of different areas of the study area. Ceramic vessels were circulated through open, unrestricted networks that linked together households in different neighborhoods and in different towns. The organization of these networks was surprisingly stable through time despite population growth and centralization at Xiaocheng and population decline and decentralization at Taojiahu, suggesting that economic control was not a source of political power for local elites. The longevity and robustness of economic ties between the two towns finally offers evidence that relations between the communities was based more strongly in cooperation than conflict.

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1.0 INTRODUCTION

The emergence of towns with massive, rammed earth walls in Neolithic China is considered to be the conspicuous archaeological hallmark of a major sociopolitical transformation. Large walled settlements first began to appear in the Liyang and Jianghan Plains of the Middle Yangzi River valley in 3,800 BCE, and were found in the Central Plains and Yellow River valley by 3,000 BCE (Figure 1.1) (Hubei 2009; Hubei and Jingshan 2008; Hubei and Tianmen 2007; Ma 2002; Ren 1998; Tianmen 1987; Underhill et al. 1998; Underhill et al. 2008; Yi 2003; Zhang 1994; Zhao 2004). Although these settlements have received significant attention from both Chinese and Western archaeologists, the social, political, and economic dynamics that contributed to their development remain poorly understood.

Most studies of these Neolithic walled towns are not surprisingly directed towards their massive earthen enclosures. These structures, which consist of some combination of mounded earthen banks and ditches, attract attention both for their sheer size and for the possible implications they have for labor relations, political showmanship, disaster prevention, and violence. Preserved remains of the oldest wall enclosures in the Jianghan Plain average 30 m in base width and 4-5 m in height, and were routinely maintained (Hunan 2002; Priewe 2012; Yi 2003). Calculations of the amount of labor that was required to build these walls vary, but do suggest that construction drew on a non-local labor force and some form of centralized planning authority (Hunan Sheng 2007:18–31; Okamura 2000; Ren 1998; Thorp 2006:52). The undoubtedly high cost of wall construction has also led scholars to argue that these earthen enclosures were used as symbols of wealth and political power (Liu 1996; Liu 2004; Wang 2003; Zhang 2000). Other scholars have instead argued that walls served a more practical purpose of protecting local settlements from seasonal flood waters (Wang 2003; Yasuda 2013). Yet others view these walls as fortification systems that were designed to protected locals from threats of outside violence or endemic warfare (Cao 1996; Pei 2004; Qian 2003; Ren 1998; Sun 1999).

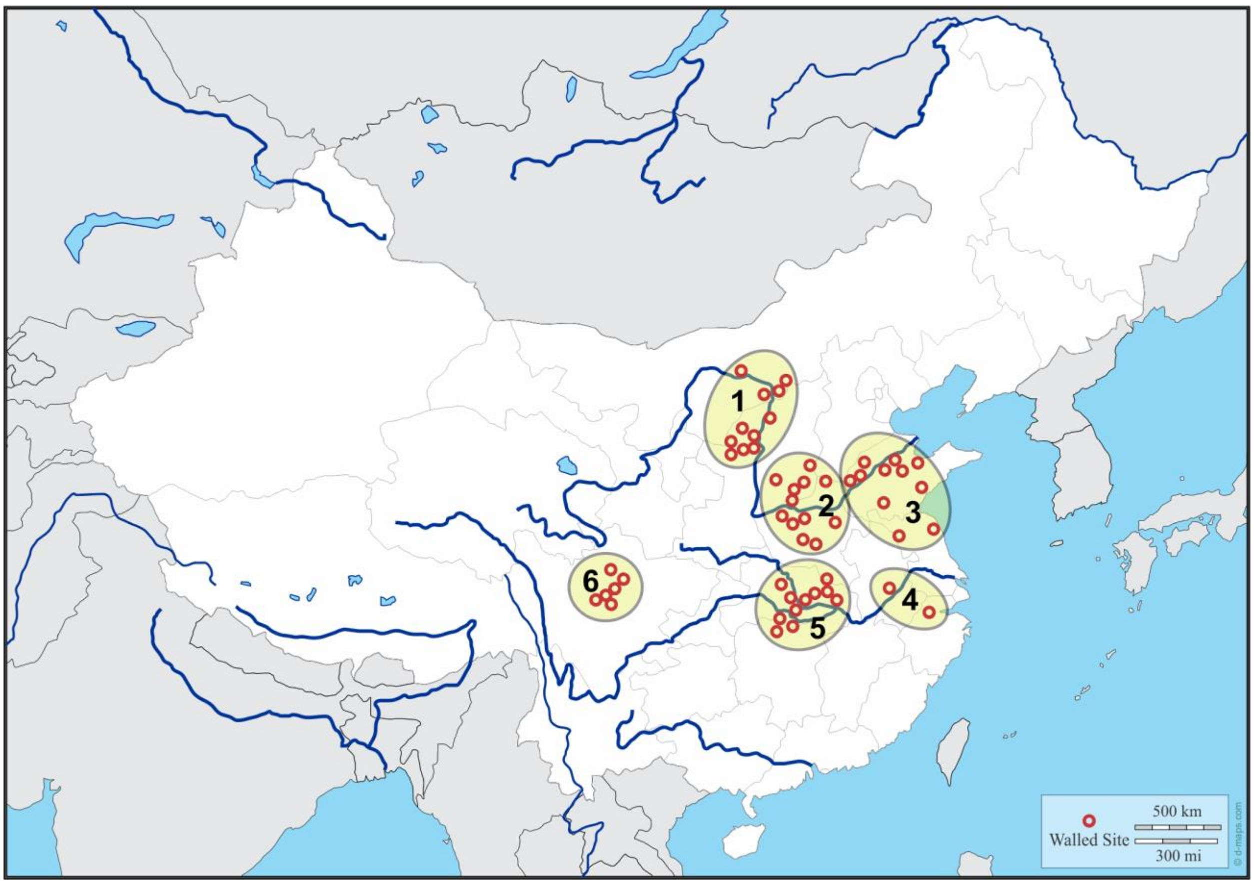

Figure 1.1: Location of Neolithic walled towns across China. Walled settlements emerged in six broad regions in the 4th millennium BCE. These regions include (1) Daihai, (2) Central Plain, (3) Haidai, (4) Taihu, (5), Jianghan Plain, and (6) Bashu.

More specific evidence of changes in the socio-economic and political organization of late Neolithic walled settlements come from the area within the enclosures. Excavations have unearthed remains of paved central plazas and roads at Chengtoushan (Hunan), Shijiahe (Hubei), and Xishan (Zhengshou) (Beijing et al. 1992; Hunan and Guoji 2007:24–31; Liu 2004:94). Similarly, networks of man-made channels and buried ceramic pipes found at Pingliangtai (Henan) and Majiayuan (Hubei) have been interpreted as early public drainage systems (Henan and Zhoukou 1983; Hubei Jingmen 1997; Zhang 2000). Lithic, jade, pottery, and lacquer production remains have been found in constrained areas within these settlements, and are cited as evidence for the centralization, and potentially specialization, of craft production by local elites (Bennett 2002; Cunnar 2007; He 1996; Hunan 2007). Platform altars and localized caches of zoomorphic figurines also point to the presence of public ritual spaces (Priewe 2012; Zhang 2013). These findings highlight the increasingly specific use of public space in walled towns and also point to a more complex organization of labor relative to that in earlier village communities.

Two new kinds of domestic architecture appeared in walled towns along with these changes in public space. Houses of the early and middle Neolithic were free-standing structures that typically accommodated single family units (e.g. Peterson and Shelach 2010; Peterson and Shelach 2012). By contrast, the late Neolithic saw the spread of long housing compounds subdivided into a row of single-room dwellings. These so-called 'big house' structures (大型房屋建筑) were built together as groups forming a U- or 凹 (*ao*)-shape around a central courtyard. These large, interconnected structures likely accommodated extended families or related kin groups; as such, their appearance likely signals a change in the composition of the basic family unit (Changjiang 1990; Chen 1999; Flad and Chen 2013; Hubei and Fugang 1997; Li 2000; Zhongguo 2001). This change would have expanded the productive potential of each family, bringing with it increased opportunities for the acquisition of surplus and wealth (Zhang 2013; Zhang 2000; Li 2000). The second new form of domestic architecture was the platform house. These houses were built on raised earthen platforms, featured multi-room and complex floor plans, and were constructed of costly building materials like stone. These characteristics led to interpretations of platform houses as ‘elite houses’ or ‘palaces’ which further symbolized growing economic inequalities between families in walled towns (Underhill 1990; Weisheu 1997; Yan 1999:144).

The appearance of new housing contexts led to a transformation in the scale and density of settlements. Swift population growth and nucleation resulted in all the trappings of a more ‘urbanized’ life, including increased pollution and higher incidence of disease. At Chengtoushan, several species of flies attracted to human and animal waste as well various parasites have been recovered from late Neolithic contexts (Yasuda et al. 2004).

Classic evidence for economic and social inequalities comes from the cemeteries of walled towns. Across the late Neolithic, burials exhibited increasing discrepancies in the size and complexity of graves, as well as in the number and richness of items that were left with the deceased (Flad and Chen 2013: 240-243; Guo 2005). At Chengtoushan, for instance, Daxi period (4300 – 3300 BCE) graves had up to 30 burial goods, a figure that rose to over 100 goods in the following Qujialing period (3300 – 2600 BCE). Qujialing burials at Chengtoushan with the largest quantity of grave goods were also most likely to include rare offerings like groundstone *fu* battle-axes and elaborate sets of serving vessels, items typically associated with high prestige and wealth (Hunan 2007:284–335; see also Underhill 2002:89–200).

The construction of walls, investment in public space, changes in domestic architecture, and growing inequalities in burial practices at walled towns were also accompanied by marked shifts in regional settlement patterns. The small, scattered agricultural villages that characterized early and middle Neolithic settlement patterns in central and southern China were consolidated into larger settlements, which in turn were integrated into broader supra-local communities (Dai

2006; Drennan and Dai 2010; Guo 2005; Liu 1996; Liu et al. 2004; Pearson and Underhill 1987; Underhill et al. 1998; Fang et al. 2004).

These changes in the structure of walled town communities together suggest underlying transformations in the organization of late Neolithic society in China. Together, they have led scholars to characterize walled settlements as incipient states (Dematte 1999; Li 2008; Liu and Chen 2003; Ren 1998; Shao 2000; Yi 2003; Yan 1992; Yan 1997; Zhang 2001) or, alternatively, as chiefdoms (Dai 2006; Lee 2004; Liu 1994; Underhill 1992; Underhill 1994; Underhill et al. 2008a). Whichever term is used, it is clear that walled settlements represent the most socio-politically complex societies to have existed in central China by this time. What remains unclear about these societies, however, are the processes that led to their development and continued occupation.

1.1 ECONOMIC CONTROL, CRAFT SPECIALIZATION, AND SOCIAL COMPLEXITY

In complex societies like the walled town polities of the Middle Yangzi region, political power is often rooted in economic control (Brumfiel and Earle 1987b; Brumfiel and Earle 1987a; Earle 1997; McGuire 1983). By manipulating the transfer of goods and services from producers to consumers, leaders can limit access to products that are needed or desired for subsistence and social life. In this way, control over the economy can generate a material foundation for political power (Brumfiel and Earle 1987a; Cobb 1996; D'Altroy and Earle 1985; Earle 1987; Earle 1997; Earle 2002; Gilman 2001; McGuire 1983; Peregrine 1991; Spencer 1993; Welch 1996). Archaeologists have documented several ways in which elites manipulate key segments of the economy to leverage their power. Some of the more common strategies include limiting access to scarce commodities or resources (Clark and Blake 1994; Earle 1997; Eerkens 2009; Langebaek 1991; Smith and Choi 2007; Steponaitis 1991), restricting the circulation of technical knowledge (Ames 1995:175; Chang 1983; Earle 2002; Inomata 2001; Liu 2003; Stein 1998; Spielmann 2002), and encouraging productive differentiation (Arnold 1996; Brumfiel and Earle 1987b; Clark and Parry 1990; Costin 1991; Feinman 2013; Feinman et al. 1984; Hirth 1996; Webster 1990; Smith and Choi 2007). This last strategy is often viewed as a focal, or 'specialized,' approach to labor, in which households (or other meaningful social units) produce a limited range of goods at a large volume to be exchanged with products from other households engaged in complementary economic pursuits (Clark 1995; Costin 1991; Costin 2001; Rice 1987:171; Schortman and Urban 2004). As production becomes increasingly specialized, households rely more heavily on other producers in the community to provision themselves, creating conditions of economic dependency. Aspiring leaders position themselves to coordinate of the flow of goods across productive sectors, and, as a result, draw power from the tightly interdependent economy and their ability to control commoners' access to basic goods.

One version of the productive differentiation strategy involves elite-controlled production and distribution of goods that have a special political or ideological significance. These prestigious goods are produced by highly-skilled specialists who are sponsored by, or 'attached,' to elites (Brumfiel 2006; Costin 2001; Dai 2006; Junker 1994; Sinopoli 1988). For example, the power of Shang elites based in central China (1600-1046 BCE) is widely thought to derive from the attached production and restricted circulation of jade and bronze ceremonial goods (Allan 2007; Chang 1980; Chang 1983; Lee 2004; Liu 2003). These prestigious jade and bronze goods were the products of immense economic networks, which spanned from Liaoning to Sichuan provinces and were centered at walled sites like Zhengzhou and Panglongcheng (Allan 2007; Chang 1980; Lee 2004; Liu 2003; Underhill 2002; Underhill and Fang 2004). These Shang-style jades and bronzes came to be used by elites throughout China as symbols of sanctioned political authority.

The high visibility of ceremonial jades and bronzes in the archaeological record has encouraged scholars of Shang political economy to focus primarily on prestige goods. Yet, recent findings suggest that the power of Shang elites may have also come from the production and exchange of utilitarian goods. Dai Xiangming's (2006) regional survey of the Yuanqu Basin, Shanxi Province offers evidence that Bronze Age elites controlled regional manufacture and circulation of utilitarian pottery. During the Erlitou (1900-1600 BCE) and Erligang (1600-1300 BCE) periods, nearly all potting tools and kilns identified during survey were found within the walls of Nanguan, the regional administrative center. Pottery collected from other settlements in the study area closely resembled the pottery found in these production areas at Nanguan, leading Dai to conclude that production and exchange of utilitarian vessels was orchestrated by Nanguan elites. Dai suggests that elites exercised control over these economic networks to increase their own wealth and material power (2006:105).

The Nanguan case illustrates that even in a classic wealth-financed state like the Shang, utilitarian economies likely played a critical role in the maintenance of elite power. While exploitation of these two economies—prestige and utilitarian—are often seen as alternate sources of power, the Shang political economy appears to have had roots in both. The prestige economy was supported with wealth acquired through the control over production and circulation of basic goods like cooking pots. Concurrently, the power to control these basic economic networks was contingent upon access to jades and bronzes that served as symbols of legitimate authority (e.g. Arnold 1996; Brumfiel 1987; Hayden 1998; Schortman and Urban 2004). Although these two economies appeared to be closely coupled in the Bronze Age, evidence from the Yuanqu Basin suggests that elite control over utilitarian economies actually *preceded* their involvement in the prestige economy. Centralization of the pottery industry in Yuanqu began in the Late Erlitou period and was fully established by the Lower Erligang period, while Shang-style jades and bronzes only began to appear in elite burials during the Upper Erligang period (Dai 2006:88).

Dai's research makes it clear that Bronze Age political centers like Nanguan functioned as economic centers from which elites controlled the production and distribution of both basic and prestige goods. What is unclear is whether earlier walled towns similarly served as economic centers for surrounding settlement. The goal of this project is to determine if political power at Neolithic walled towns was based in economic control or whether the emergence of these complex societies was driven by forces outside the economic sphere.

1.2 CRAFT ECONOMIES IN NEOLITHIC CHINA

Few studies of craft specialization and economic power in China have focused explicitly on the organization of production in non-state societies. Notable exceptions to this include research conducted by Anne Underhill (2002) in Shandong province and by Hung Ling-yu (Hung 2011) in the Gansu-Qinghai area (see also Bennett 2002; Cunnar 2007; Flad 2011; T. Li 2016). Both Underhill and Hung focus primarily on the production of labor-intensive prestige vessels that were important markers of status during the Longshan and Majiayao culture periods. These authors argue that in their respective regions, wealthy Neolithic families attempted to increase their influence by hosting competitive feasts and elaborate mortuary ceremonies. Prestigious pottery vessels were used at these events to convey the host family's economic power to attendees. While the production of these goods was not directly controlled by elites, competition among elite factions and the symbolic social value of the vessels led to an increase in their production. For both the Longshan and Majiayao culture areas, this research indicates that craft production and access to finished craft goods were closely linked to the development of social inequalities.

Underhill and Hung offer important insight into how competition for power in the Neolithic was connected to prestige economies and the display of wealth. However, by focusing primarily on prestige goods, their research accounts for only a small fraction of economic relationships of late Neolithic society. In contrast to the restricted production and circulation networks of wealth items, utilitarian goods were made and consumed daily by the bulk of the population. Indeed, both Underhill and Hung suggest that social inequalities in Neolithic China were ultimately rooted in differential access to basic items like agricultural surplus and labor. Did the production and exchange of other basic goods, such as utilitarian pottery, provide aspiring leaders with similar opportunities for control and political power as the prestige economy? Or did the economy of such basic goods fall outside of the political realm?

1.2.1 Utilitarian pottery production in the middle Yangzi River valley

Excavations in the middle Yangzi River region have highlighted several important changes in the production of pottery from the middle to the late Neolithic. During the Daxi/Youziling period (4300 – 3300 BCE), pots were built from clay slabs by hand and occasionally with the use of a tournette. By the Qujialing period (3100 – 2600 BCE) a large number of vessels were made using the fast-wheel (Figure 1.2) (Zhang 2013; Zhang 2000). Investment in a new technology like the fast-wheel implies a shift in the scale and organization of pottery production that is driven by rising consumer demands (Bettinger et al. 2006; Brown 1989; Costin and Hagstrum 1995; Ugan et al. 2003; Underhill 1991). Other evidence of investment in pottery production include kilns, which have been excavated from a handful of sites throughout the region, including Zoumaling, Qinglongquan, Yinxiangcheng, and Chengtoushan (Hubei and Fugang 1997; Hubei Sheng et al. 2003; Zhang 2013; Zhongguo 2010). Excavators at Chengtoushan found a decrease in the number of kilns at that site over time (Hunan 2007), perhaps indicating the centralization of pottery production similar to the pattern Dai (2006) observed in the Yuanqu Basin. Alternatively, clusters of kilns found at some very small Shijiahe period sites have been cited as evidence for the decentralization of pottery production by this time (Ou 1999; Zhang 2013).

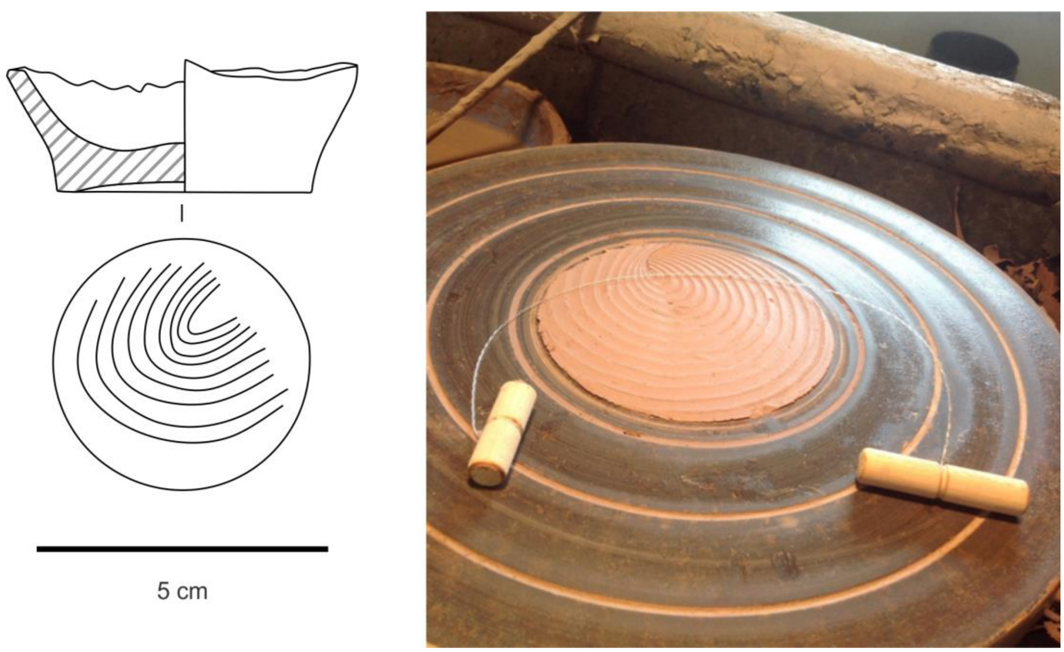

Figure 1.2: Evidence of wheel-throwing on the base of a red pottery cup found at the Yejiamiao site that dates to the Shijiahe period (left; redrawn from Hubei et al. 2012: 686). This characteristic arcing pattern occurs when the potter cuts a newly thrown pot from the wheel-head using string or wire as it is still turning. A similar pattern is seen in a modern context in the photograph on the right (photo courtesy of Simon Leach Pottery).

Such focused investigations of craft production, however, give little consideration to the integration of production with broader economic and social systems (Pool 1992). As Kenneth Hirth points out, “production and exchange are two sides of the *same* political coin and are used *together* by elites to accumulate resources and exercise control over their respective populations” (1996:207). To fully understand late Neolithic political economy in the middle Yangzi River, it is imperative to integrate a model of distribution networks with an understanding of productive systems.

1.3 RESEARCH SCOPE OF THIS DISSERTATION

The Jianghan Plain is an ideal place in which to study the role of economic control in the development of complex societies. The walled settlements of this region represent some of the earliest complex societies in China, and the development of social inequalities in the Jianghan Plain is accompanied by the adoption of new potting technologies and a new level of demand for utilitarian pottery.

In the winter of 2013, University of Pittsburgh student Li Dongdong led the first full-coverage regional settlement survey in the middle Yangzi River valley (D. Li 2016). The Taojiahu-Xiaocheng Regional Settlement Survey covered an area of 58 km^2 around two known Neolithic walled sites, Taojiahu and Xiaocheng, in the northern Jianghan Plain. While previous preliminary studies had focused on the ceramic chronology and periodization of wall construction at these sites (Hubei and Tianmen 2007; Li and Xia 2001), Li’s survey was designed to investigate the nature of sociopolitical relations both between and within Taojiahu and Xiaocheng. Using the same methodology as surveys conducted elsewhere in China

(CICARP 2011; Peterson et al. 2014), the Taojiahu-Xiaocheng survey documented the development, centralization, and abandonment, and re-emergence of communities at the walled town sites from the Youziling period to the Wei-Jin period (c. 4400 BCE – 600 CE).

The research presented in this dissertation builds on the settlement data in the Taojiahu-Xiaocheng region by examining how economic pottery networks changed in the context of the emerging complex social organizations in the Neolithic period (Qujialing period 3100 – 2500 BCE; Shijiahe period 2500 – 2000 BCE). It relies on a suite of geochemical techniques (pXRF, desktop XRF, and XRD) to trace pottery exchange networks between producers and consumers living in the Taojiahu-Xiaocheng region. The final goal of this research is to determine hot access to and procurement of utilitarian pottery shifted with respect to population nucleation and decentralization at these walled towns. I trace changes in pottery exchange networks at local, supralocal, and regional scales to address five research questions.

1.3.1 Research Question 1

How do pottery exchange networks compare among small local communities (e.g. neighborhoods)?

This research relies on variability in the geochemical signatures of pottery as the starting point to reconstruct economic networks of Neolithic pottery. The abundance of these compositionally-distinct groups of pottery within small, sub-zones of the survey region are be used to map where and how ceramic vessels were circulated. Designating sub-zones of a small enough scale moreover allows us to track these patterns of pottery circulation and procurement at the scale of clusters of five or ten households. The resulting patterns might look one of several ways. First, the abundance of pottery from every compositional group could be even across the entire study area. If this were the case, it would suggest that utilitarian pottery was distributed through a large economic network, which most likely exceeded the extent of the survey area. This pattern might also be caused by the redistribution of pottery pooled from a central place; it could also be the product of an extremely well-integrated regional trade network between walled communities. Alternatively, the proportion of compositional groups may be completely different in each neighborhood, which would point to a highly localized pottery distribution system and potentially to household- or neighborhood-based pottery production. A third possibility, which falls between these two more radical cases, would be for proportions of compositional groups to be similar for some neighborhoods and quite different for others, suggesting the presence of more complicated, smaller-scale distribution networks.

1.3.2 Research Question 2

How similar or different were the networks through which the inhabitants of Taojiahu and Xiaocheng obtained their pottery?

The second step in this analysis is be to compare the set of compositional groups present at Taojiahu with those present at Xiaocheng to assess how pottery distribution networks were similar or different at the two walled towns. Results of this larger-scale analysis might reveal completely different ceramic assemblages at each site, indicating that pottery was exchanged, consumed, and likely produced, locally at each site, and that the two communities were completely economically independent of one another. It is also possible for the ceramic assemblage of each site to be identical, which would point to the presence of a large-scale, integrated economic network for utilitarian pots in the study area. A third possibility is that multiple distribution networks—one focused on local exchange and another focused on regional exchange—may have operated simultaneously within the survey region.

1.3.3 Research Question 3

How similar or different were the networks through which inhabitants living inside walled areas and inhabitants living outside walled areas procured their pottery?

The third issue this research address is whether pottery economic networks are similar or different for consumers living inside and outside walled areas. At the heart of this question is the broader issue of the relationship between populations who occupy core or politically central settlement areas and those who live in more peripheral or marginal areas. How did the walls of Taojiahu and Xiaocheng affect the nature and intensity of interactions among households living on either side of them? One possible finding is for areas on either side of the walls to have compositionally-similar ceramic assemblages. This pattern would point to a clear economic connection between these settlement areas, and would show that access to pottery was not restricted to core areas alone. Alternatively, the pottery compositional groups found within town walls may be significantly different in kind and variety from those recovered outside town walls. This outcome would imply that the inhabitants of peripheral zones relied on different sources to gain access to pottery than inhabitants of the walled towns, suggesting that peripheral settlements were not dependent on walled core areas for these utilitarian goods. Such a finding would contradict the conventional view that small, rural communities are economically dependent on the larger settlements which they surround, and would hint at the existence of an independent pottery distribution system between rural households. If Taojiahu and Xiaocheng are not to be centers of economic activity for their hinterlands, the role of other Neolithic walled towns in their regional settlement systems would have to be reevaluated.

1.3.4 Research Questions 4 and 5

Did organization and accessibility of these distribution networks change between the Qujialing and Shijiahe periods of the late Neolithic? How did these changes correspond chronologically with the founding, growth, centralization, and disintegration of the walled towns?

The final element of this analysis will be to trace these changes in economic networks through time (Research Question 4) and in relation to contemporary changes in the sociopolitical organization of the region highlighted by settlement patterns (Research Question 5). Little change in the organization of these networks throughout the late Neolithic time would suggest that in the northern Jianghan Plain, economic and political control were manifested in separate spheres, and that the distribution of pottery operated though apolitical means. Direct household-to-household exchange, small regional marketplaces, and gift-giving may have instead accounted for the bulk of the circulation of utilitarian wares like pottery in these communities (see Graves 1991; Hirth 2013). This result would run counter to current models of the emergence of complex walled town societies in other parts of China; it would compel us to reevaluate the perceived similarity of Neolithic walled settlements as well as focus on other factors that could have facilitated the development of social inequality in the region. On the other hand, detecting a change in these distribution networks through time would allude to a closer relationship between political authority and the utilitarian economy. For example, a correspondence between settlement nucleation and the expansion of exchange networks might suggest that political power of these communities was based, at least in part, in leaders' ability to maintain economic ties with other walled towns. Alternatively, if settlement nucleation occurred alongside restriction of distribution networks, it would suggest a connection between the appropriation of political power and the ability to control access to utilitarian goods.

This research represents a critical step forward in the systematic investigation of the emergence of social and economic inequality in walled towns of the northern Jianghan Plain. Through the examination of production and distribution networks of utilitarian pottery in early complex societies, this dissertation addresses broader anthropological questions regarding the relationship between exchange, procurement and the development of political power.

2.0 SETTLEMENT PATTERNS IN THE NORTHERN JIANGHAN PLAIN

The previous chapter provided the broad theoretical background underpinning five research questions at the center of this study of pottery exchange networks in the Jianghan Plain. In this chapter, I present a more detailed description of the environmental and climatological context of the middle Yangzi River region in the late Neolithic. I then outline the results of the Taojiahu-Xiaocheng Regional Settlement Survey to describe changes in demography and settlement patterns in the northern Jianghan Plain during the Youziling (3900 – 3100 BCE), Qujialing (3100 – 2500 BCE), and Shijiahe periods (2500 – 2000 BCE) (Figure 2.1). These settlement dynamics are the foundation upon which the investigation of economic networks is constructed.

2.1 ENVIRONMENT AND CLIMATE OF THE JIANGHAN PLAIN

The middle Yangzi River basin is a low-lying floodplain that straddles modern day Hubei and Hunan provinces (Figure 2.2). This middle Yangzi region is straddled by the Dongting Plain to the south and by the Jianghan Plain to the north. The Jianghan Plain, which is also known as the Yunmeng wetland, consists of roughly 40,000 km^2 of rich alluvial lands that are replenished by seasonal floods. It is bounded by the Tongbai Mountains in the east, the Dahong Mountains in the north, the Three Gorges region to the west, and the Yangzi River in the south; between these mountainous regions most of the plain sits at an elevation less than 100 masl. The Suizao corridor connects the northeastern corner of the Jianghan Plain the Central Plains, while the Hanjiang corridor links the northwest of the Jianghan Plain with the Nanyang Basin.

Figure 2.1: Location of the middle Yangzi River valley (red circle) and basic chronology used in this dissertation. Evidence of occupation in this region dating between c. 2000 and 1600 BCE is sparse.

The Jianghan Plain has a subtropical monsoon climate with annual precipitation of 1000-1500 mm, an average summer temperature of 28˚C and average winter temperature of 4˚C. Modern vegetation includes both evergreen broadleaf forests and mixed deciduous-evergreen forests. However, most land in the plain has been cleared for mixed subsistence and commercial farming, particularly of rice, cotton, and rapeseed (canola), as well as for freshwater fish and turtle aquaculture.

The contemporary climate of the Jianghan Plain is not dissimilar from its Neolithic climate. Palynological analysis of sediments from the Qujialing site show that pine and oak forests were abundant from about 3,500 to 2,000 BCE. Algal remains indicate that lowland areas were frequently waterlogged and that the climate was warm and wet. Soil geomorphology similarly shows evidence of flooding and the presence of small, seasonal lakes across the Jianghan Plain (Zhu et al. 1997), and the discovery of *Elephas maximus* (Asian elephant) bones at the Xiawanggang site suggests that temperatures were only about 2-3˚C warmer than today (Xiang 1995). These warm and wet conditions would have fostered rice cultivation; in fact, the earliest evidence of wet rice cultivation in the world comes from Daxi period contexts at the walled Chengtoushan site in the Dongting Plain (Hunan 2007).

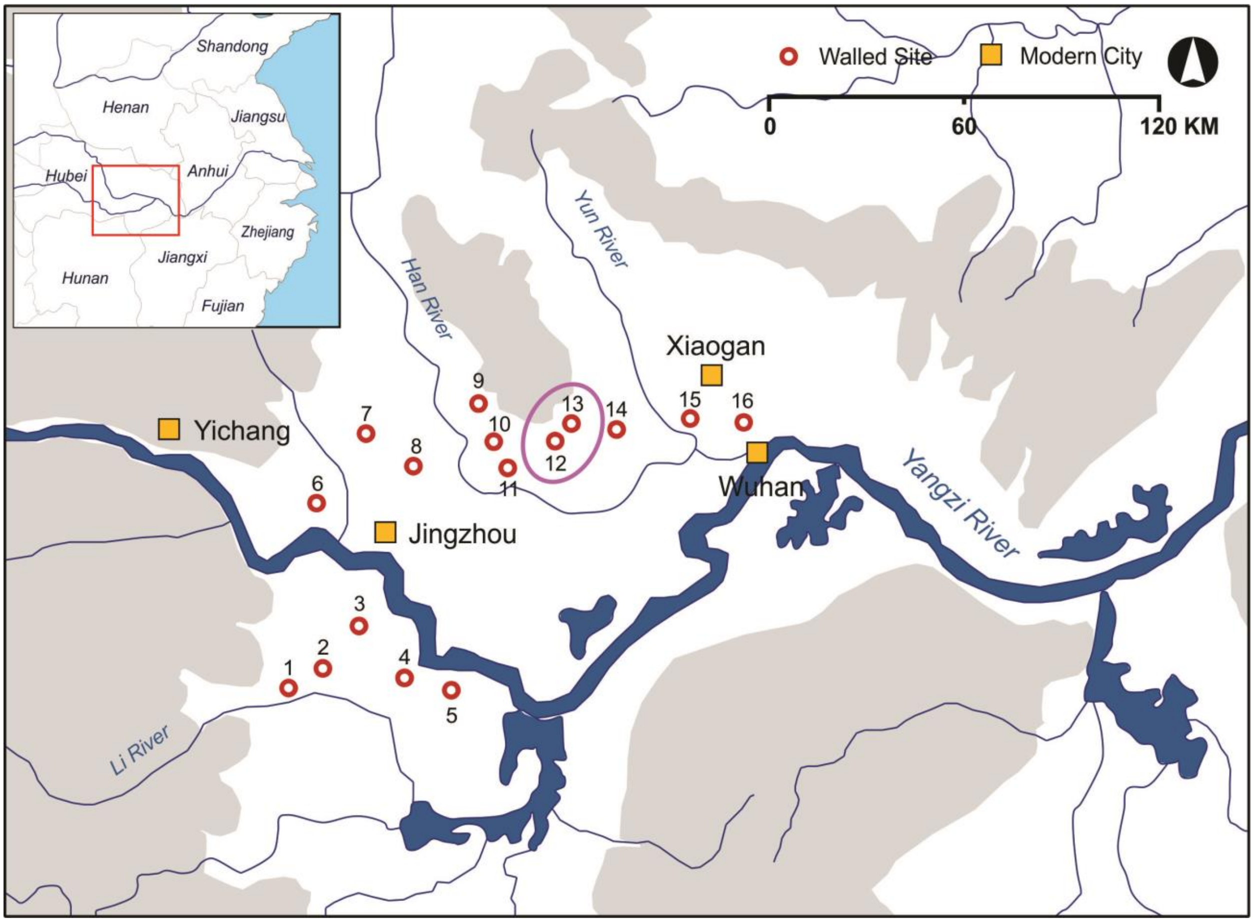

Figure 2.2: Map of the Middle Yangzi River region, the Jianghan Plain (north of the Yangzi River), and the Dongting Plain (south of the Yangzi River). The Taojiahu-Xiaocheng study area is circled in purple. Neolithic walled towns in this area include (1) Chengtoushan (城头山); (2) Jijiaocheng (鸡叫城); (3) Jimingcheng (鸡鸣城); (4) Qinghe (青河); (5) Zoumaling (走马岭); (6) Yinxiangcheng (阴湘城); (7) Majiayuan (马家院); (8) Chenghe (城河); (9) Qujialing (屈家岭) ; (10)Shijiahe (石家河); (11) Longzui (龙嘴); (12) Xiaocheng (笑城); (13) Taojiahu (陶家湖); (14) Menbanwan (门板湾); (15) Yejiamiao (叶家庙); (16) Zhangxiwan (张西湾）(Map based on Zhang 2013:537).

Beginning around 2,000 BCE, pollen records at Qujialing show that deciduous forests were slowly supplanted by grasslands, indicating a shift towards cooler, arid conditions (Li et al. 2009). Some scholars have characterized this period of cooling (the "4.2 ka BP event") as 'dramatic' or 'abrupt' and have argued that it caused the collapse of complex societies across China (Liu and Feng 2012; Li et al. 2014; Wang et al. 2014; Yasuda 2013). However, by some estimates these cold conditions reflect temperatures only 1-1.5˚C lower than they are today (Cao 1994).

While changes in climate may have affected these societies, it was certainly not the immediate cause for population growth, the development of social complexity, or dispersal of the walled towns of the middle Yangzi River. Rather, understanding what led to the emergence and decline of these societies requires a systematic investigation of local dynamics of walled towns themselves.

2.2 THE TAOJIAHU-XIAOCHENG REGIONAL SETTLEMENT SURVEY

The Taojiahu-Xiaocheng regional settlement survey (TXRSS) is a full-coverage pedestrian survey in the northeast area of the Jianghan Plain that designed and directed by Li Dongdong as part of his doctoral dissertation (Figure 2.3; D. Li 2016). This particular area was chosen for the survey because it encompassed two Neolithic walled settlements, Taojiahu and Xiaocheng, and the territory surrounding them, providing the opportunity to systematically investigate settlement patterns within and around these large-scale earthen enclosures from their initial construction to their abandonment.

The survey zone covers an area of 58 km^2, and is naturally divided into northern and southern regions by the meandering Zaoshi River, which flows northwest to southeast to meet the Hanshui and ultimately the Yangzi Rivers. The southern half of the survey area is located on the broad, fertile floor of the Zaoshi valley, with elevations of roughly 20 masl. The northern half of the survey area lies at the foot of the Dahong Mountains and is characterized by low, rolling hills with elevations between 30-90 masl. The Silong and Taojiahu Rivers runs through the northern part of the survey zone where they join in the middle of the Taojiahu walled settlement.

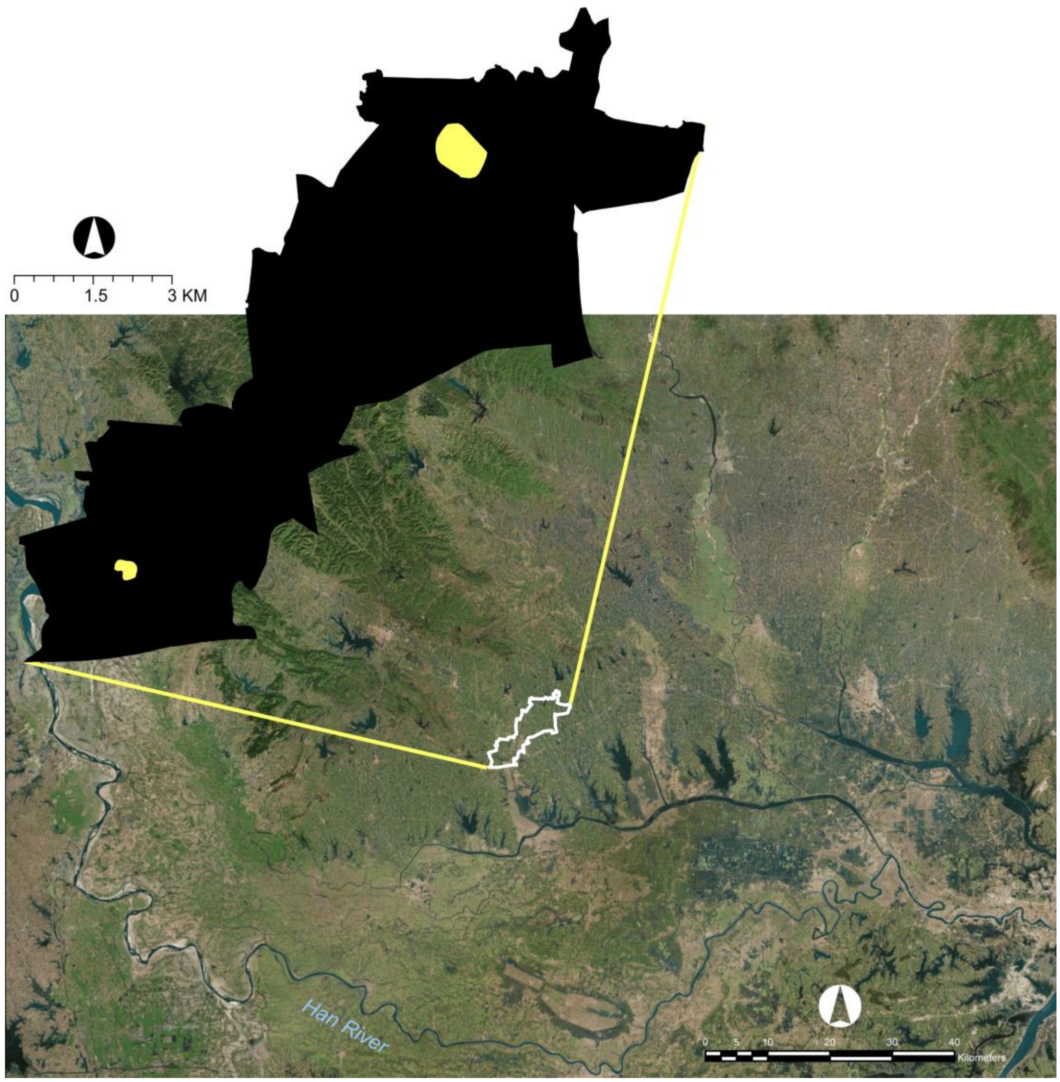

Figure 2.3: The location and boundary of the Taojiahu Xiaocheng Regional Settlement Survey. Walled towns are marked in yellow.

The TXRSS was conducted in 2013 under the purview of the Hubei Sheng Wenwu Kaogu Yanjiusuo and Wuhan University. Visibility conditions are fairly good across the region, though occasionally participants used hoes to clear away brush that obstructed their view of the ground surface. A handful of hamlets and small towns dot the modern landscape, restricting systematic coverage of some zones of the study area yet, these zones accounted for a very small portion of the survey region and do not appear to mask significant areas of prehistoric settlement.

In the sections that follow, I summarize previous investigations of the Taojiahu and Xiaocheng sites and describe the methodology and results of the Taojiahu-Xiaocheng regional survey. The TXRSS collected information about settlement of the region from the Youziling (3800 – 3100 BCE) to the Wei-Jin period (220 – 589 CE), but I will focus here on the settlement patterns through the Neolithic. For a full account of the results of the TXRSS, see D. Li (2016).

2.2.1 Previous research in the Taojiahu-Xiaocheng region

The Taojiahu-Xiaocheng survey is the first full-coverage investigation of settlement patterns and population dynamics to be carried out in the Jianghan Plain. However, the Hubei Institute of Cultural Relics and Archaeology has engaged in a long-term, archaeological research program targeting Neolithic walled settlements that are scattered across the Middle Yangzi River basin. Because of this program, both Taojiahu and Xiaocheng have been studied previously by local and provincial research teams.

***Taojiahu Site* (陶家湖遗址):** Taojiahu is situated in the northern half of the survey area, at the confluence of the Taojiahu and Silong Rivers. At 67 ha, it is much larger than Xiaocheng (which is 9.8 ha) and is surrounded by a drainage ditch and ovular earthen enclosure. Today, this wall enclosure rises 1-4 m above ground level, with base width of 25 m and a top of 2-4 m.

Within the walls, rice, cotton, rapeseed, peanut, soybean, and hemp were cultivated, and the farmers who live in this area also kept water buffalo that watered at the meeting point of the Taojiahu and Silong rivers. As a result, this portion of the site has been subject to heavy eroding at the river banks (Figure 2.4).

A preliminary survey of the settlement in 1998 conducted by the Hubei Sheng Wenwu Kaogu Yanjiusuo and the Yingcheng Bowuguan suggested that the site was occupied from the late Qujialing period to the early- to middle Shijiahe period (Li and Xia 2001). The results of the TXRSS and Li Dongdong's analysis has since revised the date of earliest occupation at the Taojiahu site to the Youziling period. No excavations of Taojiahu have been conducted to date.

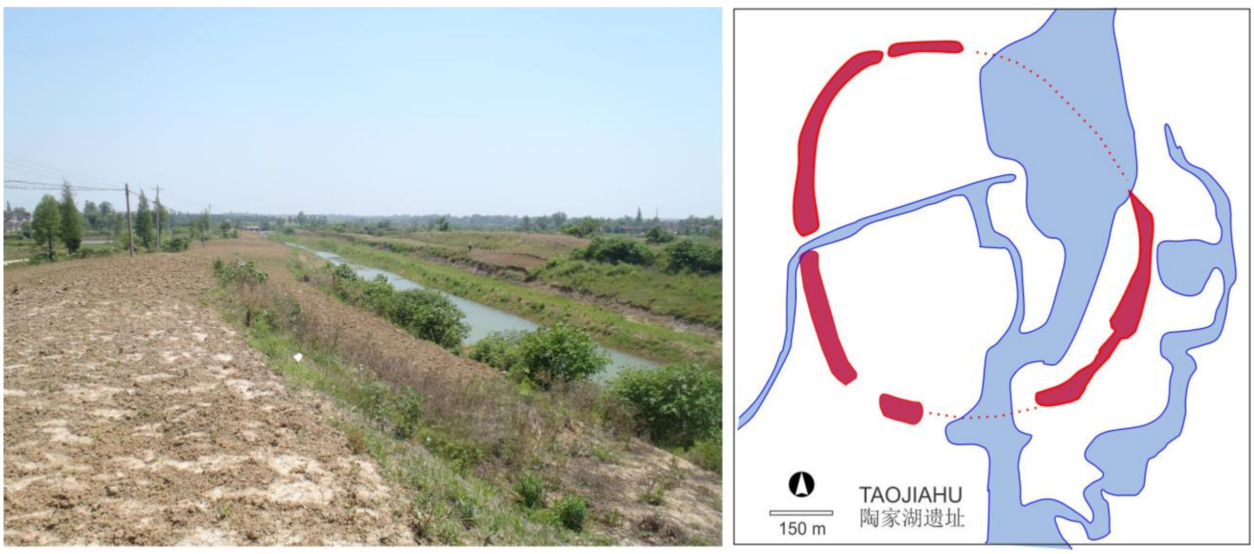

Figure 2.4: Photograph taken from the top of the eastern wall at Taojiahu facing south (left) and a map of the Taojiahu site (right; redrawn from Li and Xia 2001). Water is marked in blue and the Neolithic walls in dark red.

***Xiaocheng Site* (笑城遗址):** Xiaocheng is located in the southern portion of the survey zone in the middle of the Zaoshi river valley. It is one of the smaller Neolithic walled settlements found in the Jianghan Plain at 9.8 ha in total area. The earthen enclosure is L-shaped and the interior of the settlement is slightly higher in elevation than the area just outside the walls (Figure

2.5). Today, the Xiaocheng core area – the area enclosed by the walls – is planted with peanut, rapeseed, and ornamental tree crops, among others. Wet-rice crops and ponds for freshwater fish and turtle are common throughout the Zaoshi valley outside of the Xiaocheng walls.

In 2007, an archaeological team representing the Hubei Province Institute of Archaeology and the Tianmen County Museum excavated portions of the Xiaocheng core area and its earthen enclosure (Hubei Sheng 2007). Based on relative ceramic sequences, the excavators identified three phases of occupation and two periods of wall construction at the site. The first period of occupation is dated to the late Qujialing period at which point the first stage of wall construction was undertaken. The wall was not built in a single event, but rather was constructed in several episodes, with each episode distinguished by a different color of soil. Xiaocheng was occupied again in the Shijiahe period, though no wall construction or maintenance was undertaken during this time. After the Shijiahe period, Xiaocheng was not occupied again until the Zhou period, when the original Qujialing walls were built upon and expanded.

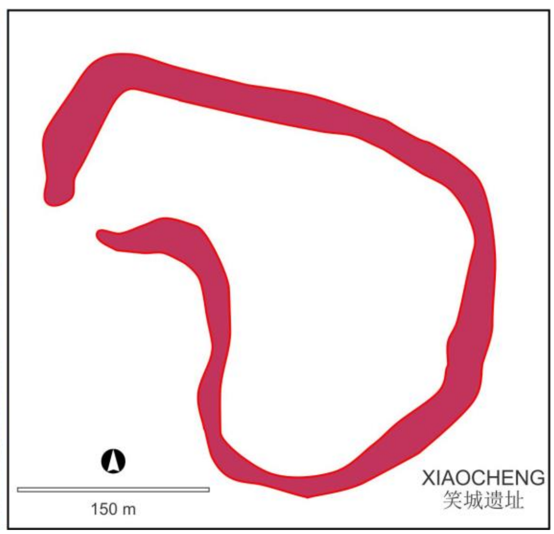

Figure 2.5: Photograph taken from the top of the northwestern wall at Xiaocheng facing north (left) and a map of the Xiaocheng walled area (right; adapted from Hubei and Tianmen 2007).

2.2.2 Survey methodology

The full-coverage, systematic pedestrian survey of the Taojiahu-Xiaocheng area was carried out using methods employed in other parts of China, specifically the Chifeng region and Upper Daling Valley (CICARP 2011; Peterson et al. 2014), which themselves derive from the methodology of the Basin of Mexico and Valley of Oaxaca regional settlement surveys (Blanton et al. 1982; Kowalewski et al. 1989; Sanders et al. 1979). During November and December 2013, a crew of archaeologists and students from the Hubei Province Institute of Archaeology, Wuhan University, and the University of Pittsburgh divided into several survey teams of three or four individuals. Team members walked transects spaced 50m apart, covering an average of 2 square kilometers each day.

Settlement evidence consisted primarily of surface scatters of ceramics, and in a few cases, flaked or ground lithic artifacts. As surveyors encountered areas where more than 3 sherds were found within a roughly 1 ha area, an artifact collection was made and that location recorded on 1:10,000 print of high resolution satellite imagery. Field boundaries, roads, creeks, and other visible surface features often served as convenient borders for these collection lots. Attempts were made to measure each lot at 1 ha, yet due to practical limitations including variations in terrain and the judgements of different survey teams resulted in lot sizes ranging from 0.08 - 1.76 ha, with a mean of 0.58 ha. In areas where the density of artifacts was low, a general collection was made of all the surface artifacts in that lot. If, however, the density of artifacts in a collection lot was high (roughly 0.5 sherds per m^2), a systematic collection was made by randomly drawing a $10m^2$ circle from within which all surface artifacts were collected. A total of 324 general collections and 132 systematic collections were made from 456 collection lots located across the survey zone.

Two sets of population estimates were made for each period of occupation based on both areal extents and density of sherd scatters. The rationale for these approaches is that, all else being equal, larger numbers of people produce more refuse than do smaller numbers of people (Drennan et al. 2015). The first approach uses settlement area as an index for population size, and is based on the idea that settlements that cover larger areas have larger populations. A site-size index was adopted by archaeologists working in the Rizhao region of eastern Shandong Province (Fang et al. 2004), who used modern and historic census data to determine that one hectare of occupation represents 72.2 individuals. The second population index combines both the area and density of artifact scatters to account for differences in the intensity of their occupation. Factors such as the spacing between houses and the length of their occupation have profound effects on the number of people who live in a one hectare area (Drennan et al. 2015). Settlement survey in the Chifeng and Daling regions of northern China combined information about the area and density of surface ceramic scatters with excavation data from Neolithic and Early Bronze Age households in order to translate the number of sherds per square meter into population numbers for each period of occupation (CICARP 2011; Peterson et al. 2014). The area-density index provides a view of local population size averaged across the span of an archaeological period, so that a group of 10 people living in an area for 100 years produces the same pattern as a group of 100 people living in an area for 10 years.

Employing both settlement size and area-density indices to make population estimates was crucial for understanding settlement dynamics of the Taojiahu-Xiaocheng region. During the Qujialing period, for instance, most evidence of occupation was in the walled areas at Taojiahu and Xiaocheng. Qujialing population estimates based on site area are relatively low (5,000 individuals), but the area-density estimates are twice this figure (7,000 – 14,000 individuals).

The disparity between these estimates demonstrates that these settlements were much more populous than expected given their physical size, suggesting there was some force that was pulling populations in towards the walled towns in this period.

2.3 NEOLITHIC OCCUPATION OF THE JIANGHAN PLAIN

2.3.1 Youziling Period (3900 – 3100 BCE)

The Youziling period is named after the Youziling site in Jingshan County, Hubei, that was excavated in the 1980s. It is the eastern regional culture period contemporaneous to the Daxi/Daixi culture period in the rest of the middle Yangzi River basin; Youziling-period materials have been recovered from a handful of sites in the Jianghan Plain, including Liuhe, Longzui, Tanjialing, and Xihuayuan.

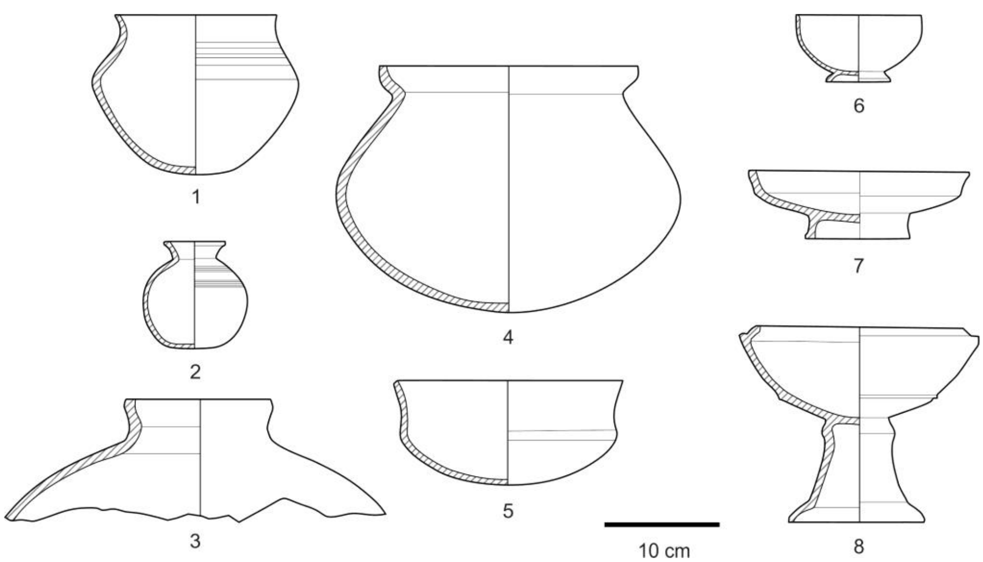

Figure 2.6: Examples of common Daxi period (contemporaneous with northern Jianghan Youziling period) pottery from the Chengtoushan site: 1, 2, 3 – guan 罐; 4 – fu 釜; 5 – bo 钵; 6 – wan 碗; 7 – pan 盘; 8 – dou 豆 (Redrawn from Hunan 2007:364-439).

Though the Taojihau-Xiaocheng area was thought to be first settled in the Qujialing period, several Youziling sherds were collected by survey teams. These sherds show traces of being hand-built from a sandy clay with crushed lacustrine shell inclusions, and were fired to a reddish-orange to dark-gray color (Figure 2.7). The friability of these sherds suggests they were fired at low temperatures. Identifiable vessel forms include *wan* 碗and *bo* 钵bowls, *weng* 瓮urns and *ding* 鼎 tripod cooking vessels. Surface decoration is rare, though the feet of ding are sometimes decorated with impressions potters made by using their fingertips.

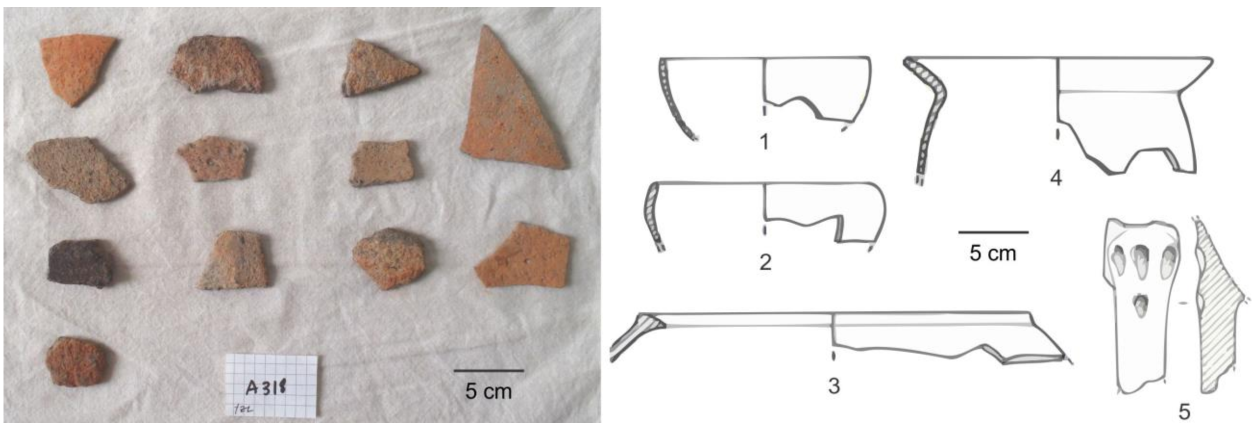

Figure 2.7: Youziling sherds recovered from survey (left) and illustrations of vessel forms identified during survey (right): 1 – bo 钵 (A39: 4), 2 – bo 钵 (A39:3); 3 – weng 瓮 (A39:1); 4 – ding 鼎 (A39:2); 5 - ding foot 鼎足 (A39:5). Drawing adapted from D. Li 2016: 22.

Only 57 Youziling sherds were recovered from 15 collection lots (Figure 2.8). All but one collection lot containing Youziling sherds were located in the northern half of the survey area in the Silong river valley. A single collection lot yielding Youziling materials was found in the southern zone in the low-lying Zaoshi river valley. This collection lot, as well as a second, isolated lot in the north, likely represent single family homesteads or small clusters of a few households who lived together for a brief portion of the period. The collection lots located along the Silong valley were clustered together over roughly a 1 km area and likely represent a small, dispersed middle Neolithic village composed of several households that would have interacted with one another on a fairly regular basis. The location of these areas of occupation on or near rivers would have provided residents with access to abundant wild riverine resources as well as land that would have required minimal management to support wet-cultivation of rice and other cereal crops.

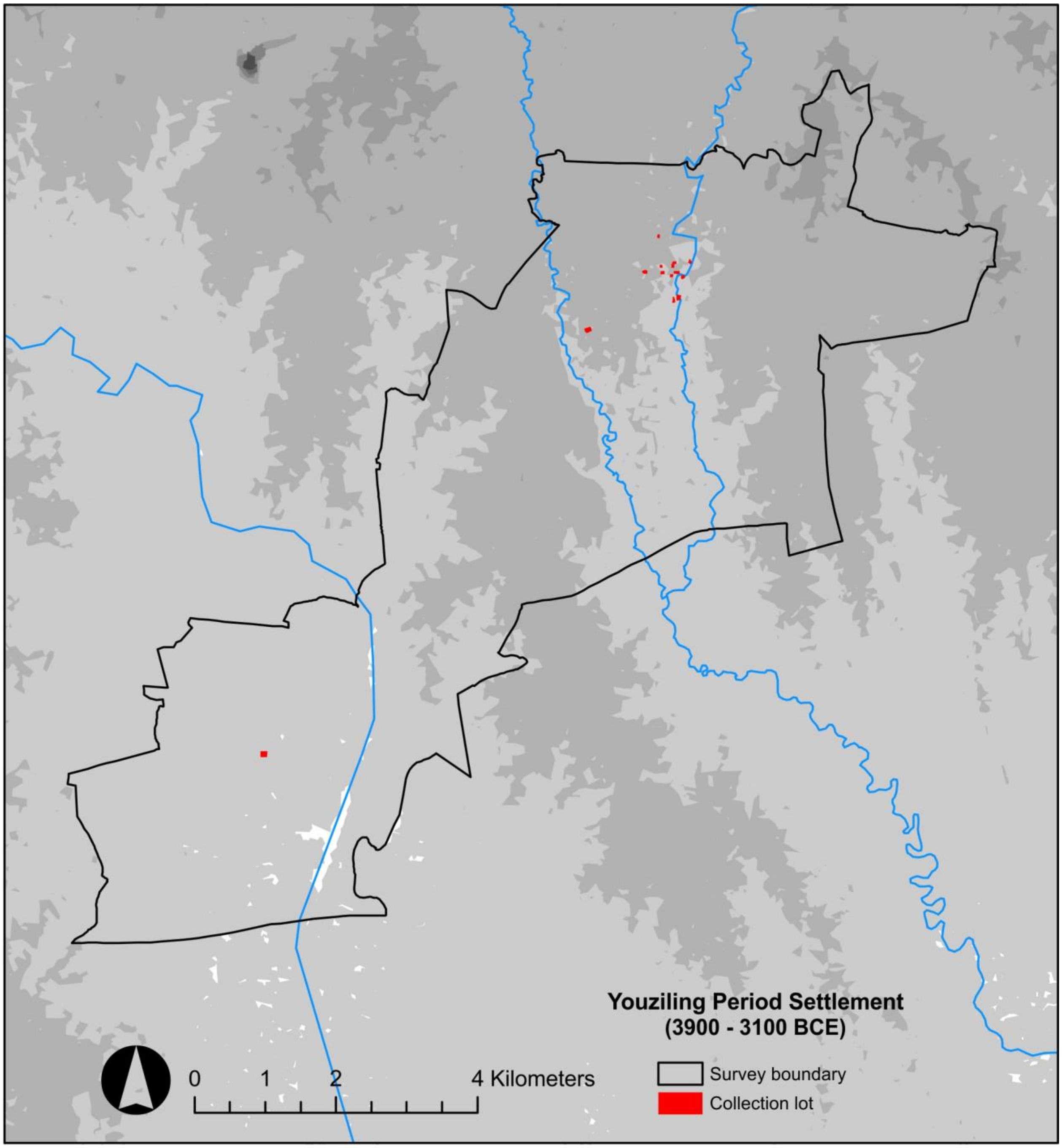

Figure 2.8: Location of collection lots containing Youziling period sherds.

Regional population estimates for the Youziling period are 50-100 individuals with the Chifeng index and 400 individuals with the Rizhao index. Although these estimates appear quite disparate, they ultimately both characterize Youziling period settlement comprised of low-density, dispersed homesteads and hamlets.

2.3.2 Qujialing Period (3100 – 2600 BCE)

The Qujialing type site is located in Jingshan County, roughly 40 km west of Taojiahu and Xiaocheng. Materials associated with the Qujialing archaeological culture have been found at enclosed Neolithic sites throughout the middle Yangzi River valley, as well as north in the Nanyang Basin and Central Plains, west to the upper Yangzi valley, and south to the Dongting Plain.

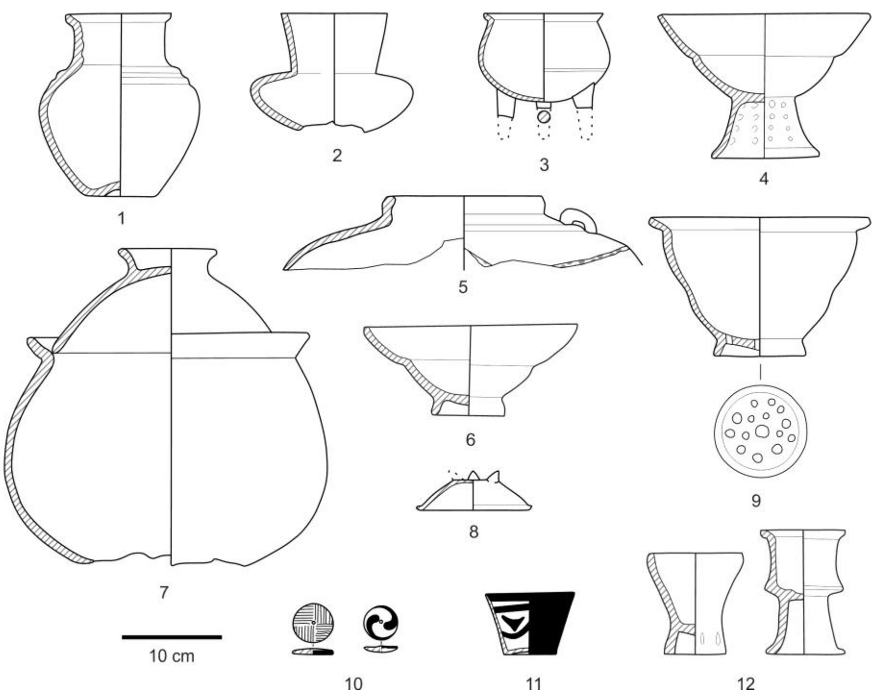

Figure 2.9: Examples of Qujialing style pottery: 1 – guan 罐; 2 – hu 壶; 3 – ding 鼎; 4 – dou 豆; 5 – weng 瓮; 6 – wan 碗; 7 – fu with lid 釜、器盖 (used as a burial urn); 8 – lid 器盖; 9 – zeng 甑; 10 – spindle whorls 芳纶; 11 – painted bei 杯; 12 – bei 杯; (2, 3, 10 redrawn from Hubei and Tianmen 2007: 474-477; all others redrawn from Hubei et al. 2003:43 -77).

A major distinguishing characteristic of Qujialing pottery is that most small and medium-sized vessels were thrown on the fast-wheel. As a result, many Qujialing vessels are made of a very fine paste with little to no inclusions, though some larger vessels have very coarse pastes and were likely made by coiling or other hand-building techniques. Angular quartzite sand and, occasionally, organic fibers were apparently potters' preferred additives to increase the 'tooth' and green strength of clay pastes. Potters also intentionally manipulated the surface color of vessels by managing firing environments to produce dark grey and black wares through reduction, or red and orange wares through oxidation. Most vessels were, however, tan or light gray in color with minimal decoration. Where applied, common Qujialing decorative motifs include cord-marking, check-stamps, incised lines, and appliqued bands. Several excavation reports describe cups and small vessels that were slipped and painted with elaborate geometric designs, but no such sherds were recovered during the Taojiahu Xiaocheng survey, either because the exterior slip eroded away through exposure or these kinds of vessels were used primarily for burials and were otherwise exceedingly rare in surface collections. Typical Qujialing vessel forms include *ding* 鼎 tripod cooking vessels, *guan* 罐 jars, *bei* 杯 cups, *pen* 盆 basins, *wan* 碗 bowls, and vessel lids (Figure 2.9). Other objects, such as spindle whorls, were also made of fired clay.

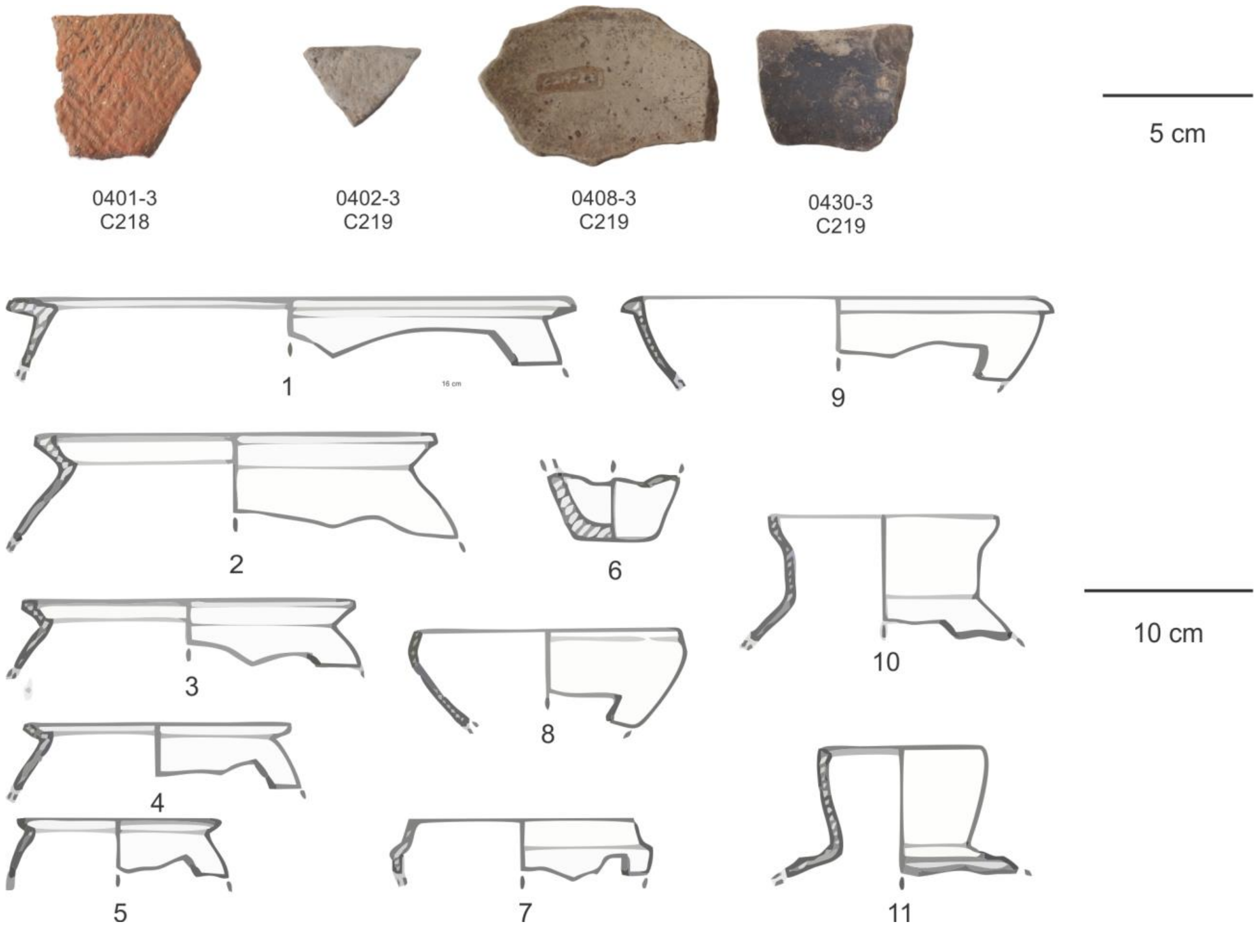

Figure 2.10: Qujialing period pottery recovered in survey (top) and illustrations of vessel forms identified during survey (bottom): 1-5 - guan 罐 (A15: 2, A318:7, A338:1, A344:1, A39:6); 6 – bei 杯 (A368:1); 7 – guan 罐 (A39:8); 8 – bo 钵 (A39:8); 9 – pen 盆 (C188:1); 10–11 – guan 罐 (B1:1, C242:9). (Drawings adapted from D. Li 2016: 24).

Nearly 4,000 Qujialing sherds were recovered from 117 collection lots, with 88 (75%) of these collection lots situated within the two walled enclosures (Figure 2.10). The northern zone, the area north of the Zaoshi River, contained 96 of these collection lots, almost all of which were spread across the walled core zone of the Taojiahu settlement (83 lots; 86%). By contrast, 21 collection lots with Qujialing period sherds were found in the southern zone of the survey area, only five of which were located within the walled core area of Xiaocheng. The remaining 16 southern collection lots were dispersed more widely across the land just outside of the Xiaocheng walls (Figure 2.11).

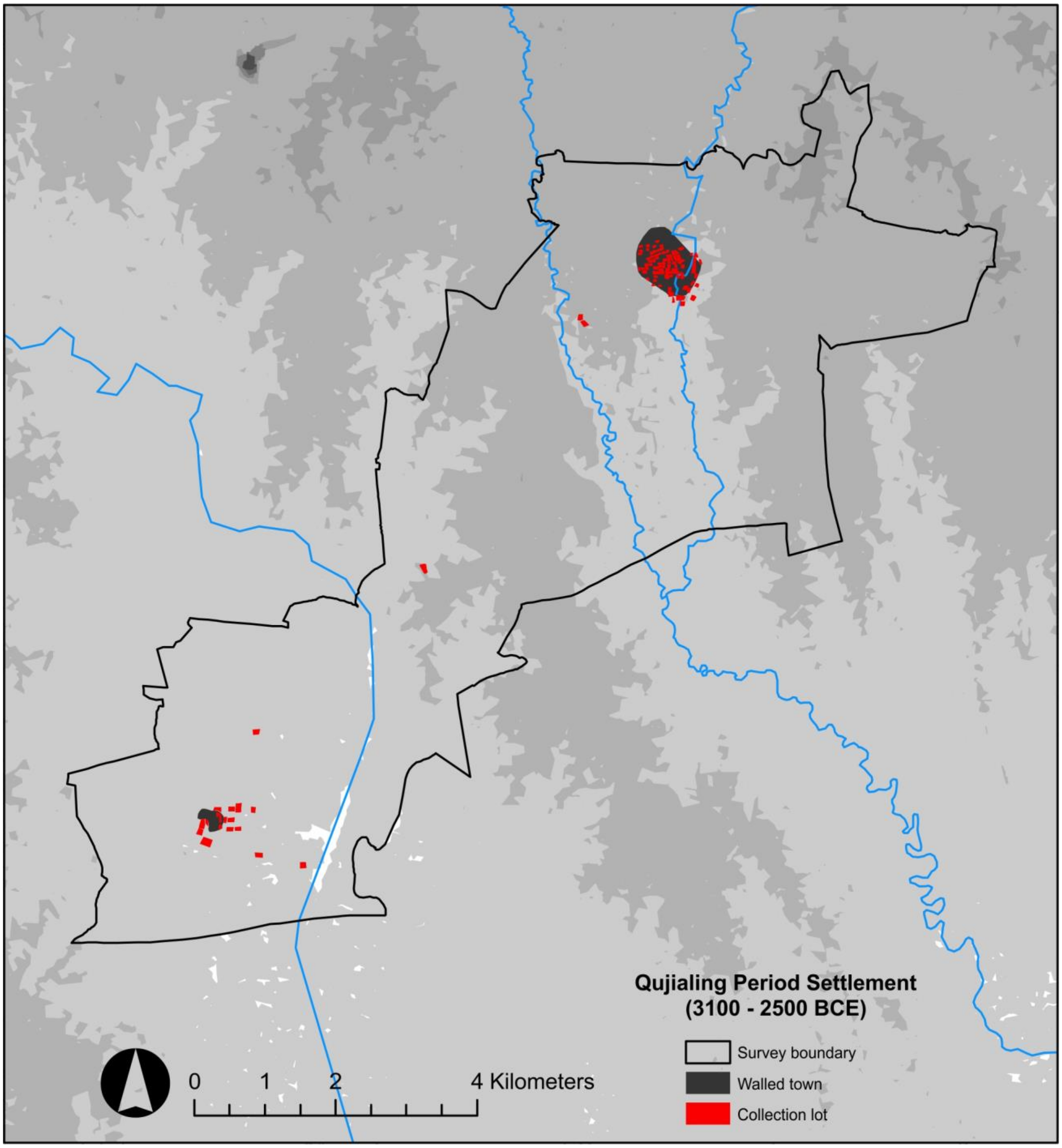

Figure 2.11: Location of collection lots containing Qujialing period sherds.

Population estimates for the Qujialing period are 7,000 – 14,000 individuals with the Chifeng index and 5,000 individuals with the Rizhao index. The disparity between these two estimates highlights the fact that people were living in much more compact settlements than in the Youziling period or even today in modern farming villages. These populations were split between two large, clustered communities centered at the Taojiahu and Xiaocheng walled settlements. Most occupants of the region lived in the northern zone (9,000 individuals) and especially in the Taojiahu walled core area, which had an approximate population of 6,800 individuals. To offer some context, this means that the 67 ha within the Taojiahu walls had the same population density as the five boroughs of modern-day New York City. The southern zone was less populated than the north (1,500 individuals), and approximately half of the southern population lived at Xiaocheng (830 individuals). Though Xiaocheng was much smaller than Taojiahu, these population estimates show that the 10 ha enclosed by the wall was as densely populated as modern Paris.

There is some indication that the emergence of these communities was a local development as opposed to a migration from elsewhere. This is hinted at by the correspondence of Taojiahu with the site of the northern village identified in the Youziling period. Moreover, the close spatial correlation between areas of occupation and the location of walls suggests that the walls were constructed at roughly the same time as, or just before, local population growth. If populations grew before the walls were constructed, we would expect to see more evidence of occupation beyond the perimeter of the walls. This is consistent with other archaeological evidence: ceramic data recovered in excavations of the Xiaocheng walls points to a construction date in middle- to late Qujialing period (Hubei and Tianmen 2007).

The most notable feature of the Qujialing period settlement patterns is the scarcity of settlements found in the landscape outside of Taojiahu and Xiaocheng. While some of this area was occupied, it is much less than would be expected for a 500-year period. It is this aspect of settlement patterns, along with the observation that the walled communities were more densely populated than their areal extents would imply, that offer the most compelling evidence for the emergence of centralized leadership in these communities.

2.3.3 Shijiahe Period (2600 – 2000 BCE)

The Shijiahe period is named for the Shijiahe site, located roughly 30 km southwest of the Taojiahu-Xiaocheng survey area in Tianmen County, Hubei Province. Shijiahe is a massive settlement complex composed of 8 km^2 of occupied territory centered on a walled core measuring 120 ha. The Shijiahe period represents the final phase of Neolithic occupation in the Middle Yangzi River area; the end of Shijiahe period occupation is followed by a lack of evidence of occupation at sites from the Jianghan and Dongting Plains to the Liangzhu region of the lower Yangzi River valley.

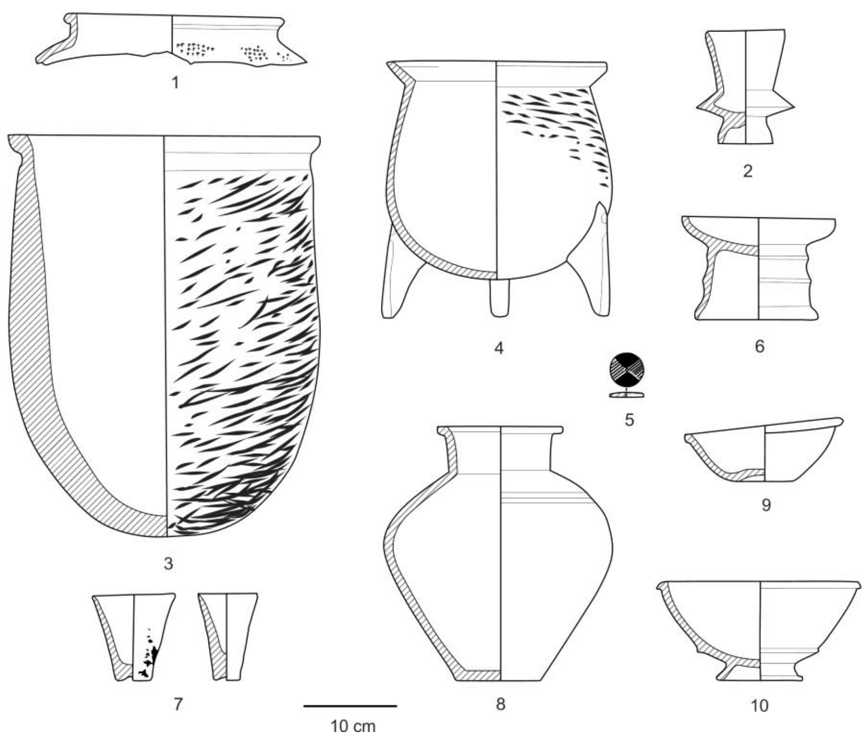

Figure 2.12: Examples of Shijiahe period pottery: 1 – weng 瓮; 2 – hu-shaped vessel 壶形器; 3 – gang 缸; 4 – ding 鼎; 5 – spindle whorl 芳纶; 6 – pan 圈足盘; 7 – bei 杯; 8 – guan 罐; 9 – bo 钵; 10 – wan 碗. (4 and 8 redrawn from Hubei and Tianmen 2007: 480; all others redrawn from Hubei et al. 2003: 160-171).

Shijiahe pottery, like Qujialing pottery, is wheel-thrown and is often grey, red, or black in color. Apart from storage and cooking vessels, most pots have a fine paste with few inclusions. Many of the same vessel classes are represented in Shijiahe pottery as in Qujialing pottery including *ding* 鼎 tripod cooking vessels; *pan* 盘 and *dou* 豆 dishes, *wan* 碗 and *bo* 钵 bowls, and *bei* 杯 cups for serving; *weng* 瓮 urns, *gang* 缸 vats, and *guan* 罐 jars for storage (Figure 2.12). Shijiahe vessels are more often decorated than Qujialing vessels, however, with cord-marking and stamping the most common decorative motifs, followed by appliqued or impressed horizontal banding. Other decorative patterns include circular stamps (as if with a reed) and denticulate banding, which are usually found just below the vessel orifice. Storage vessels and jars are very often decorated. Red *bei* cups are common in Shijiahe period contexts, with thicker bottoms and taller walls than their Qujialing period counterparts (Figure 2.13). A large number of clay figurines depicting humans and animals have been discovered at the Shijiahe site, but none were recovered from the Taojiahu-Xiaocheng survey region.

Some 3,700 Shijiahe period sherds were collected from 207 collection lots across the study area (Figure 2.14). In the north, 48 collection lots were located inside the Taojiahu walls while 77 were located outside; in the south, 16 were located inside the walled area of Xiaocheng while 66 were located outside. These numbers alone reveal that settlement in the Shijiahe period was much more dispersed than in previous periods.

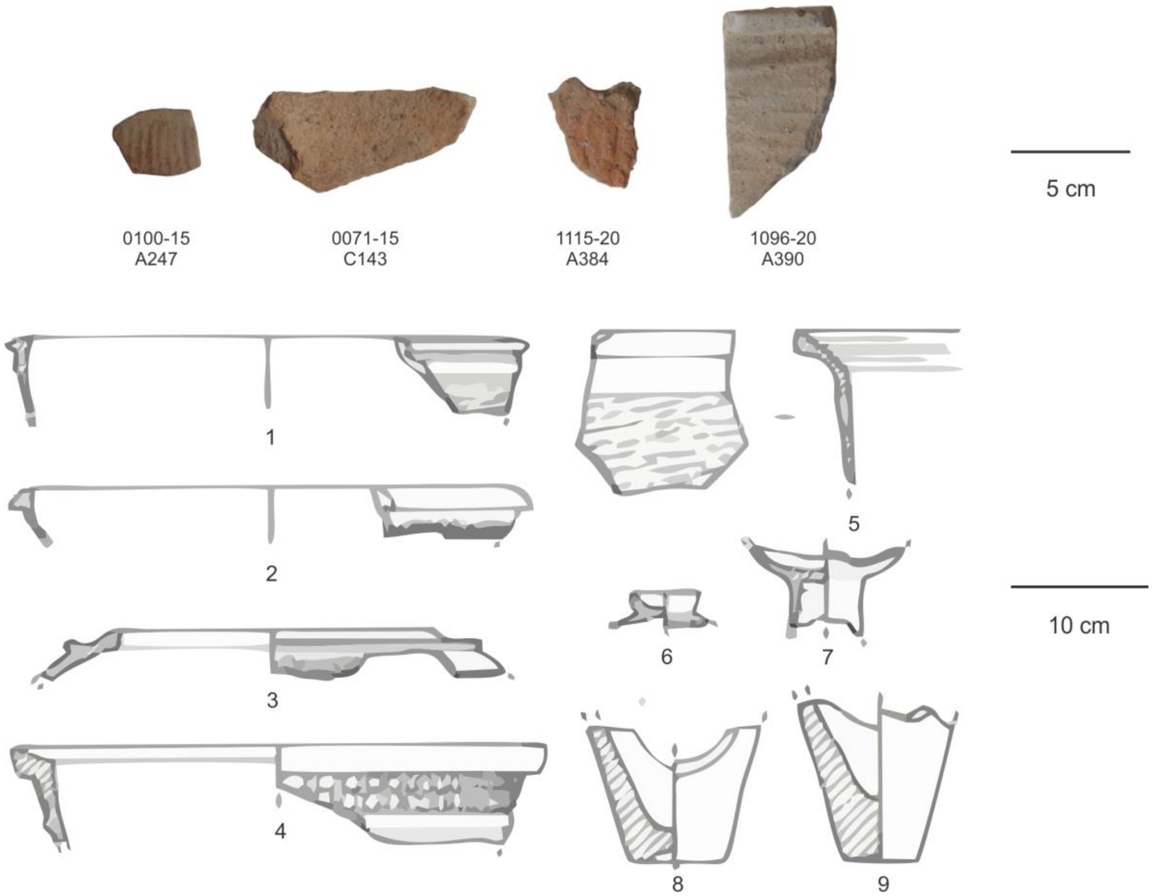

Figure 2.13: Shijiahe period pottery recovered in survey (top) and illustrations of vessel forms identified during survey (bottom): 1, 4, 5 - gang 缸 (A371:2, A370:3, A379:17); 2 – pen 盆 (A107:2); 3 - weng 瓮 (A379:16); 6 - lid 器盖 (A337:2); 7 - dou 豆 (A379:2); 8-9 – bei 杯 (A376:1, C242:8). (Drawings adapted from D. Li 2016: 25).

Population estimates for the Shijiahe period are 5,500 – 11,000 individuals with the Chifeng (area-density) index, and 9,000 with the Rizhao (site area) index. These values represent a slight decrease in the area-density population index and a slight increase in the site area index, together revealing that population levels stayed stable while settlement became more dispersed. This was accompanied by a demographic shift from north to south. Populations declined to 5,550 individuals in the northern zone, as populations living in the southern zone rose to 2,700 individuals. A similar demographic pattern emerged at the settlement level, as the population fell at Taojiahu (from 6,800 to 3,800 individuals) and grew at Xiaocheng (from 830 to 1,400 individuals). Thus, over time, Taojiahu declined in population and became less centralized while Xiaocheng grew in population and became increasingly centralized.

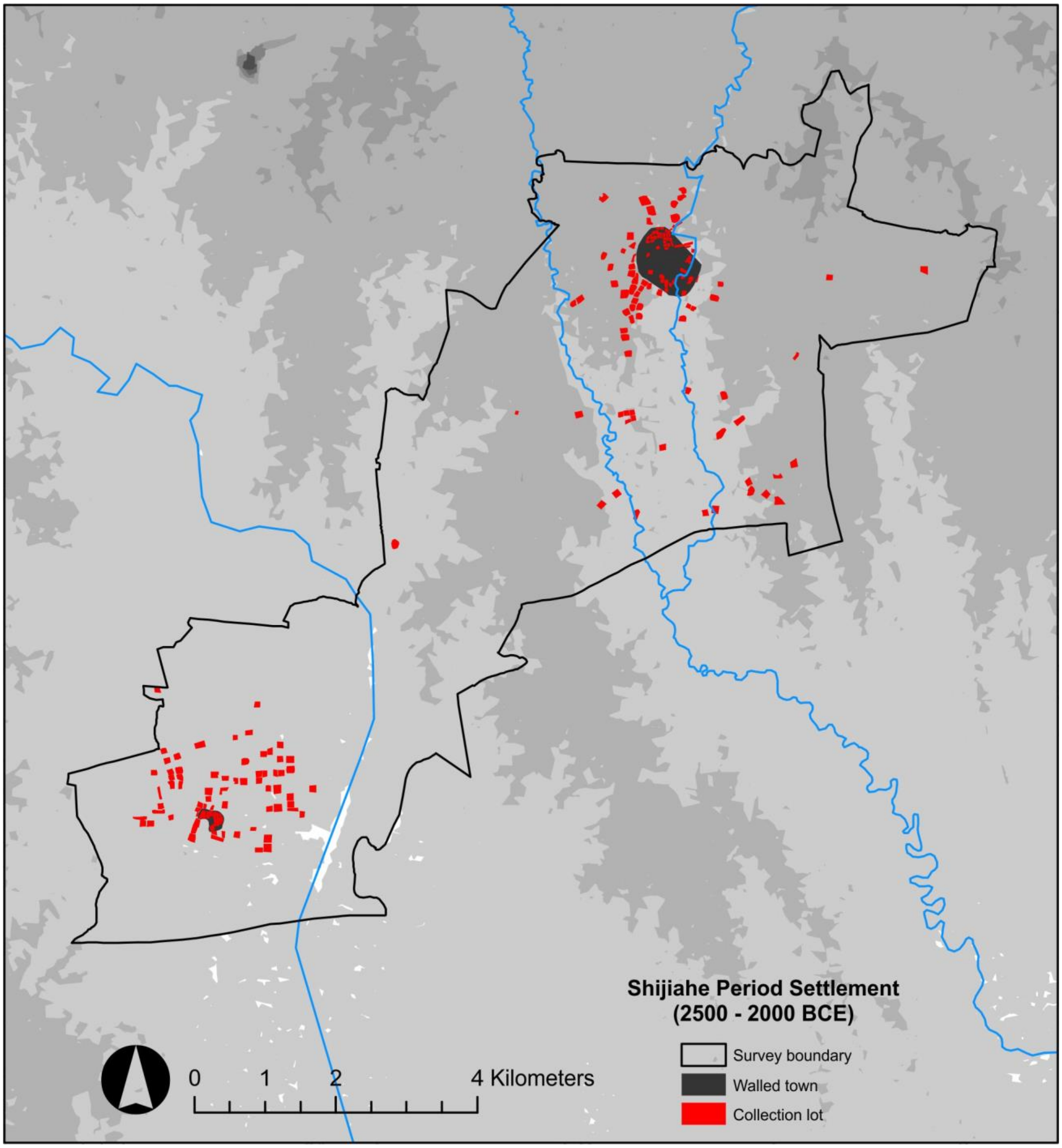

Figure 2.14: Location of collection lots containing Shijiahe period sherds.

The Shijiahe settlement patterns point to a fundamental shift in the sociopolitical structure of these communities. On the one hand, population decline and dispersal at Taojiahu suggests a dissolution of the centripetal forces that led to such strong population nucleation in the Qujialing period. On the other, population growth in and around Xiaocheng suggests a corresponding increase in such forces to the south.

2.3.4 Post-Shijiahe Period

The Shijiahe period was followed by a large-scale depopulation of the Taojiahu-Xiaocheng region that lasted until the Western Zhou period (1046 – 776 BCE). Only six Shang period (1600 – 1046 BCE) sherds were recovered, all of them from Taojiahu. The survey results accord with findings from the 2007 Xiaocheng excavations (Hubei and Tianmen 2007), which documented a hiatus in occupation of the site from the end of the Shijiahe period to the Zhou period. Similar trends have been observed at archaeological sites along the Yangzi River, leading some scholars to refer to the 'collapse' of Neolithic society in southern China (for an overview, see Deng et al. 2009).

2.4 SOCIAL DYNAMICS OF THE JIANGHAN PLAIN

The Taojiahu-Xiaocheng survey systematically documented the transformation of small, scattered agricultural farmsteads into large, centralized walled towns in the northern Jianghan Plain. These towns are unique in that they developed through *in situ* population growth rather than by drawing existing hinterland populations to the core. In fact, the survey demonstrates that a very small fraction of the landscape outside of the walled towns was occupied in the Neolithic. Thus, the Taojiahu-Xiaocheng region lacked emergence of regional settlement hierarchies of the kind that are associated with the development of complex societies in other parts of the world (Drennan and Peterson 2006; Liu et al. 2004; Wright and Johnson 1975). Accordingly, this raises the issue of what caused population nucleation within these walled towns, and what function these walls served. Several hypotheses have been put forward, including the threat of conflict from other walled towns (Guo 2005; Pei 2011) as well as from outside the Jianghan Plain (Meng 1997; X. Zhang 1998; Z. Zhang 1994), the risk of flooding (Lu 1999; Wang 1998), yet neither phenomenon can sufficiently account for settlement patterns. Mortuary analyses have revealed almost no evidence of skeletal trauma typically associated with warfare, and, as Li argues, the large, sloping wall enclosures at Taojiahu and Xiaocheng are not efficient fortifications, especially compared to other, known fortifications in northeastern China (D. Li 2016). Similarly, Li concluded that flooding was not likely to be the major catalyst for the construction of walled towns, as populations actually moved to the south, which is at a slightly lower elevation than the north, and occupied areas outside the protection of the walls in the Shijiahe period. Other theories proposed for the development of these walled towns involve ritual authority and interpret wall construction as a specific ritual that served to integrate local populations (Priewe 2012).

What is evident from these settlement patterns is that population growth, centralization, and the construction of walls all happened within a relatively small window of time. The large number of people that lived together in these settlements would have interacted with one another regularly and intensively; this intensive interaction may have facilitated the development of economic interdependence between households. It is this issue of economic interaction and interdependence that the research presented in the next chapters seeks to examine.

3.0 MATERIALS, METHODS, AND ANALYSIS OF POTTERY COMPOSITION

As was introduced in Chapter 1, the goal of this research is to characterize the relationship between political and economic networks by tracking long-term changes in pottery exchange networks in the Taojiahu-Xiaocheng region. Identifying patterns of pottery exchange within this region requires that we can distinguish between sources of pottery on the basis where or by what groups it was made. This chapter outlines the methodology and sampling strategy devised to detect meaningful patterns in the compositional variability of pottery from the study region. A combination of portable x-ray fluorescence (pXRF), desktop x-ray fluorescence (WD-XRF), and x-ray diffraction (XRD) were used to characterize the chemical and mineralogical signature of a utilitarian pottery. Groups of compositionally similar sherds were then identified through multivariate analyses.

Central to this research was the development of a sampling strategy that would facilitate estimating the proportions of different compositional groups present within local communities with a high degree of statistical confidence. A stratified sampling strategy was developed in which sherds were chosen from discrete spatial units across the study area that correspond with meaningful social units. This ensured that all occupied areas of the survey zone were represented in the full sample.

This chapter begins with an overview of the use of geochemical analyses in the study of archaeological pottery. For this research, I use a combination of portable and desktop x-ray fluorescence spectroscopy, and x-ray diffraction technologies to identify compositionally similar groups of pottery. The feasibility of these methods was initially demonstrated by a pilot study of 80 sherds from the Taojiahu-Xiaocheng region, and these techniques were ultimately applied to a much larger sample of 1,150 sherds.

3.1 USING GEOCHEMICAL TECHNIQUES TO CHARACTERIZE POTTERY COMPOSITION

Geochemical analysis has emerged as a key methodology for archaeologists endeavoring to reconstruct systems of craft production and exchange. Compositional studies of pottery have repeatedly demonstrated that the chemical signature of potting raw materials varies from region to region in terms of major, minor, and trace elements. More importantly, a subset of these studies have detected chemical variations between different clays from a single region, in some cases among pots produced in communities only two kilometers apart (Cui et al. 2015; Stark et al. 2000; Bishop et al. 1988; Jorge et al. 2013; Vaughn and Neff 2004). Such fine-grained data can be used not only to help reconstruct patterns of long-distance exchange in the archaeological record, but also to understand the nature of sociopolitical and economic interactions both between and possibly within communities.

There are two major types of study that link the composition of pottery with the distribution of sherds across a landscape. The first type is the traditional sourcing study, in which the chemical signature of archaeological pottery is compared with that of modern raw materials to determine the provenance of ancient raw materials (Bonomo 2017; Glascock and Neff 2003; Gomez et al. 2002; Joyce et al. 2006; Vaughn and Neff 2004; Stark et al. 2007). As this approach is based on the notion that modern clays can be used to characterize ancient clays, it is first necessary to demonstrate that the clays that are accessible to researchers today are the same clays that were used by ancient potters. Traditional sourcing studies offer important insight into procurement patterns and resource availability, and the long distance movement of goods. The second type of study uses the relative compositional variability within a sample of sherds to identify 'source' groups quantitatively (Culbert and Schwalbe 1987; Frankel and Webb 2012; Hall and Minyaev 2002; Hung 2011; Zhu et al. 2004). As sherds are only compared with other sherds rather than modern clay samples, it is not necessary to prove that modern and ancient clay deposits are the same. This is especially critical for investigations of floodplain regions like the Jianghan Plain, where modern clays are both abundant and exposed to the surface. Conditions such as these make it exceedingly unlikely that attempts to match specific clay beds accessible today with raw materials used by Neolithic potters will succeed. Even if it were possible to pinpoint the locations of these clay sources, this information is not especially instructive to aims of this research project. Instead, the aim of this study is to characterize the nature and extent of pottery distribution networks, not to identify where raw materials were originally collected, which is readily accomplished by analyzing the patterns of variation in compositional groups of pottery recovered across the survey area. It is for these reasons I chose not to divert resources to the analysis of clays obtained from modern deposits, and instead adopted the second 'relative' type of compositional study.

Compositional groups that are determined through the relative sourcing approach are not only related to separate raw material sources but also reflect the ratio of clay to temper in the clay paste. The recipe potters use to produce a workable clay paste is often part of a suite of techniques that are shared among potters trained in the same community. These shared techniques tend to be deeply embedded in potters' practice and, as such, are resistant to change (Arnold et al. 1991; Costin 1991; Hall et al. 1999; Lave and Wenger 1991; Sillar and Tite 2000; Stark et al. 2000; Wenger 1998). Thus, even if all ceramic vessels present in a region are made from a single type of clay and temper, it may be possible to identify distinct potting communities based on unique combinations of plastic and non-plastic inclusions present in ceramic vessels.

To identify the compositional signatures of pottery samples, archaeologists commonly use one of several geochemical techniques. Among these techniques are neutron activation analysis (NAA), atomic absorption spectrometry (AAS), inductively coupled plasma atomic emission or mass spectroscopy (ICP-AES, ICP-MS), X-ray fluorescence (XRF), and X-ray diffraction (XRD) (Bishop et al. 1982; Chen et al. 1999; Hunt and Speakman 2015; Speakman et al. 2011; Tsolakidou and Kilikoglou 2002). This research will employ a combination of portable XRF (pXRF), desktop WD-XRF, and XRD analysis to characterize the composition of archaeological sherds on the basis of elemental and mineralogical differences (Bakraji 2006; Chen et al. 2011; Ma et al. 2004; Wu et al. 2005; Zhu et al. 2004; Zhu et al. 2002). This combination of techniques importantly offers practical advantages relative to other techniques: analyses by pXRF, WD-XRF, and XRD require considerably less money and time in the field than do other geochemical techniques, specifically NAA and ICP-AES. These factors are of key importance to this project, as answering the research questions with a high degree of statistical confidence requires a sample of sherds much larger than the sample size of most contemporary studies (Anderson et al. 2011; Bonomo 2017; Cui et al. 2015; Falabella et al. 2013; Hung 2011; Iizuka 2013; Jorge et al. 2013; Kosakowsky et al. 2005; Stark et al. 2007).

There has been significant debate circling the question of whether of pXRF is capable of reliably characterizing the composition of non-homogenous materials like pottery (Shackley 2011). However, careful application of the technique has been shown to produce compositional data that is reliable and accurate and, most vitally for the current study, reflective of behavioral differences in the archaeological record (Speakman et al. 2011; T. Li 2016). Rather than rely on other studies, however, I developed a pilot study designed to test the feasibility of using pXRF, desktop XRF, and XRD for the identification of Neolithic pottery exchange networks. Furthermore, close tracking of instrumental drift and a secondary study testing the reliability of the particular pXRF instrument I used, demonstrate that the results of this study both accurately and reliably capture geochemical differences in Qujialing and Shijiahe pottery.

3.2 PILOT STUDY

During the summer of 2014, I selected 80 sherds from the Taojiahu-Xiaocheng Regional Settlement Survey for elemental and mineralogical analysis through portable x-ray fluorescence (pXRF), desktop XRF, and x-ray diffraction (XRD). This pilot study was designed to determine whether it was possible and practical to study pottery economic networks in the northern Jianghan Plain with this constellation of geochemical methods.

Of these three methodologies, the pilot study was predominantly focused on pXRF analysis, with desktop XRF and XRD methods representing complementary, but secondary, sources of data. Desktop XRF is often considered to provide more reliable and accurate results than pXRF because the preparation of samples for desktop XRF analysis involves grinding up a small sample of sherd into a homogenous substance. This may also be related to the environments in which readings are taken (a laboratory setting versus a field setting) than the instruments themselves (Speakman et al. 2011). To clarify whether there is any truth in this assumption, the same sherds were tested using both techniques. XRD spectroscopy identifies mineralogical composition, and was selected to complement the elemental analyses provided by both XRF methods. Minerals such as the polymorphous K-feldspars sanidine, orthoclase, and microcline, which were formed under different conditions and as a result have different crystalline structures, look identical at the atomic level (all three potassium feldspars share the chemical equation $KAlSi_3O_8$). Relying on elemental composition alone may cause us to overlook important mineralogical variations between sherds arising from the use of different raw materials by different production units.

The 80 sherds that were selected for pXRF analysis included 20 sherds from each Taojiahu and Xiaocheng dating to the Qujialing period (3100 -2500 BCE) and 20 sherds from each settlement dating to the Shijiahe period (2500 – 2000 BCE). Of these 80 sherds, 28 were analyzed further by desktop WDXRF, and 16 were analyzed by XRD. These sherds were not selected randomly, but rather were chosen to represent the broad range of pottery paste colors and textures present in the region under the assumption that these sherds would have the most dissimilar compositional signatures. This allowed me to determine the feasibility of these techniques for understanding pottery exchange in the Jianghan Plain. If it turned out that the geochemical profiles of these sherds showed little difference, it would make distinguishing between clay sources or production locales of sherds that were visibly more similar extremely difficult. If, on the other hand, the results of these analyses could identify compositional variations between sherds, it would demonstrate that this combination of techniques was sensitive enough to answer the broader questions this research was designed to address.

3.2.1 Pre-treatment procedures

Although pXRF is in principle a non-destructive technology, I opted to pre-treat sherds to reduce the probability that contaminants on the sherd exterior would unduly affect compositional readings. First, a thumbnail-sized sample of each sherd was removed and the surface of the fresh break was sanded to produce a flat surface. This procedure served both to preserve additional material for future analyses and to reduce the likelihood of external contamination. A Thermo Scientific Niton XL3t 950 GOLDD+ pXRF spectrometer was used to take readings at four different points along the newly-sanded section of each sherd to capture the range of chemical variability of the specimen's clay paste. Each of the four readings taken per sherd lasted 180 seconds. This 180 second assay consisted of three 60 second irradiation cycles: a main range filter (Al and Fe filter; 40kV, 50mA), a high range filter (Mo filter; 50 kV, 40mA), and a low range filter (Cu filter; 20kV, 100mA), all of which were compiled into a single output spectrum by software internal to the Niton. The four 180-second readings were then averaged together to reduce the degree to which readings were affected by the heterogeneous nature of the clay paste.

Preparations for desktop XRF and XRD analysis were more extensive. The 28 sherds that were analyzed by desktop XRF were prepared and processed by Dr. Luo Wugan of the Department of Archaeometry, University of the Chinese Academy of Science. His lab ground a small portion of each sherd into a homogenized powder with an agate mortar, which was subsequently passed through a 360-mesh sieve. The powdered specimen was kept at 200˚C for two hours until it dried fully, and then 0.5 g of dry powder were fused into a glass bead using a CLAISSE M4 Gas Fluxer and 5.0 g of lithium tetraborate ($Li_2B_4O_7$) as a fluxing agent. This produced a fused glass bead containing a small, homogenous sample of each sherd specimen. This glass bead was then analyzed using a PANalytical Axios-Minerals wavelength dispersive

XRF spectrometer, equipped with a 2.4 kW Super Sharp Tube (SST) and Rh anode x-ray excitation system. Preparation and processing of the 16 sherds analyzed by XRD was carried out by Dr. Huang Jiwu at the Key Laboratory of Non-Ferrus Metal Material Sciences and Engineering, School of Material Science and Engineering, Central South University. As with the preparation protocol for desktop XRF, specimens analyzed by XRD were prepared by grinding a portion of each sherd into a fine, homogenized powder using an agate mortar and pestle. Each powdered sample was mounted on a Rikagu D/Max-2500 X-ray diffractometer, and patterns of diffraction were analyzed using the MDI Jade XRD software package.

3.2.2 pXRF results of the pilot study

Thirty-three elements were measured in the 80 sherds analyzed by pXRF, 12 of which were reliably detected in each of the four readings for each specimen (Ba, Ca, Cr, Fe, K, Mn, Rb, Sr, Ti, V, Zn, and Zr). All elements were measured in atomic abundance (photon counts per second), and these raw measurements were automatically converted and reported as parts per million with Niton's factory preinstalled calibration routine for soil analysis. The lack of flexibility is not ideal for this kind of analysis, a point which has been made repeatedly (for example, Speakman et al. 2011). However, as all measurements were converted to ppm following the *same* calibration curve, the relative compositional differences observed among specimens ultimately reflected geochemical variation. Given that the purpose of the pilot study was not to determine the absolute compositional signatures of pottery, but rather to evaluate if it was even possible to identify relative differences between sherds, this problem was temporarily overlooked.

After all the pXRF readings were taken, sherds were organized into groups based on the similarity of their composition. These groups represent statistical 'sources' of pottery, and the distribution of these source groups through space can be used to highlight how these sources were accessed and consumed by occupants of the northern Jianghan Plain.

While there are many ways to identify compositional groups, this study employs a combination of principal component and hierarchical cluster analyses. Some researchers have pointed out that the use of cluster analysis alone may produce skewed compositional groups, because elemental abundances never represent truly independent observations (Glascock et al. 1998). If several variables reflect the same phenomena, cluster analysis may produce skewed groupings which overemphasize certain relationships and downplay others. As important as this point is conceptually, it can be a complicated distinction to maintain in practice. For exploratory applications similar to that employed here, managing the potentially confounding effects of dependent variables is best accomplished with prudent analysis and a careful reading of results. Other complementary analyses can be used to parse out the codependency of variables and to gain a better understanding of the structure of the dataset. In this case, I used principal component analysis to reduce data dimensionality and to clarify the relationships between cases and variables.

Another issue that has arisen in the literature of ceramic sourcing is the impact of various production activities on affecting or ‘diluting’ the chemical signature of a particular clay source (Sterba et al. 2009). This is an important factor to keep in mind when the goal of geochemical analysis is to identify what clay beds are used by potters. In this case, however, my goal is to characterize clay paste *recipes*, meaning the combination of clay, temper, and degree of clay processing (i.e. levigation, sorting, etc.), potters use to produce vessels. Ethnographic research has shown that different communities of potters often rely on the same sources of raw materials (Arnold 1985; Arnold 2008), but the way these similar materials are combined varies by production group (Gosselain 1992; Gosselain 1998; Gosselain 2008). In this study, I intentionally opt not to use dilution filters to preserve those differences relating to production choices that the filters obscure.

Table 3.1: Principal Component Analysis (PCA) of the 12 elements consistently detected among the 80 sherds analyzed in the pXRF pilot study. This analysis indicated that eight variables were particularly able to discriminate between compositionally distinct sherds.

	PC 1	PC 2	PC 3	PC 4	PC 5
Zr	**0.676**	-0.489	0.366	-0.181	0.116
Fe	**0.623**	-0.375	0.162	-0.414	-0.334
Rb	**0.555**	**-0.664**	0.326	0.012	0.149
Mn	-0.045	-0.297	-0.483	-0.457	-0.493
Sr	-0.081	**0.738**	-0.346	-0.131	0.390
Ca	-0.343	-0.482	-0.433	0.033	0.266
V	-0.396	0.345	0.399	**-0.534**	0.249
K	-0.442	**-0.508**	0.277	**0.535**	-0.102
Ti	-0.464	-0.425	**0.512**	0.302	-0.187
Cr	-0.497	0.006	0.400	-0.526	0.234
Zn	**-0.573**	-0.159	0.285	-0.193	-0.425
Ba	**-0.658**	-0.486	-0.234	-0.220	0.071
Eigenvalue	2.854	2.504	1.601	1.456	0.917
Variance	23.8%	20.9%	13.3%	12.1%	7.6%
Total Variance	23.8%	44.4%	58.0%	70.1%	77.8%

Principal component analysis of the 12 variables with values that were above the limits of detection for all sherds in the pilot sample was performed taking the 80 sherds as cases. As some elements, like iron, were present in much higher concentrations than others, the elemental abundances of each sherd were standardized by variable using z-scores. The results of PCA showed that 70% of the compositional variation between sherds could be explained by the first four components, with 8 elements having a particularly strong ability to discriminate between compositionally distinct sherds (Ba, Fe, K, Rb, Sr, Ti, Zn, Zr; Table 3.1). More importantly, the way that variables are loaded onto these components makes sense from a geochemical perspective. For example, high negative loadings of rubidium and potassium and high positive loading of strontium on the second component reflects the mineralogy of the clay. In igneous rocks, the ratio of rubidium (which substitutes for potassium) to strontium increases with cooling time of magma, meaning that the ratio of rubidium to strontium is lower in high temperature minerals like plagioclase and higher in low temperature minerals like muscovite. These high temperature minerals are the least stable and thus are the first to weather and form clays.

Concentrations of these eight elements were then used as the variables in a hierarchical cluster analysis of 80 cases. Euclidean distances were calculated between each pair of sherds based on concentrations of these eight elements, again standardized by z-score. The resulting dissimilarity matrix was used in a hierarchical cluster analysis of cases using an array of linkage methods including complete, single, and Ward's minimum variance methods in R statistical package. Unsurprisingly, the use of different clustering methods produced slight variations in the structure of the dendrograms, but the underlying relationship between cases remained stable. Ward's method ("ward.D2" in the hclust package for R) ultimately produced clusters that best highlight patterns in the data, and is reproduced in Figure 3.1. Dendrograms produced with complete and single linkage methods are available for comparison online at the Comparative Archaeology Database of the University of Pittsburgh Center for Comparative Archaeology (Sturm 2017).

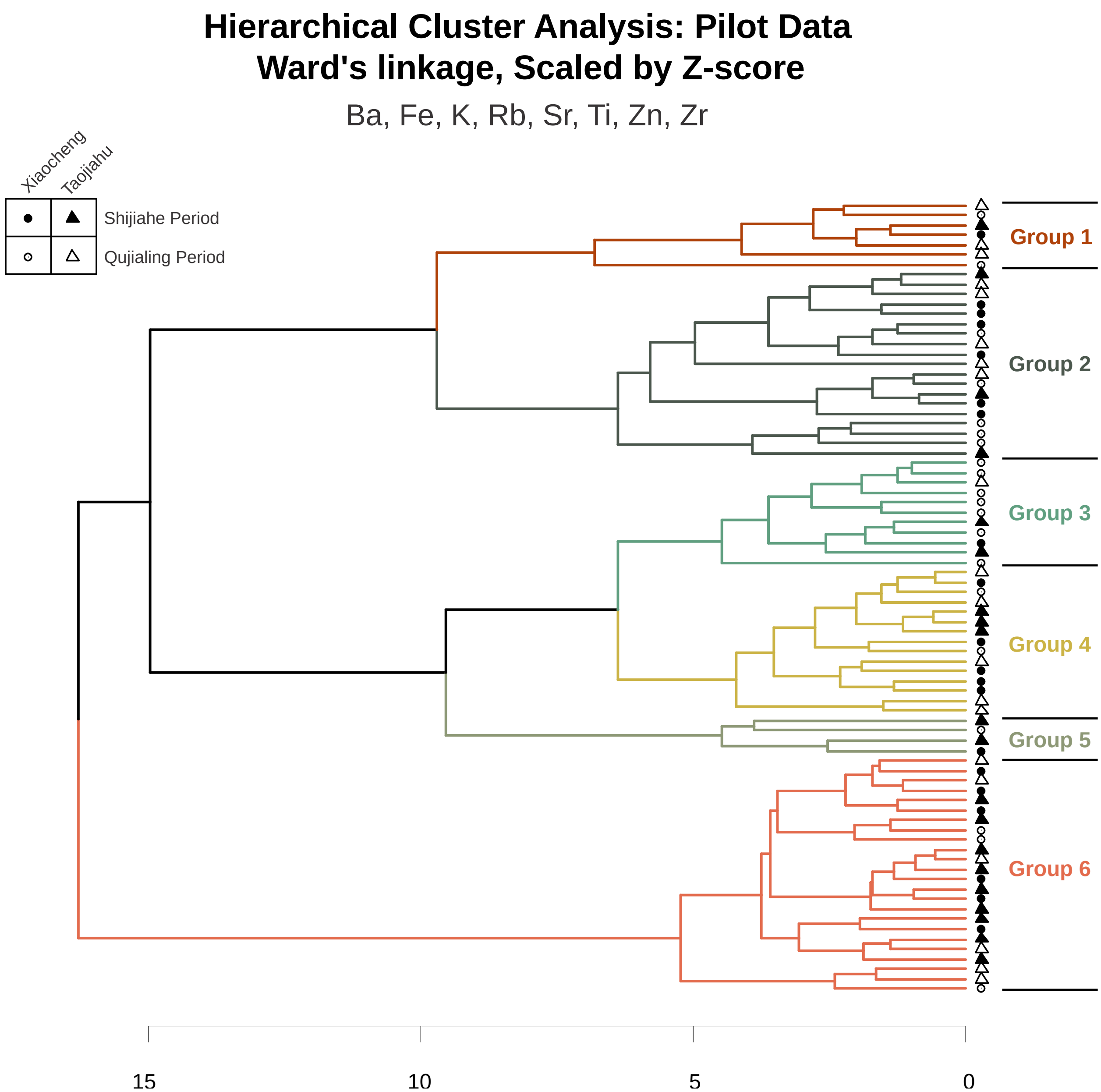

Figure 3.1: Dendrogram of pXRF pilot study data scaled by z-score.

The dendrogram in Figure 3.1 can be divided into clusters of sherds at several different scales. At two or three groups, the variation between sherd compositions likely reflects regional differences in clay sources. Even at this broad level, we see that potters relied on the same clay sources throughout the late Neolithic, and that pottery made from these various sources was used at both walled sites. A much more detailed picture of spatial and temporal variation in pottery composition emerges if we divide the dendrogram into six groups. Compositional group 3, for example, is most common at Xiaocheng during the Qujialing period, while Group 6 is better represented at Taojiahu during both periods. The pattern of the distribution of these compositional groups reflects expected distribution patterns for pottery around their production source, and thus it may be that the pottery represented by Group 3 was produced at Xiaocheng and that in Group 6 was produced at Taojiahu. More significantly to the research at hand, the presence of lower proportions of sherds in Groups 3 and 6 at Taojiahu and Xiaocheng, respectively, suggests that pottery was circulated between these communities. As the pilot sample is not statistically representative of the entire regional population of Neolithic pottery sherds, these observations can provide little concrete information about the nature of these circulation networks.

3.2.3 Desktop WD-XRF results of the pilot study

Since concern has been raised over whether pXRF is suitable for ceramic compositional analysis (Speakman et al. 2011) and specifically about the impact of the Niton calibration on the reliability of pXRF measurements (Speakman and Shackley 2012), we compared patterns of major, minor, and trace elements obtained by pXRF to those obtained by more standard techniques (desktop WD-XRF). Desktop XRF eliminates the potential confounding effects that a heterogeneous material like pottery might have on compositional analyses by grinding up a portion of the sherd into a homogenous powder. The results show a positive correlation between the measurements of major, minor, and trace elements obtained with each technique, indicating that any effects of the Niton calibration on the accuracy of element measurements were minimal (Figure 3.2). Despite the shortcomings of this instrument, the general agreement between the results of the WD-XRF and pXRF analyses indicates that we can be confident about the ability of pXRF to identify compositional groups of sherds.

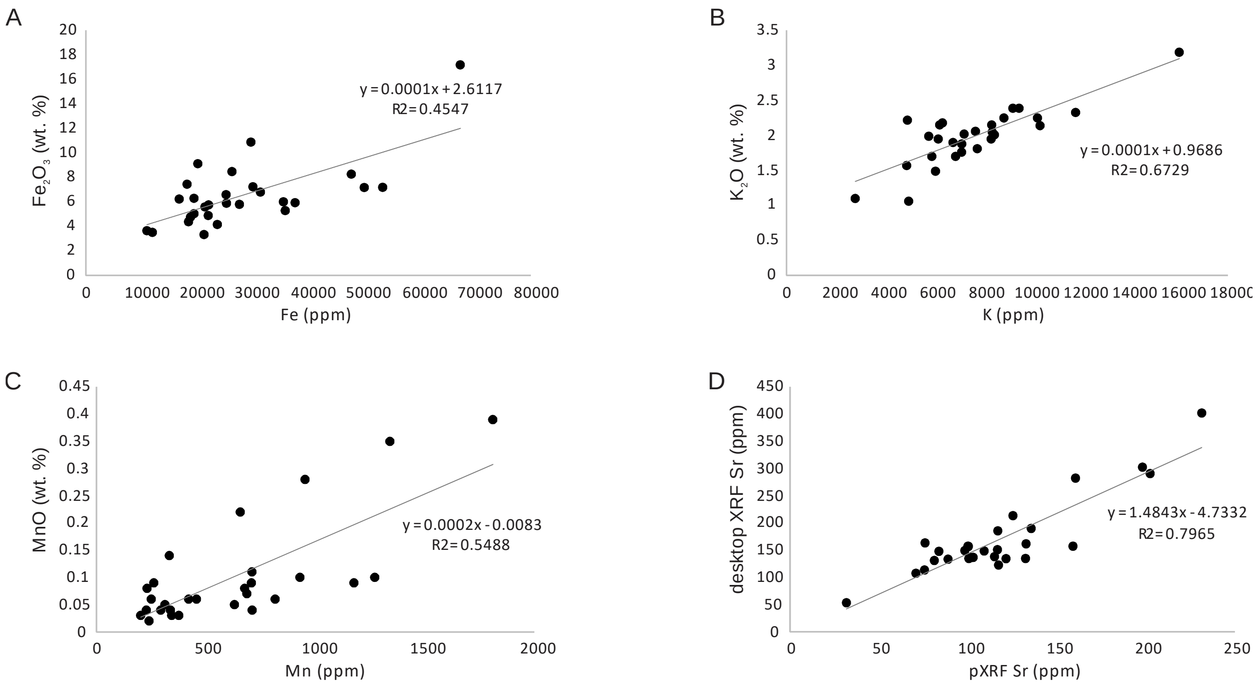

Figure 3.2: Scatterplots depicting the strong, positive correlation between results of desktop XRF and pXRF analyses for major (A), minor (B, C), and trace (D) elements.

Clustering results of the desktop WD-XRF data highlighted similar compositional patterning as was found with the pXRF data. Euclidean distances were calculated between the 28 sherds based on weight percent of 10 oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, and P_2O_5). Ward's linkage method was then used to produce the dendrogram in Figure 3.3. Results show that sherds from pXRF Groups 4, 6, and 3 tended to cluster together at the top, middle, and bottom of the desktop XRF dendrogram, respectively. While the groupings derived from these two sets of data do not match perfectly, the broad correspondence between groupings indicates the compatibility of desktop and portable XRF analyses.

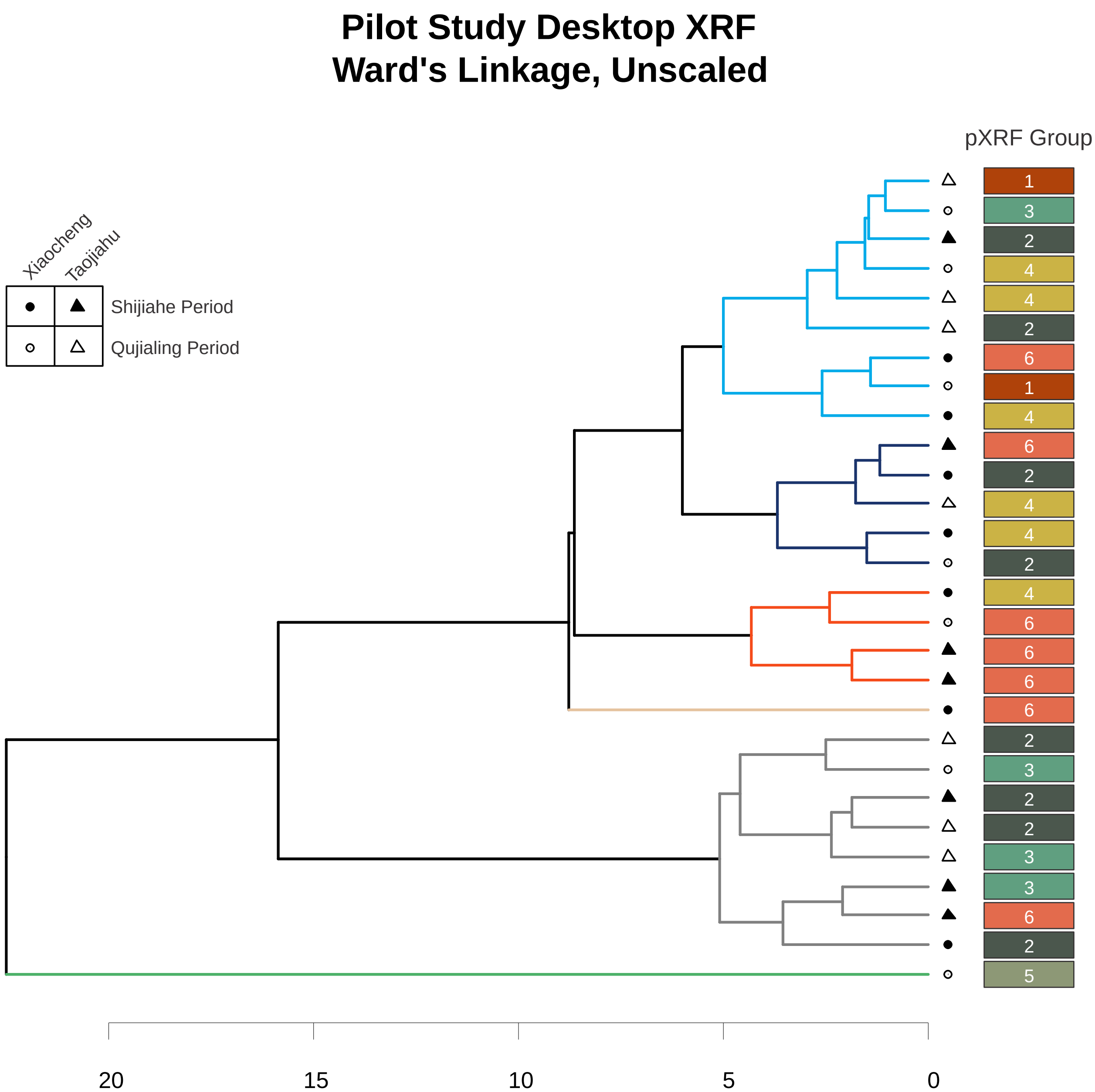

Figure 3.3: Dendrogram of unstandardized desktop XRF data from the pilot study.

3.2.4 XRD results of the pilot study

Mineralogical characterization of the 16 sherds sent for XRD analysis indicated that these vessels were made of a paste composed of illite clay with varying quantities of quartz and feldspar. Whole pattern fitting and Reitveld refinement were used to convert the raw XRD data into weight percent of minerals. As with the desktop XRF data, these data were used to produce a dissimilarity matrix between 16 cases using unstandardized variables (weight percent of quartz, microcline, anorthite, muscovite, spinel, spinel hercynite, adularia, hematite, sanidine, hollandite, and clinochlore). Cluster analysis of the resulting matrix with Ward's linkage methods produced three clusters (Figure 3.4). Sherds in the first group were almost entirely from Xiaocheng, while all sherds the second group and most sherds in the third group were from Taojiahu. This pattern suggests that the clay mineralogy represented by XRD Group 1 probably characterized the area around Xiaocheng, and those represented by Groups 2 and 3 characterized the Taojiahu area. The persistence of these divisions across both archaeological periods lends additional support for this interpretation. As compelling as these trends may be, given the small size and non-representative nature of this sample, it is important not to push these results too far beyond the realm of tentative observations.

The more immediately critical result of the XRD analysis is that both mineralogical and elemental data reflect differences in pottery in a similar way. Sherds from pXRF Group 6, which was more common at Taojiahu than at Xiaocheng, clustered together in XRD Groups 2 and 3. Similarly, sherds from pXRF Group 3, which was more abundant at Xiaocheng, clustered in XRD Group 1 with the other Xiaocheng sherds. Together, this indicates that differences in the abundance of different elements corresponds with the use of different raw material resources, clay processing strategies, or paste recipes used to produce pottery in both the Qujialing and the Shijiahe periods.

In sum, the findings of the pilot study provide the methodological foundation for the application of these methods to a larger-scale, representative sample of sherds. First, these findings confirm that this combination of geochemical techniques, pXRF, WD-XRF and XRD, are sensitive enough to detect compositional differences in local pottery, despite the proximity and expected homogeneity of raw material resources in the Jianghan floodplain. Second, these findings illustrate that the geochemical data acquired through these methodologies can be used to characterize distribution networks in the survey area.

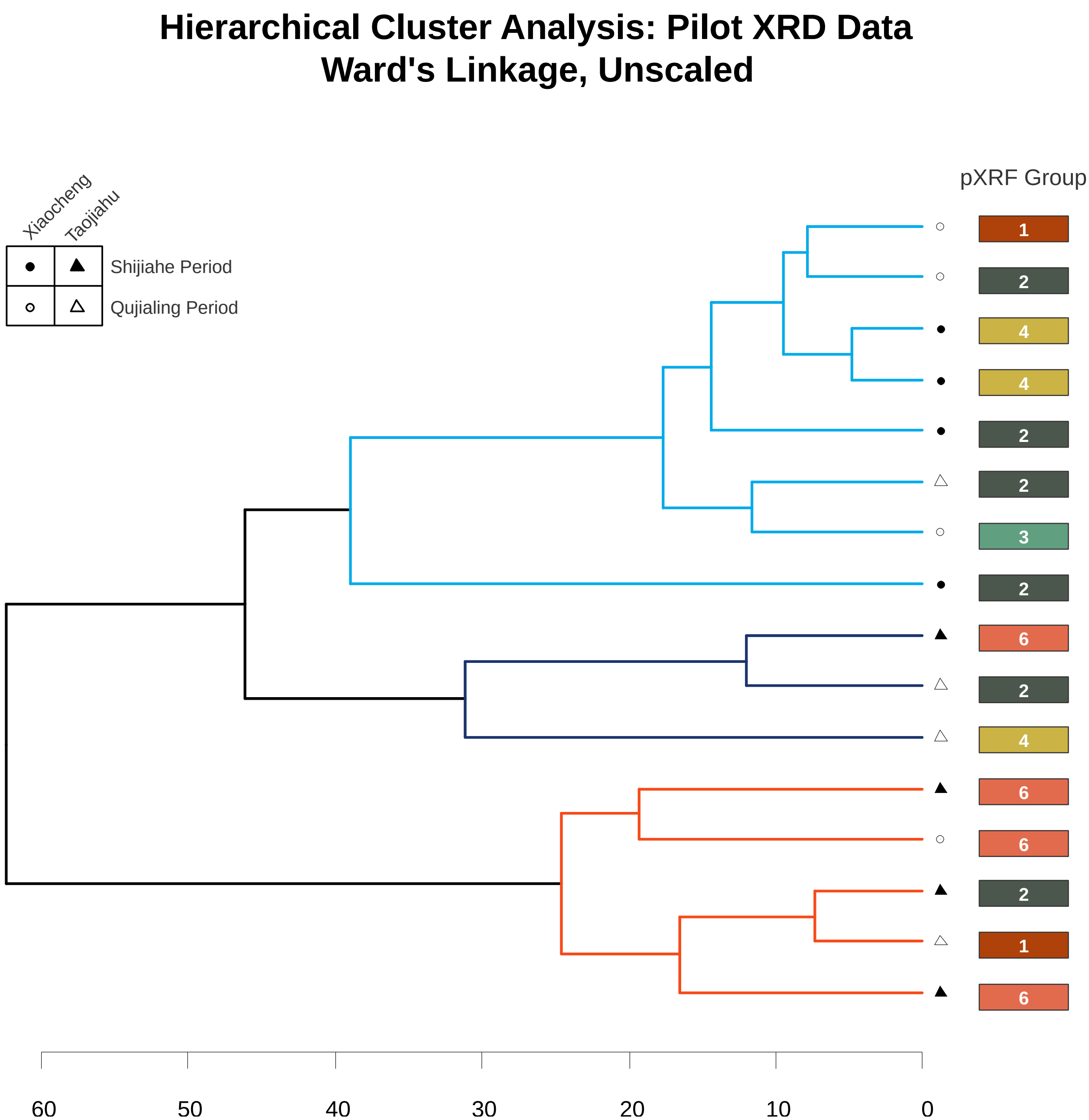

Figure 3.4: Dendrogram of unstandardized XRD data from the pilot study.

3.3 SAMPLING STRATEGY FOR THE FULL DATASET

The pilot study served to demonstrate that this constellation of geochemical techniques could be used to successfully identify production activities in the past, yet, to characterize patterns of social and economic behavior in this region requires these methods be applied to a statistically significant sample of pottery sherds. Not only did the full sample need to represent the range of pottery used in this region during the late Neolithic and recovered in survey, but it also had to represent all pottery assemblages across the study area. This was accomplished by adopting a stratified sampling strategy for each period, wherein each stratum represented a spatially-constrained zone from which a set number of sherds were randomly selected for analysis. The size of these sampling units and the number of sherds selected from each stratum was a compromise between a desire for precision and the costs of analysis. Ultimately, the results of the compositional analysis had to be tied to changes in settlement patterns; thus, underlying the sampling logic was the condition that each sampling unit had to correspond with a meaningful unit of social organization.

3.3.1 Identifying sample strata

The first step towards creating a sample of sherds for this analysis was to determine the size and location of each spatial unit that would comprise a sampling stratum. During regional settlement survey of the Taojiahu-Xiaocheng region, surface materials were collected from discrete units measuring roughly a half hectare in size. Ideally, these collection lots would also serve as strata in the sample, making it possible to identify economic networks at the scale of roughly one to three households. However, the number of sherds in each collection lot varied substantially, with the top 5% of collection lots accounting for 24% and 47% of Qujialing and Shijiahe period ceramic assemblages, respectively. More importantly, many of these collection lots contained fewer than 10 sherds corresponding to each period, meaning that the ceramic assemblages of some parts of the study area would be underrepresented in the full sample.

One way to overcome this problem would have been to focus only on those lots with higher numbers of sherds and ignore the remaining lots that had low numbers of sherds. If about 50 sherds would be needed to make statistically significant comparisons of pottery exchange and procurement, the only collection lots that could be included in the sample would be 3 collection lots from Xiaocheng and 20 from Taojiahu dating to the Qujialing period, and 4 lots from Xiaocheng and 10 from Taojiahu dating to the Shijiahe period. Although this approach would retain the high degree of detail afforded by such small-scale sampling units, it also would have required arbitrarily omitting substantial parts of the society—particularly settlement outside the two towns' walls—that the project was designed to study.

An alternative solution, and the one adopted here, was to combine several collection lots together into slightly larger units. This would ensure that each unit had a large enough pool of sherds to make the kinds of comparisons that were hinted at in the pilot study, with comprehensive coverage of the region. The gain in coverage comes a slight cost to detail, with the combined collection lots offering a slightly coarser view of economic activity than would be possible if collection lots were compared individually.

The next step was to consolidate collection lots into larger analytical units. The size of individual collection lots suggests that, on average, each lot corresponded to a cluster of two or three households. A slightly larger residential unit would correspond to what is called a "ward," "barrio," or "neighborhood," formed of as many as tens of households that that have some meaningful sociocultural coherence. Residents of neighborhoods engage in considerable face-to-face interaction with one another and, all else being equal, have access to similar sets resources and social and economic networks. Other factors, such as shared identity and ethnic background, are also important characteristics of both modern and ancient neighborhoods (Smith 2010). For these spatial and social qualities, I chose to combine collection lots into groups that approximated neighborhoods.

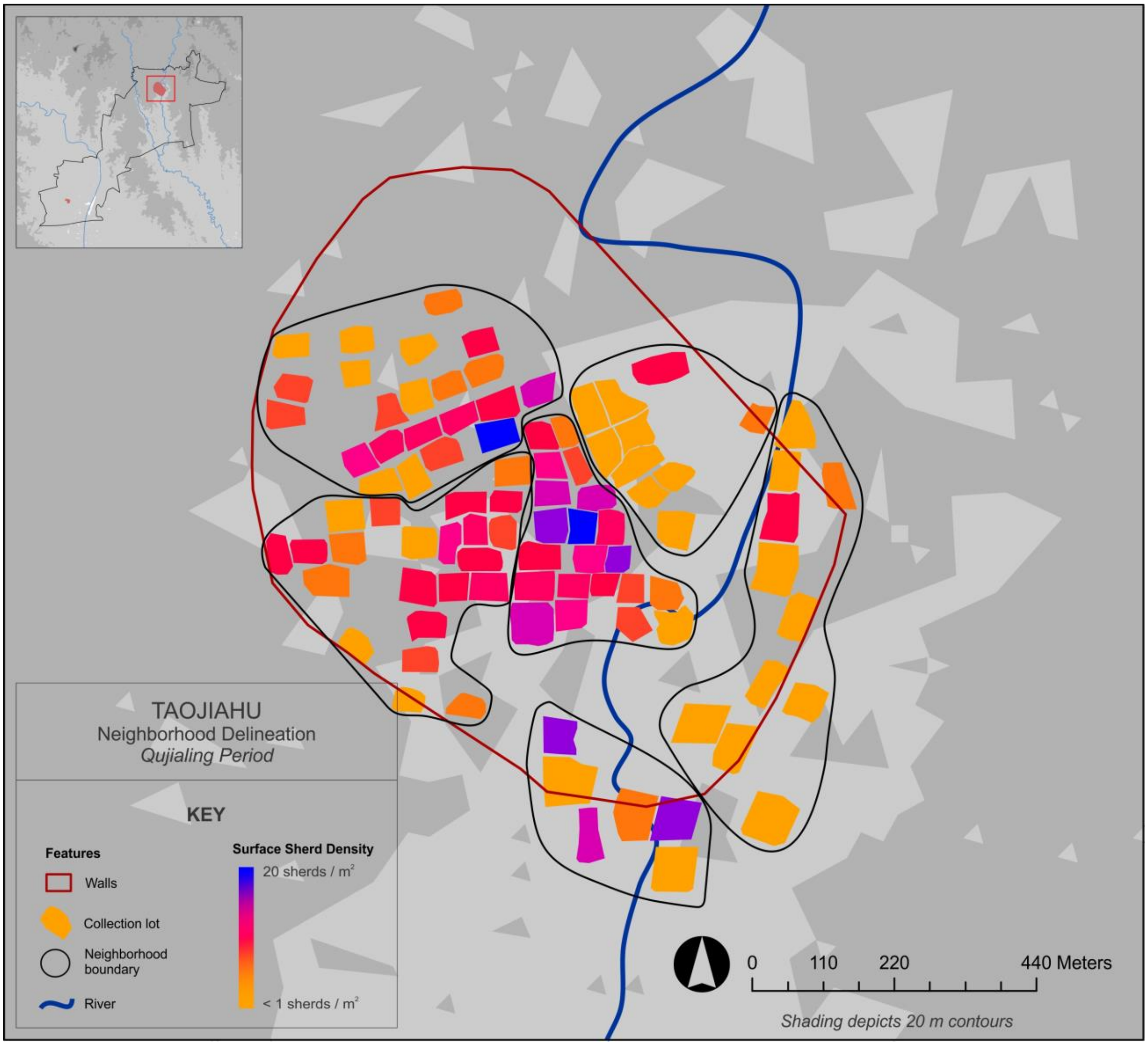

Figure 3.5: Map of Qujialing period Taojiahu showing the process of neighborhood delineation. This process was based on the density of sherds in collection lots, the spatial distribution of collection lots, and variation in landscape features such as topography, waterways, and the location of the rammed-earth walls.

Without direct evidence of the configuration of houses in the study region, I relied on distance-interaction principles to delineate neighborhoods (Peterson and Drennan 2005). This process drew on patterns in the density of surface artifacts across the study area, variations in topography, as well as my own on-the-ground experience on this landscape to demarcate neighborhoods. An example of this process is depicted in Figure 3.5, which shows the separation of six neighborhoods at Taojiahu in relation to artifact density and topography. In some cases, collection lots that were directly outside of the walls were included in inside-wall units, with the assumption that these locations represent midden deposits from the settlement within the walled town.

In total, I defined 11 Qujialing and 12 Shijiahe period neighborhoods, which measured on average between 7 and 10 ha (Figure 3.6Figure 3.7). Qujialing neighborhoods 1 through 10 and Shijiahe neighborhoods 12 through 22 represent the kind of nucleated residential zones that correspond closely to the definition of neighborhoods outlined above. Neighborhoods 11 (Qujialing) and 23 (Shijiahe) deviate from this model because they included the remaining collection lots for each period that are distinct in their dispersed distribution across the region. In these two cases, the characterizing feature of each neighborhood is the distance of households from one another and, importantly, from the densely nucleated settlements at Taojiahu and Xiaocheng. These neighborhoods capture the 'rural' or 'peripheral' late Neolithic experience relative to core-zone living characterized by the other neighborhoods.

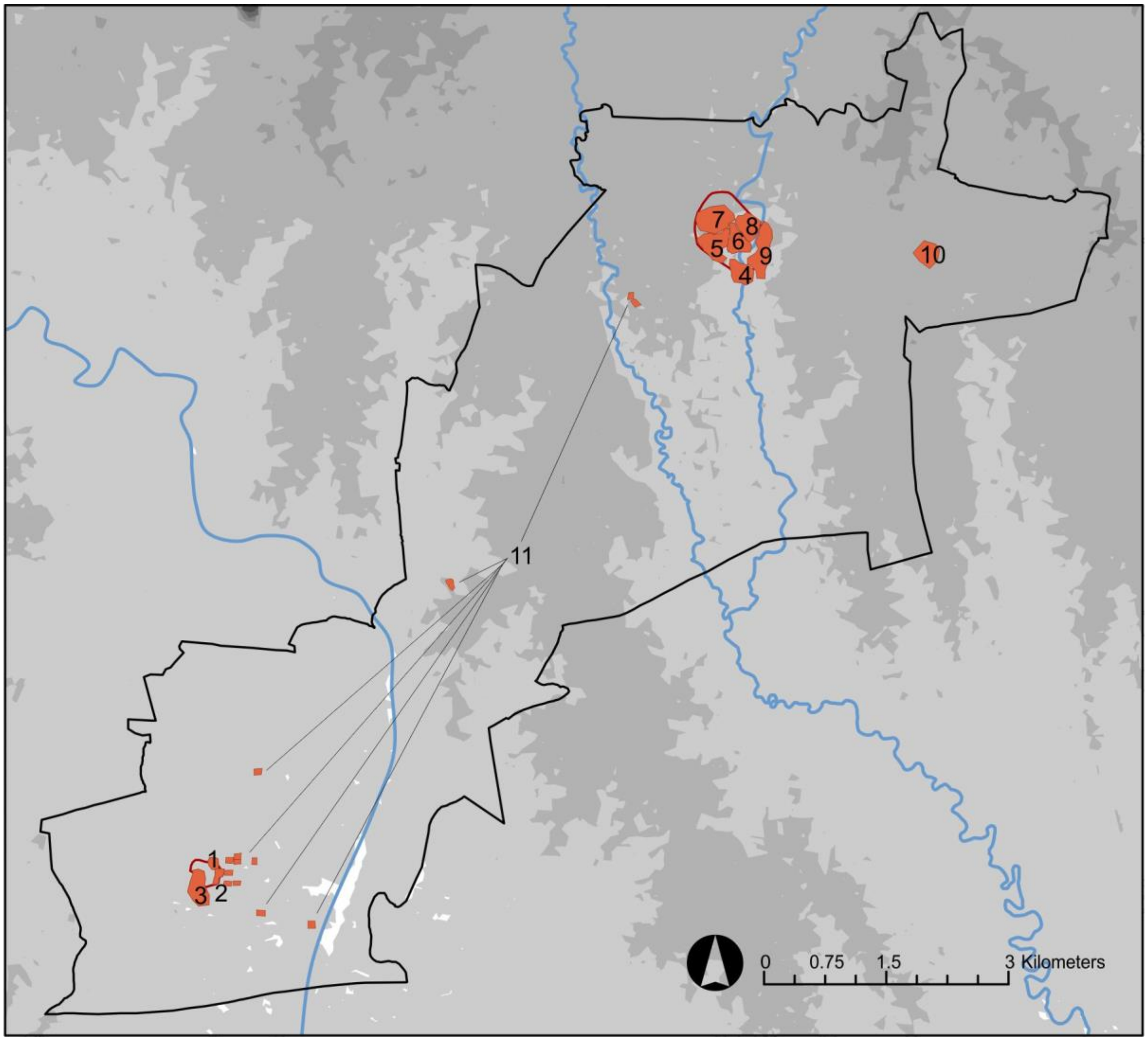

Figure 3.6: Map of all 11 Qujialing period neighborhoods (1-11). Neighborhood 11 represents all dispersed collection lots.

Once the spatial extents of each sampling stratum were determined, the next step was to calculate the number of sherds that needed to be sampled from each neighborhood to detect meaningful differences in the presence of compositionally distinct pottery. By meaningful, I mean that these patterns reflect behavioral differences in access to and procurement of pottery that are indicative of divergent economic strategies. Differences in the proportions of compositional groups that are less than 10% are likely too small to indicate meaningful differences in patterns of pottery procurement. For instance, if the proportion of sherds in compositional group Z were 52% in one neighborhood and 47% in a second neighborhood, this would suggest that households in these two neighborhoods acquired roughly half of their pottery from the same source. Alternatively, if the proportions of group Z sherds in the two neighborhoods were 62% and 47%, respectively, this would point to different pottery acquisition practices in each neighborhood. It is critical that such differences can be confidently attributed to patterns of procurement rather than to the vagaries of sampling.

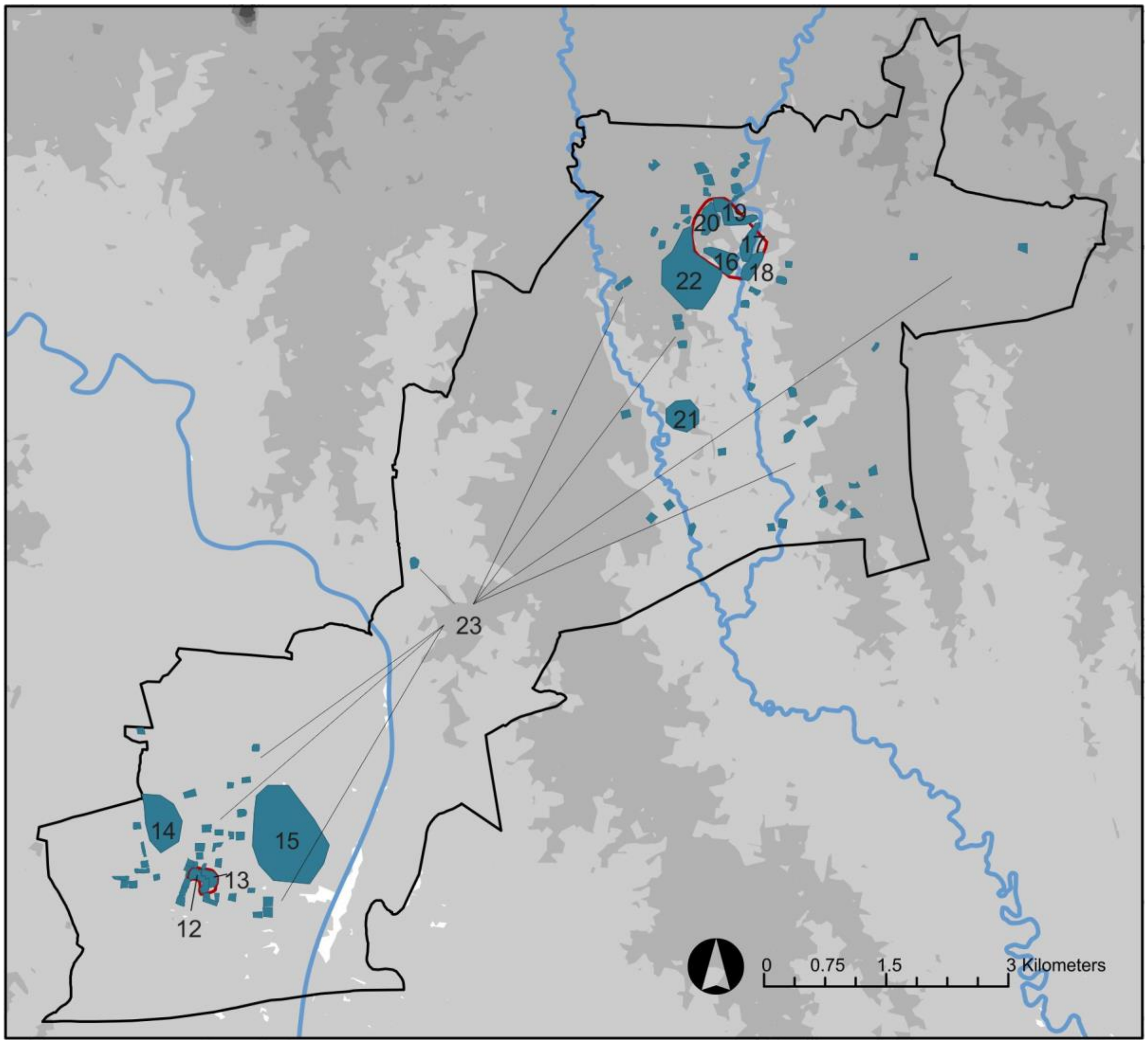

Figure 3.7: Map of all 12 Shijiahe period neighborhoods (12-23). Neighborhood 23 represents all dispersed collection lots.

A sample of 55 sherds from each neighborhood would make it possible to estimate the percentage of sherds in each compositional group with an error range of ± 10% at the 90% confidence level. By selecting the sample in this way, each neighborhood represents a single stratum of a stratified sample, which allowed for more precise estimates to be made about the population of Qujialing and Shijiahe period sherds than a simple random sample (Drennan 2009:233–237). Pooling these neighborhoods together into larger units also facilitated more rigorous comparisons between distribution networks on supra-local and regional levels.

3.3.2 Sampling sherds from neighborhoods

Following the determination of a target sample size and the delineation of neighborhoods, a sample of sherds had to be selected from each neighborhood for geochemical analysis. The sherds that were randomly selected from each neighborhood had to meet three basic criteria. The first was that sherds had to be large enough to allow for multiple readings to be taken with the pXRF. The diameter of the instrument's analytical window is 3 mm; thus, to keep from simply taking the same reading repeatedly, sherds that were much smaller than 9 mm^2 were omitted from the sample. The second was to limit the possibility that multiple sherds from a single vessel were included in the sample. Sherds that either shared overwhelmingly similar paste characteristics or could be physically refit with other sherds were omitted from the sampling pool so as not to artificially inflate the presence of one compositional type of pottery. The third was that it was important to ensure that some sherds with identifiable vessel forms be included in the sample. In some parts of the world, differences in the composition of clay pastes may relate more closely to the various vessel forms potters make than to separate potter groups (Carpenter and Feinman 1999). Including sherds that had been identified by vessel form in the sample would allow us to test this theory for late Neolithic potters of the Jianghan Plain. Typological analysis of sherds from the survey was conducted by ceramic specialist, Qifang Xiang (向其芳), Hubei Institute of Cultural Relics and Archaeology, making sure that the identification of vessel forms in this project is consistent with that of other archaeological projects in Hubei.

The selection of the full ceramic sample took place at the Hubei Institute of Cultural Relics and Archaeology in May 2015. A target sample of 60 sherds– including 5 diagnostic and 55 non-diagnostic sherds – was chosen for each neighborhood. Including a few extra sherds in each sample made it possible to provide substitutes for sherds that might later be deemed ill-suited for without affecting the randomness of the sample. It was also important that the diagnostic and non-diagnostic components of each sample be selected independently to avoid bias. Several factors would have unintentionally impacted the recovery of sherds with known vessel form in each collection lot during survey, including the experience of the surveyors, the size of the sherds, and the placement of 10 m^2 surface collection areas within each lot. Moreover, as sherds with identifiable form represent only about 10% of all sherds from survey, there was a good chance that if samples were taken randomly, these sherds would be underrepresented in neighborhood assemblages. Ensuring that roughly 10% of each neighborhood sample included sherds with known vessel form thus helped avoid sampling bias.

All sherds from collection units associated with a single neighborhood that met the criteria outlined above were laid out together in rows along a table and counted (Figure 3.8. A random number generator application for OSX (Random Number Generator v. 2.1.5, Intermodino Group) was used to provide 55 random integers from the total number of sherds present. Sherds were counted from left to right, and those that corresponded with the list of 60 random numbers were selected for analysis. The same procedure was carried out to select 5 sherds of known form from each neighborhood. Selected sherds were given unique identification numbers and were bagged individually. Ultimately, 5 of 23 neighborhoods had too few sherds that met the sampling criteria to meet even the 55-sherd goal (N8, N9, N11, N14, and N18); as many sherds as possible were sampled from these neighborhoods (Table 3.2). Ultimately, 1,240 sherds were analyzed by attribute and 1,150 were analyzed geochemically by portable x-ray fluorescence.

Table 3.2: Number of collection lots, total population of sherds, and number of sherds in each sample strata by neighborhood. Note N8, N9, N11, N14, and N18 have too few sherds to be able to meet the 55-sherd sample target.

Neighborhood	Period	Total collection lots	Total population sherds	Total vessel form ID sherds	No. sherds in sample
1	QJL	3	74	19	55
2	QJL	4	60	22	55
3	QJL	4	69	22	55
4	QJL	6	131	16	55
5	QJL	22	176	56	55
6	QJL	21	352	94	55
7	QJL	22	289	33	55
8	QJL	10	37	0	**37**
9	QJL	11	40	0	**40**
10	QJL	1	69	0	55
11	QJL	13	22	6	**22**
12	SJH	7	67	17	55
13	SJH	9	67	13	55
14	SJH	9	32	2	**32**
15	SJH	20	99	16	55
16	SJH	9	81	10	55
17	SJH	7	65	6	55
18	SJH	4	30	3	**30**
19	SJH	23	585	76	55
20	SJH	9	105	12	55
21	SJH	6	92	11	55
22	SJH	18	60	4	55
23	SJH	86	86	28	55

Figure 3.8: Sampling sherds at the Hubei Province Institute of Cultural Relics and Archaeology.

3.4 COMPOSITIONAL ANALYSIS OF THE FULL POTTERY SAMPLE

The methodology and preparation procedures employed in the full sample of sherds were, in large part, similar to those employed during the pilot study. The XRD and desktop XRF analyses were carried out by Dr. Huang Jiwu and Dr. Luo Wugan, respectively, following precisely the same procedure outlined above. A Bruker Tracer IV was used instead of the Niton instrument used in the pilot study. The Tracer provides the user more control over data collection than the Niton because it records readings as raw spectral counts (fluorescence intensity per second) rather than automatically converting the data to ppm values. This conversion process can obscure patterns in the data by fitting raw spectral data to generalized calibration curves that are not specific to the materials being analyzed. In using the Tracer, I relied on the data that most directly characterizes the composition of each sherd, with the flexibility to create project-specific calibrations at a later date.

To prepare the 1,150 sherd samples for pXRF analysis, a portion of the interior and exterior surfaces of each specimen was sanded with silicon carbide sandpaper to remove potential contaminants and to produce a flat surface for analysis. The Tracer-IV pXRF spectrometer was then used to take four readings (two on each face) along the prepared surface of each sherd. Each reading was 60 seconds at 40kV, 17.2µA using a 25µm Ti - 300µm Al filter (Figure 3.9). A standard sample was irradiated with these settings every time the pXRF unit was turned on for the first time in an analytical cycle to test for instrumental drift. During the period that this research was conducted no drift was detected.

Figure 3.9: A sherd that has been prepared for analysis (left) and taking readings with the Bruker Tracer pXRF (right).

Raw spectral data was processed in ARTAX, Bruker's spectral analysis software package. Bayesian deconvolution was used to identify the presence of 27 elements (Al, Ar, As, Ba, Br, Ca, Cr, Cu, Fe, Ga, K, Mn, Nb, Ni, Pb, Pd, Rb, Rh, S, Si, Sn, Sr, Th, Ti, Y, Zn, and Zr) across the pottery sample. The spectral data was then exported as an Excel spreadsheet, with K- and L-peaks for relevant elements expressed in atomic abundance. Before proceeding with data analysis, however, it was important to determine how much elemental variation should be expected between readings due to the heterogeneous nature of the sherd, and how much could be attributed to the detection limits of the instrument. I used a simple reliability test to address these issues.

3.4.1 Reliability testing and statistical processing of pXRF data

To evaluate the reliability of the individual pXRF spectrometer used in this analysis, a sherd with inclusions and paste texture typical of the sherds in the sample (0854-13) was analyzed for 10 successive trials with the same settings as the full analysis (60 seconds, 40kV, 17.2μA; 25μm Ti - 300μm Al filter) without replacing the sherd between reading cycles. The coefficient of variation (CV) was calculated for the 27 elements that were detected in the sample to see how reliability varied by element. CV is a measure of the relative dispersal of a sample, and is defined as the sample standard deviation divided by the mean, typically expressed as a percentage. The more tightly distributed a sample, the smaller the CV. A completely random set of numbers has a CV of roughly 58% (Eerkens and Bettinger 2001).

Five elements demonstrated high levels of variation (CV > 30%) in this first test. These elements —aluminum (Al), bromine (Br), lead (Pb), sulfur (S), and tin (Sn)—are marked with red in Table 3.4. The palladium (Pd) and rhodium that were detected come from internal components of the Tracer; their low CV scores (2%) represent a general baseline for the maximum reliability of the Bruker instrument. The remaining 20 elements all share relatively low CV scores, illustrating that the machine is consistently able to measure the abundance of these elements in a sample, and that differences in readings reflect true compositional differences (Table 3.3).

Variation in readings can arise from to intrinsic properties of the instrument as well as to the compositional heterogeneity of the specimen being analyzed. To distinguish between these two factors, the same sherd (0854-13) was analyzed for another 10 trials, but the sherd was adjusted slightly after every reading cycle to target a different point on its surface. The same five elements as in the previous test demonstrated high levels of variation (CV > 30%). A sixth element, manganese (Mn), also had a high level of variation in this test (CV = 45%). The fact that manganese readings exhibited low variability (CV = 3%) in the first test but substantial variability in the second test implies that the concentration of manganese varies widely across a single sherd (Table 3.3). This pattern of variation suggests manganese will not be useful in distinguishing between compositionally distinct sherds.

The results of the reliability analysis made it clear that in certain circumstances, the variability between the four readings of a single sherd could skew the results of the compositional analysis. As a result, it was important to systematically identify the sources of variability in the full dataset. I used an unbiased thresholding method to identify outlying values in the four readings for every sherd specimen. For those sets of readings with a CV of greater than 30%, outliers were defined as values that fell outside three standard deviations of the mean of the other three readings. If the CV of the four readings for a sherd were less than 30%, no values were eliminated. In the case that an outlier was identified, the value for that element was calculated as the average of the three remaining cases. This process allowed me to target readings that were way above or below the expected levels given the amount of variability in the other three readings, and that were likely due to differences in instrumental detection rather than to the composition of the sherd paste. Roughly 3% of all readings fell outside this threshold, but two-thirds of the eliminated readings were of the five elements with particularly low reliability identified above (Al, Br, Pb, S, and Sn). Only 1% of readings of the remaining 20 elements (including Mn) were eliminated as outliers.

Table 3.3: Results of reliability testing on sherd specimen 0854-13. In the 'without replacement' trial, 10 readings were taken of the sherd without moving it between readings. In the 'with replacement' trial, the sherd was repositioned between each of the 10 readings. All readings refer to the K-peak unless otherwise noted.

Element	Without Replacement CV (Test 1)	With Replacement CV (Test 2)
Al	54%	55%
Ar	18%	19%
As	22%	18%
Ba	16%	21%
Ba (L)	9%	13%
Br	108%	137%
Ca	6%	5%
Cr	26%	23%
Cu	8%	8%
Fe	<0.5%	11%
Ga	13%	12%
K	5%	6%
Mn	3%	45%
Nb	17%	13%
Ni	8%	10%
Pb (L)	46%	34%
Pd	2%	4%
Rb	2%	4%
Rh	2%	4%
S	56%	69%
Si	11%	15%
Sn	34%	45%
Sr	3%	8%
Th (L)	16%	16%
Ti	3%	6%
Y	11%	11%
Zn	5%	7%
Zr	3%	5%

3.4.2 Defining compositional clusters using pXRF data

Several elements were eliminated from the dataset because their atomic weight fell outside the known detection limits of the machine or because they failed the reliability test. First, according to Bruker, elements with a mass equal to or less than calcium cannot be detected accurately without the use of a vacuum pump. As I did not use a vacuum, I eliminated data from these lighter elements—aluminum (Al), silicon (Si), sulfur (S), argon (Ar), potassium (K), and calcium (Ca)—from further analysis. Second, as discussed above, aluminum, bromine, lead, sulfur, and tin were poor markers of compositional variability between sherds as readings of these elements were shown to have low reliability. Third, the reliability tests showed that manganese readings varied tremendously within a single sherd, which raises the question of whether averaged manganese values can sufficiently characterize the abundance of the element in each sherd. Fourth, arsenic (As) is commonly found in groundwater, where it is adsorbed to and coprecipitated with metal oxides (especially iron oxides) and to clay-mineral surfaces (Welch et al. 1988). While I cannot be certain that the presence of arsenic in the sample is entirely due to adsorption processes, comparison of values for arsenic and iron in the sample reveals a strong, positive correlation ($r = 0.783$, $p < 0.0005$, $y = 0.004x - 0.017$), suggesting there is a good chance that arsenic abundance in the sherds better reflects their post-depositional context than the chemical signature of the clay originally used to make the vessels. For this reason, arsenic was also eliminated from the dataset.

The remaining 14, reliably-measured elements were used as variables in a principal component analysis of all 1,150 sherds (Table 3.4). Variables were standardized by z-score to facilitate comparison between elements that were present in high quantities in sherds with those that found only in trace amounts. The first four components of the resulting analysis of accounted for 66% of the variability in the dataset. The results of a principal component analysis indicate that all 14 elements (Ba, Cr, Cu, Fe, Ga, Nb, Ni, Rb, Sr, Th, Ti, Y, Zn, and Zr) are strong predictors of compositional variation between sherds, and thus were used as the variables in a hierarchical cluster analysis.

Table 3.4: Principal components analysis results clarifying the relationship between 1,150 sherds (cases) and 14 elements (variables), standardized by z-score.

	PC 1	PC 2	PC 3	PC 4
Ti K	**0.892**	0.101	0.033	0.197
Sr K	**-0.787**	0.17	0.122	0.075
Ba K	**-0.695**	0.068	0.202	0.241
Cr K	**0.633**	-0.293	0.265	-0.315
Th L	**0.625**	-0.298	0.077	-0.033
Fe K	0.383	**-0.822**	0.098	0.178
Nb K	0.366	**0.778**	-0.106	0.218
Ga K	0.278	**0.649**	0.146	-0.49
Zr K	0.359	**0.636**	-0.382	0.28
Y K	0.235	**0.611**	-0.096	0.306
Rb K	-0.184	**0.595**	0.067	**-0.531**
Cu K	-0.053	0.137	**0.741**	0.306
Zn K	0.139	0.351	**0.722**	0.184
Ni K	0.123	0.073	**0.515**	-0.171
Eigenvalues	3.303	3.200	1.672	1.132
Variance	23.59%	22.86%	11.94%	8.09%
Total Variance	23.59%	46.45%	58.39%	66.48%

Euclidean distances were calculated between the 1,150 sherd cases based on values for each of the 14 elements, standardized by z-score. This distance matrix was used in a hierarchical cluster analysis with Ward’s minimum variance linkage method to identify groups of compositionally-similar pottery sherds. Ultimately, 18 groups were identified, providing the foundation for the analysis of pottery exchange networks presented in Chapter 4 (Figure 3.10).

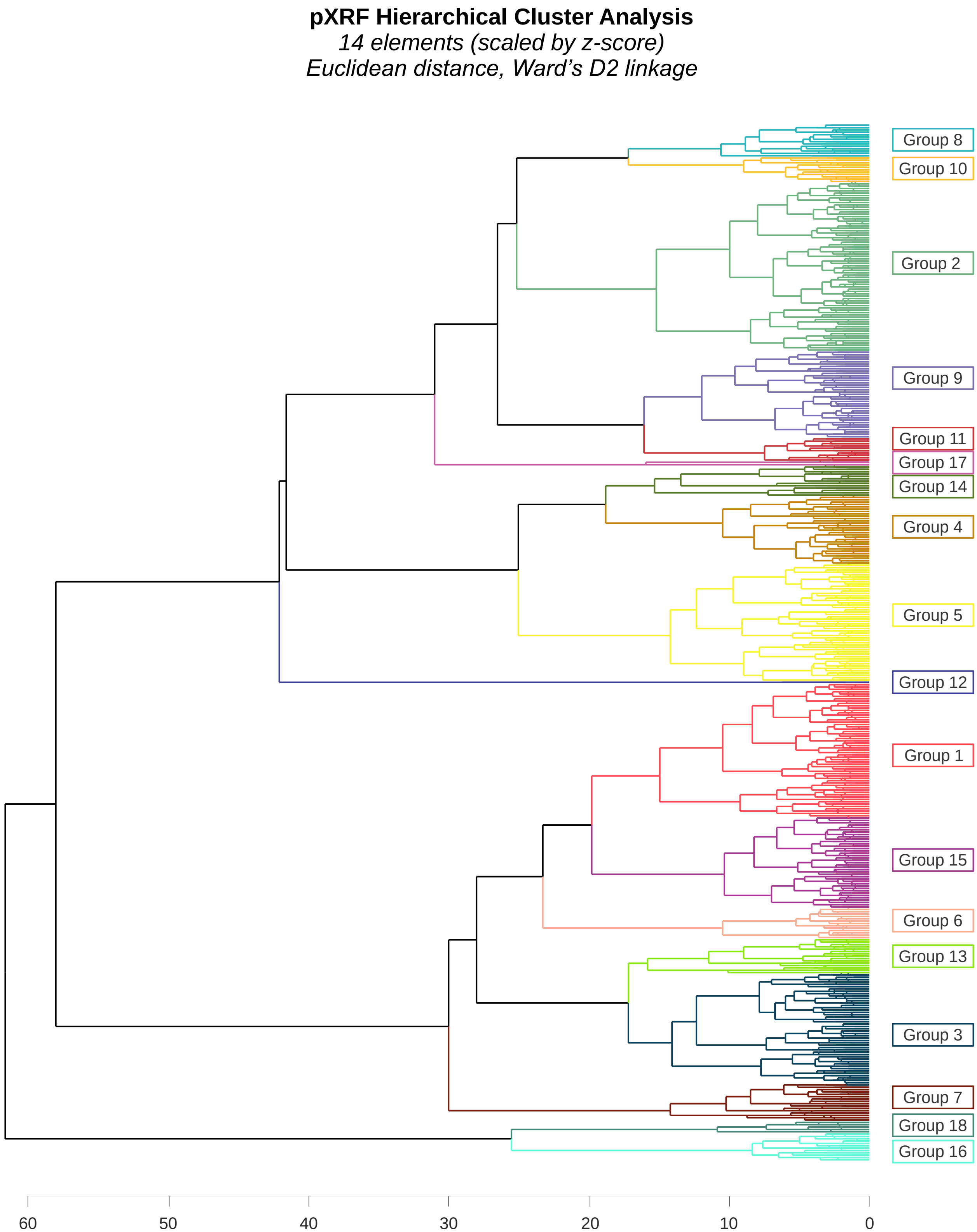

Figure 3.10 Dendrogram of the full pXRF dataset scaled by z-score (based on 14 elements: Ba, Cr, Cu, Fe, Ga, Nb, Ni, Rb, Sr, Th, Ti, Y, Zn, and Zr). Ward's minimum variance method was used to delineate 18 compositional groups.

3.4.3 Characterizing compositional variability with desktop XRF and XRD

Desktop XRF detected varying quantities of 10 major oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, and P_2O_5) and 8 minor and trace elements (Cr, Cu, Ba, Ni, Sr, V, Zr, and Zn) among 58 pottery sherds from the full sample. As major elements were not used to the statistical analysis of the pXRF data, I focused on the ppm measurements of the 8 minor and trace elements to compare the results of desktop XRF and pXRF analyses.

Euclidean distances were calculated between the 58 sherds based on z-score scaled concentrations of chromium, copper, barium, nickel, strontium, vanadium, zirconium, and zinc. This dissimilarity matrix was then used to produce a hierarchical clustering analysis with Ward's D linkage criteria. The resulting dendrogram, depicted in Figure 3.11, reveals three major compositional groups. While it was unlikely that this dendrogram would perfectly replicate the structure of the pXRF dendrogram given the smaller sample size and use of slightly different elements as variables, there is remarkable correlation in the organization of both dendrograms. Desktop XRF (dXRF) Group 1 includes sherds from pXRF groups C8, C10, C2, and C9, all of which cluster together at the top of the pXRF dendrogram. Sherds belonging to C1 and C15, which are adjacent to one another on the pXRF dendrogram, also cluster together in dXRF Group 1. dXRF Group 2 includes sherds from C1, C6, C3, and C7 which also cluster together in the pXRF dendrogram. Finally, all of the sherds from pXRF group C13 cluster together in dXRF Group 3.

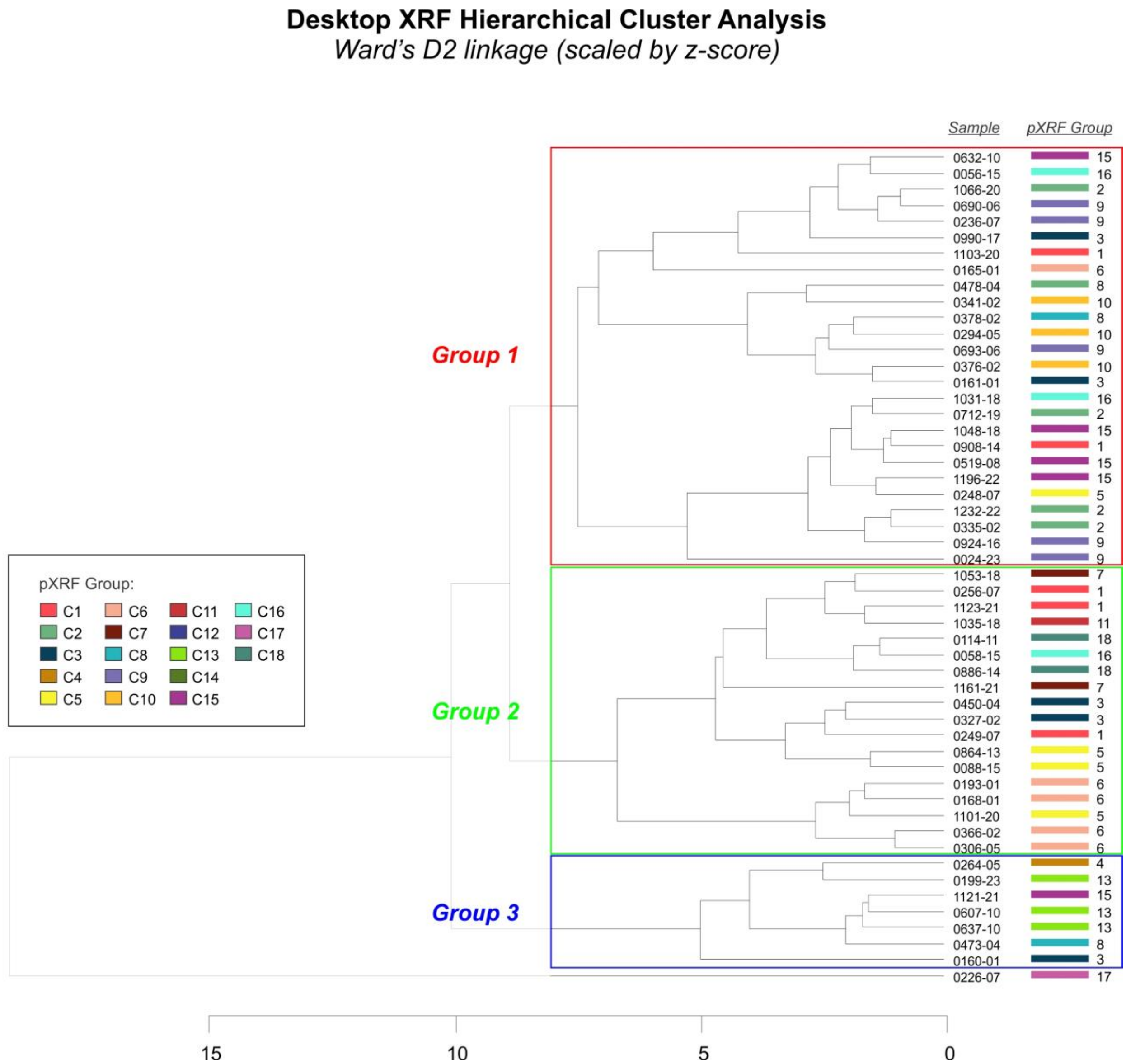

Figure 3.11: Dendrogram of the 57 pottery sherds analyzed by XRF based on Cu, Cr, Ba, Ni, Fe, Sr, Zn and Zr. Three groups were delineated based on elemental variations.

The high fidelity of hierarchical clustering results of both XRF analyses is paralleled by the generally strong positive correlation in the measurement of Cu, Cr, Ba, Ni, Fe, Sr, Zn, and Zr obtained by each method. Measurement for barium, iron, and strontium by pXRF and desktop XRF exhibited especially strong positive correlation (Ba: $y= 49097x - 372.13$, $R^2= 0.726$; Fe: $y= 0.234x - 2.418$, $R^2= 0.861$; Sr: $y= 205.32x - 26.47$, $R^2= 0.940$; see Figure 3.12). Together, the similarities in the structure of dendrograms and the positive correlation between individual readings across elements emphasizes the validity of compositional data obtained through pXRF analysis.

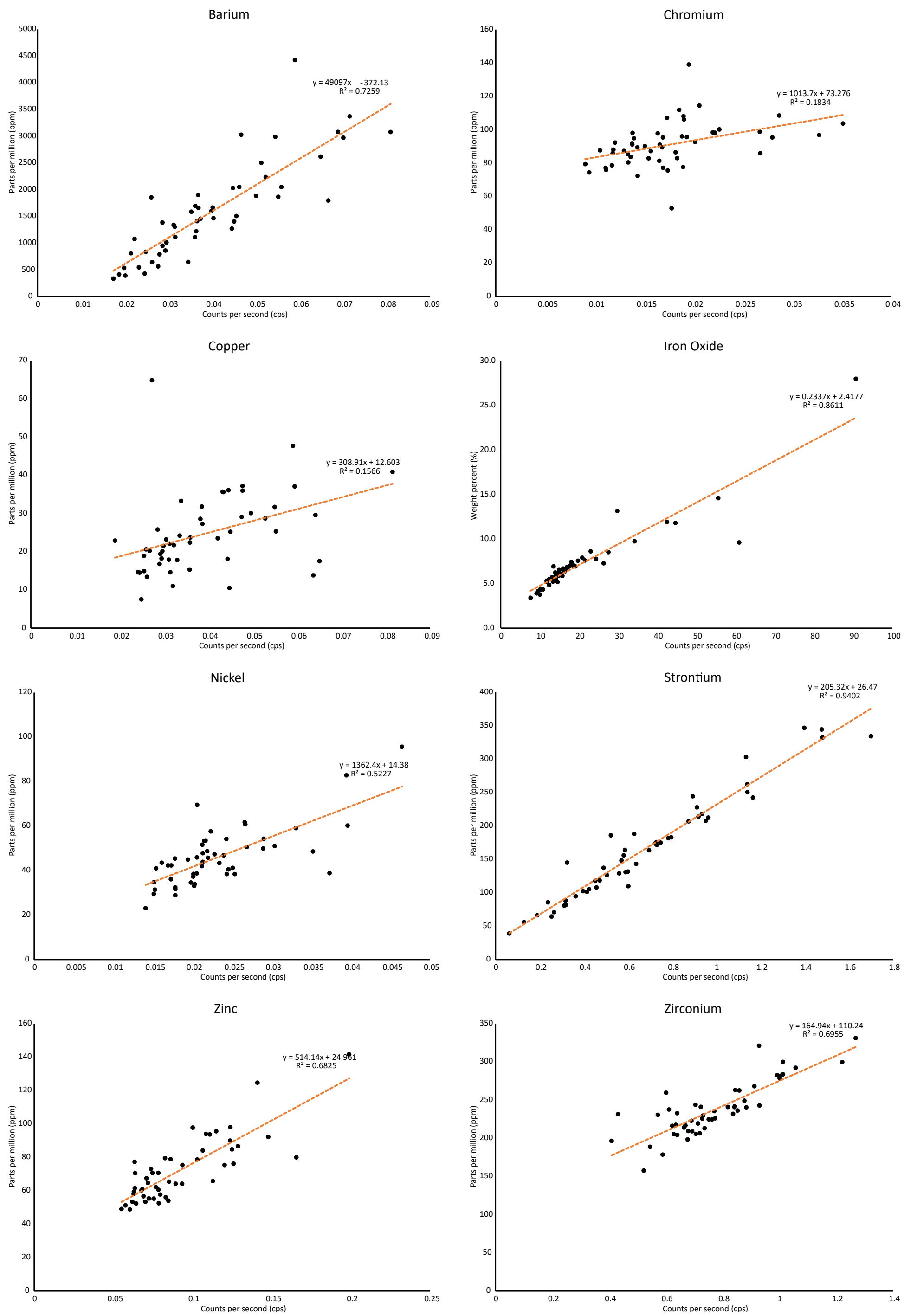

Figure 3.12: Linear regression of pXRF data (x-axis) and desktop XRF data (y-axis) for Ba, Cr, Cu, Fe, Ni, Sr, Zn, and Zr values.

Phase identification analysis was conducted for a subset of 60 sherds to determine how the geochemical variations associated with the 18 production units corresponded with differences in sherd mineralogy. Qualitative phase identification reported the presence of 14 minerals in the clay matrix and/or as mineral inclusions of the 60 sherds. These minerals are quartz, goethite, anorthite, muscovite, albite, orthoclase, hercynite magnesian, hematite, spinel, sanidine, microcline calcite, hornblende, and clinoclore. Calcite, hornblende, and clinoclore were present in only three specimens, two of which were non-anthropogenic, and the third was non-ceramic but anthropogenic (these samples were subsequently removed from the pXRF analysis). Beyond these aberrant cases, the XRD analysis indicates that quartz, feldspars (albite, anorthite, microcline, orthoclase, sanidine), mica (muscovite), and other ferrous, magnesium, and spinel-rich materials (goethite, hematite, hercynite magnesian, spinel) were the primary mineralogical components of clays and inclusions used in Qujialing and Shijiahe pottery.

Hierarchical cluster analysis of the 60 XRD samples was conducted with variables standardized by z-score and the Ward's D linkage method. The resulting dendrogram, seen in Figure 3.13, shows three major mineralogical pottery groups. The first two groups each include 8 sherds, while the much larger Group 3 consists of 41 sherds. The three ungrouped specimens are the previously mentioned non-ceramic materials; their distance from the other 57 cases underscores the sensitivity of hierarchical cluster analysis to ordering compositional data.

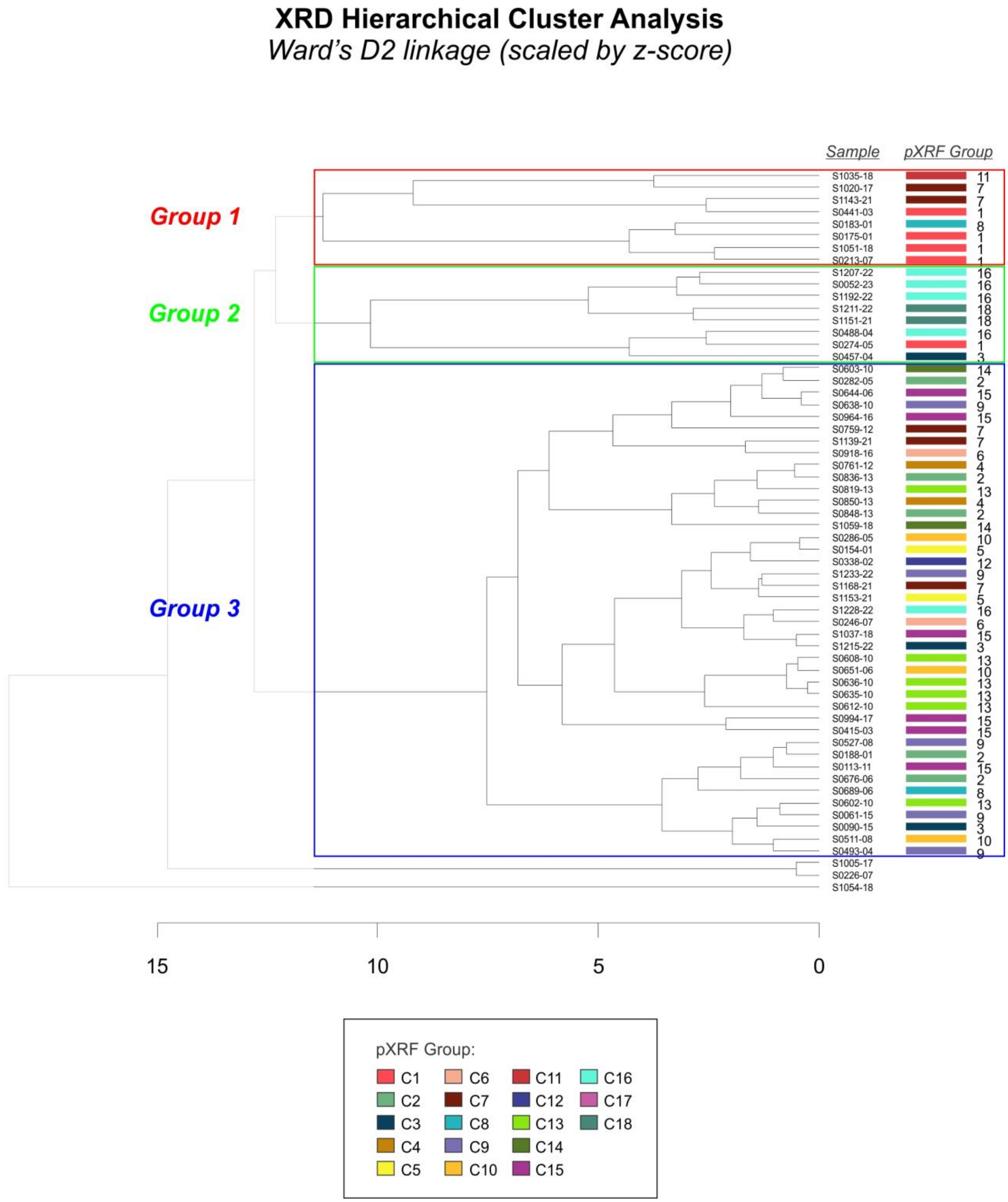

Figure 3.13: Dendrogram of the 60 pottery sherds analyzed by XRD based on the weight percent of quartz, goethite, anorthite, muscovite, albite, orthoclase, hercynite magnesian, hematite, spinel, sanidine, microcline calcite, hornblende, and clinoclore. Three groups were delineated based on mineralogical variations.

Quartz represented about 50% by weight of the 57 pottery samples in Groups 1, 2, and 3. In addition to quartz, sherds in Group 1 are characterized by higher quantities of plagioclase feldspar minerals anorthite and albite, which constitutes 11% ± 4.9% and 15% ± 4.2% of sherd mass, respectively, at the 95% confidence interval. Sherds in Group 2, by contrast, tend to be richer in iron-bearing minerals: goethite and hematite represent 13% ± 8.1% and 7% ± 6% of sherd composition, at the 95% confidence interval. Sherds in the much larger Group 3 have higher quantities of alkali feldspar minerals (albite: 10% ± 1.1%; orthoclase: 10% ± 1.6%, at the 95% confidence interval) and mica (muscovite: 14% ± 2.3%, 95% confidence interval). Pottery from pXRF group C1 are especially abundant in mineralogical Group 1, while pottery from pXRF groups C16 and C18 appear to be closely associated with the mineralogy of XRD Group 2. Many other chemically distinct groups of pottery appear to share the same mineralogy in Group 3, though pottery from chemical groups like C13 and C15 are found close together within Group 3. Overlap between mineralogical and elemental analyses underscores the compatibility of these three techniques for identifying meaningful patterns of compositional variation in archaeological pottery.

3.5 THE SOCIAL MEANING OF COMPOSITIONAL GROUPS

3.5.1 Compositional groups and vessel forms

The results of the three analyses presented above reveal clear and consistent patterns in the compositional variability of the ceramic sample. I have used these patterns to delineate 18 groups of pottery that are similar in their geochemical and mineralogical signatures. The issue that now arises is how these compositionally-distinct groups of pottery sherds are related to the behaviors and decisions of social agents. What factors produce geochemical and mineralogical variability in pottery?

In some parts of the world, potters use different clay paste recipes to produce vessels with distinct functions (Longacre 1991; Underhill 2003; see also Cheng et al. 2009). Cooking pots, for example, may be made with materials that make them more resistant to thermal stress caused by repeated heating and cooling, while serving vessels might be made with particularly fine clays to appear delicate or to mimic more exotic materials like stone or bronze. Hence, one possible explanation for the compositional variation observed in the pottery sample is that the compositional groups represent distinct forms or functional classes of vessel.

To test this proposition, I examined the relation between compositional group and vessel form for each period. Of the full sample of sherds analyzed by pXRF, the original vessel form of only 124 sherds could be identified, which include *bei* 杯, *bo* 钵, *ding* 鼎, *dou* 豆, *gang* 缸, *guan* 罐, *hu* 壶, *pen* 盆, *wan* 碗, and *weng* 瓮 (Table 3.5). Due to the small number of sherds with a known vessel form and the large number of compositional groups, a direct comparison of the two categories offers little insight into their relationship. I instead consolidated the 10 vessel forms into three groups based on function. These functional classes include vessels used for cooking (*ding*), vessels used for serving (*bei, bo dou, hu, pen,* and *wan*), and vessels used in storage (*gang, guan,* and *weng*) (

Table 3.6).

Table 3.5: Count of vessel forms associated with each compositional group for the Qujialing period. The 11 vessel forms were combined into three functional classes as follows – cooking (ding), serving (bei, bo, dou, hu, pen, wan), and storage (gang, guan, and weng). Lids were omitted from these functional counts.

Compositional Group	Bei	Bo	Ding	Dou	Gang	Guan	Hu	Lid	Pen	Wan	Weng	Cook	Serve	Store
1	0	0	0	1	0	1	0	0	0	1	0	0	2	1
2	4	1	1	0	1	3	0	0	0	2	0	1	7	4
3	1	0	2	1	1	1	0	0	1	3	0	2	6	2

4	0	0	0	1	1	1	1	1	0	1	0	0	3	3
5	0	0	0	1	2	1	0	1	3	1	0	0	5	4
6	0	1	0	2	0	0	0	0	0	1	0	0	4	0
7	0	0	0	0	0	1	0	0	0	0	0	0	0	1
8	2	2	0	1	0	2	0	0	2	1	0	0	8	2
9	1	0	1	1	0	0	0	0	1	0	0	1	3	0
10	1	0	1	0	0	1	0	0	0	1	0	1	2	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	1	1	1	0	0	0	0	0	1	0	1	3	0
14	0	0	0	0	0	1	0	0	0	0	0	0	0	1
15	0	0	1	0	2	1	0	0	0	0	0	1	0	3
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0

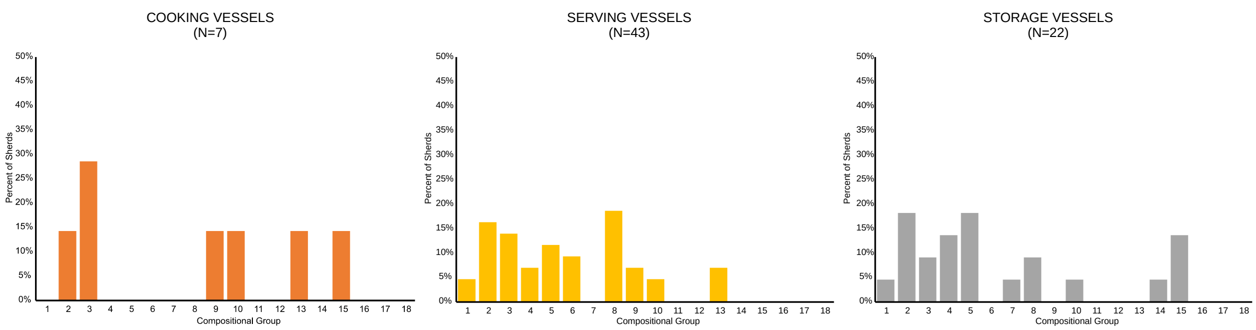

Figure 3.14: Proportion of identifiable Qujialing cooking, serving, and storage vessels associated with each compositional group.

Table 3.6: Count of vessel forms associated with each compositional group for the Shijiahe period. The 11 vessel forms were combined into three functional classes as follows – cooking (ding), serving (bei, bo, dou, hu, pen, wan), and storage (gang, guan, and weng). Lids were omitted from these functional counts.

Compositional Group	Bei	Bo	Ding	Dou	Gang	Guan	Hu	Lid	Pen	Wan	Weng	Cook	Serve	Store
1	0	0	0	0	2	2	0	0	1	0	1	0	1	5
2	0	0	0	1	3	4	0	2	1	1	0	0	3	7
3	0	0	1	1	0	4	0	0	0	1	0	1	2	4
4	1	0	0	1	0	0	0	0	0	0	0	0	2	0
5	0	0	0	0	2	2	0	0	1	0	1	0	1	5

6	1	0	0	0	0	0	0	0	0	0	0	0	1	0
7	0	0	0	0	2	0	0	0	0	0	1	0	0	3
8	0	0	1	0	1	0	0	0	0	0	0	1	0	1
9	0	0	1	0	0	4	0	0	0	0	0	1	0	4
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	1	1	0	0	0	0	0	0	0	1	1	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	1	1	0	0	0	0	0	0	0	1	1
14	1	1	0	0	0	0	0	0	0	0	0	0	2	0
15	0	0	0	1	0	1	0	0	1	0	1	0	2	2
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0

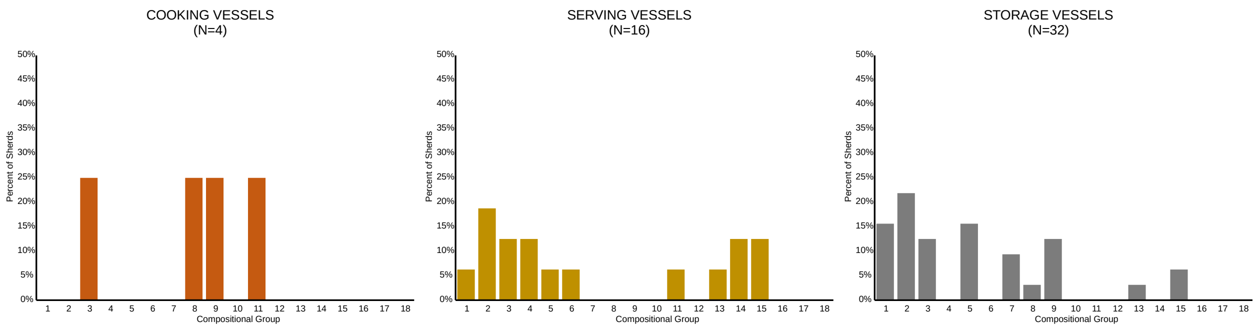

Figure 3.15: Proportion of identifiable Shijiahe cooking, serving, and storage vessels associated with each compositional group.

However, a careful examination of graphs in Figure 3.14 and Figure 3.15 reveals a lack of a relationship between compositional group and vessel function. For example, in the Qujialing period, nearly every compositional group is associated with both serving and storage vessels. Cooking vessels are found less frequently across the sample, but they always appear together with vessels of another function. In the Shijiahe period, several storage vessels are associated with compositional group C2 (n=7, 22%), though many storage vessels are also associated with C1, C3, C5, and C9. C2 also has the highest number of serving vessels associated with it (though 3 vessels is still a small number), indicating that the same raw materials were used to produce cups and bowls as well as vats for holding grain or fermenting vegetables. Cooking vessels, though present in smaller numbers, again appear together with both serving and storage vessels at several different compositional groups. Together, this data implies that potters were not using specific clays or other raw materials to produce vessels designed for particular tasks. Thus the variability in the geochemical composition of pottery shown in the dendrogram in Figure 3.10 is related to factors other than vessel form and function.

3.5.2 Compositional groups and production units

Another possible interpretation of the compositional variability of the pottery sample relates not to the identity of ceramic vessels but to the identity of the producers. At its most basic, the compositional signature of a pot is linked to both geology and culture. Natural clay and mineral inclusions contain trace amounts of elements derived from the geological forms in which they are located. This means that vessels made by two potters who get their clay and temper from the same sources will have very similar compositions. At the same time, differences in processing and preparation of clay pastes will also impact the chemical and mineralogical signatures of pottery. If the first of our two potters uses a 1:2 temper-to-clay ratio to make her pot while the other uses a 1:10 ratio for hers, the overall (bulk) composition of the two vessels will be distinct even though the raw materials were the same. Bringing together these two basic principles, we can argue that pottery with a similar composition was made using the same raw material resources, and/or following a common set of production practices. It follows that producers of compositionally-similar pots lived in places with access to the same raw materials, and practiced similar traditions for preparing clay pastes.

I refer to each of these 18 compositional groups as a ‘production unit’: a group of potters of an unknown size and duration, who used similar raw materials and clay paste recipes to produce pottery. A production unit might describe a community of related potters who rely on local resources to produce pots in a traditional manner, just as well as it could describe an industrial pottery workshop. Though this definition is necessarily broad, we can draw some reasonable expectations for these production units. Given the degree of geochemical variation observed among sherds, it is improbable that the same raw materials were present everywhere in the study area, nor is it likely that raw earthenware clays were themselves traded. These factors suggest that production units were spatially focused on areas much smaller than the study area. Interpreting compositional groups as production units allows us to explore the ceramic dataset not just in terms of atoms and minerals but from social and economic perspectives. Thinking in terms of production units brings people—producers and, inevitably, consumers (who may be the same individuals)—into the frame of this analysis. The 18 compositional groups identified in this chapter are the 18 production units that form the basis of my analysis of pottery exchange and procurement patterns in the following chapter.

4.0 POTTERY EXCHANGE AND PROCUREMENT IN THE TAOJIAHU-XIAOCHENG REGION

This chapter builds on the 18 pottery production units and 23 neighborhoods described in the previous chapter to develop a model of utilitarian pottery exchange networks in the northern Jianghan Plain during the Qujialing and Shijiahe periods. I examine patterns of pottery circulation and procurement between neighborhoods, between communities living inside and outside walls, and between settlements in the northern and southern zones of the region. A multiscalar approach was used to trace economic interactions that emerge among clustered groups of households that were obscured at the regional level, as well those that unfolded on a regional scale but may have been invisible at the level of neighborhoods.

This study of pottery exchange networks begins with the final stages in the use-life of a ceramic vessel. For most archaeological cases, and particularly those focused on domestic contexts, the locations where sherds were recovered corresponds to where they were used and ultimately discarded. Examining patterns in the kinds of pottery distributed throughout the study area provides a window into patterns of pottery circulation and consumption strategies of the late Neolithic.

For each period, several experimental questions were evaluated. First, I identified how pottery from each production unit was circulated across the region. Second, I investigated whether populations living in different locations had access to pottery from the same sets of production units. Third, I determined whether patterns of pottery procurement varied across the region. Fourth, I evaluated whether vessels from all 18 production units circulated equally among neighborhoods, or whether pottery from certain sources circulated more widely than others. Finally, I examined how the organization of these exchange networks shifted across time.

4.1 POTTERY EXCHANGE AND PROCUREMENT IN THE QUJIALING PERIOD

4.1.1 Pottery exchange

Patterns of pottery exchange were identified by comparing the frequency of pottery from each production unit in the ceramic assemblages of each neighborhood. Figure 4.1 depicts the distribution of sherds from the 18 pottery production units across 11 Qujialing period neighborhood assemblages. Each bar graph in the figure represents a neighborhood ceramic assemblage, with the colored bars depicting the proportion of the total assemblage corresponding to a given production unit. A quick visual comparison of these neighborhood assemblages reveals substantial overlap in the pottery that was being used across the study region. Residents of Neighborhood 9 and Neighborhood 1, for instance, relied on pottery from many of the same production units in similar proportions. In fact, the overarching semblance of these assemblages dismisses the possibility that one workshop produced all the pottery at Xiaocheng and another produced all the pottery at Taojiahu, or even that each neighborhood had its own pottery workshop. Instead, pottery circulated through a complex set of overlapping networks that likely extended far beyond the boundaries of the study area. This image of freely circulating pottery contrasts sharply with the picture of regional interactions in the Qujialing period settlement patterns described in Chapter 2. It also goes against many scholars' interpretations of these settlements as atomistic units that were isolated from one another by earthen walls or moats. Although there are some differences in the kinds and quantities of pottery that were consumed by residents of walled and unwalled areas, the sweeping similarities in pottery assemblages across the study area indicate that these walls did not obstruct economic interactions between communities.

Next, to characterize variation in consumer access to exchange networks, differences in the distribution of sherds were quantified using chi-square tests of homogeneity. This process involved comparing observed frequencies of sherds to expected, uniform frequencies by neighborhood. Expected frequencies were calculated by finding the proportion of all Qujialing sherds that represented each production unit. This proportion was then weighed by the number of sherds sampled in each neighborhood to determine how many sherds of a given production unit would be expected if all 18 production units were represented equally across neighborhoods. Networks with low χ^2 values, coupled with low significance and strength, indicate diffuse circulation networks to which consumers at all (or most) neighborhoods have equivalent access. In other words, access to these networks, as indicated by sherd frequency, did not decline significantly with distance at the scale of the survey area, suggesting these networks were geographically large (Hodder 1974; Renfrew 1977). Networks with high χ^2 values, significance, and strength, on the other hand, point to focused pottery exchange networks that not all consumers accessed equally. Distances considerably smaller than the survey area had clear effects on the abundance of these pots and thus indicated that the extents of these networks were geographically small. Due to the low number of sherds available from certain production units, chi-square tests were only calculated for production units with 20 or more sherds (C1, C2, C3, C4, C5, C6, C8, C9, C10, C13, and C15). Finally, χ^2 residuals for each neighborhood were compared to identify neighborhoods in which pottery was present in frequencies that were one and two standard deviations away from what was expected. I discuss these neighborhoods as *focal points*, or centers of gravity, in the exchange network of a particular pottery source.

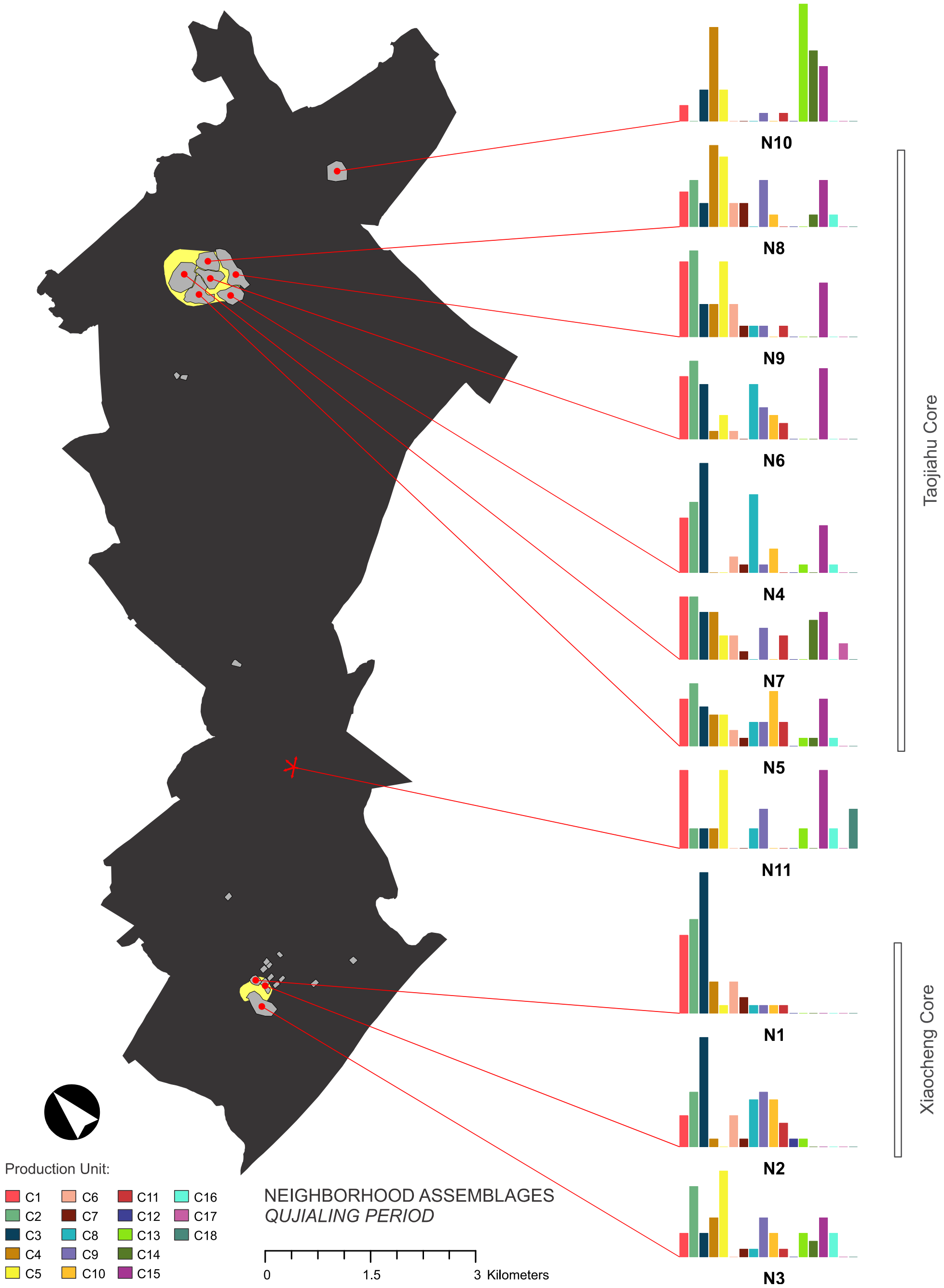

Figure 4.1: Qujialing neighborhood ceramic assemblages depicting the frequency of pottery from each production unit.

The first notable finding of this analysis is that Qujialing period pottery circulated through many different exchange networks (Table 4.1). Frequencies of pottery from C1, C2, and C9, and to a lesser extent from C6 and C15, did not deviate much from expected values, indicating that a substantial portion of Qujialing pottery was distributed evenly across neighborhoods. Two exchange scenarios yield distributional patterns in which frequencies of objects show little attenuation effects beyond the vagaries of sampling. The first scenario is that pottery from these production units was exchanged through large enough networks that we failed to see evidence of distance decay from our 58 km^2 vantage point. In other words, the point of origin for these pots was far enough away from the study region that the 10 km separating Taojiahu and Xiaocheng had minimal impact on pottery frequencies (notably, XRD results suggest that pottery from production unit C1 may have been produced somewhere outside of the survey zone). The second, related scenario, is that of *down-the-line exchange*, where goods are circulated preferentially between central places where they are subsequently distributed to surrounding settlement (Renfrew 1977:85–87). Given the limited evidence of settlement outside of the Taojiahu and Xiaocheng core areas at this time, a down-the-line model of pottery trade would result in a more uniform distribution of pottery than what is seen in a region with a more settled hinterland (e.g. Sidrys 1977). Distributional patterns of pottery from production units C6 and C15 offer additional insight to Qujialing period pottery exchange networks. Pottery from C6 was only recovered in core areas (albeit in very low frequencies) while C15 was concentrated primarily in the north. This suggests pottery was circulated through non-directional, large networks (C15) and directional, down-the-line networks between walled settlements (C6). Both scenarios indicate that Taojiahu and Xiaocheng had economic ties with other communities in the broader Jianghan region. These networks were clearly important economic channels, as they circulated roughly 45% of Qujialing pottery in the region.

Table 4.1: Relative scale (large, intermediate, or small) of Qujialing pottery circulation networks from 18 production units. Individual neighborhoods with χ^2 residuals that were one or two standard deviations from the mean are noted here and indicate areas with higher than expected frequencies (or lower than expected frequencies) of pottery for a given production unit.

Production Unit	Distribution Scale	χ^2	*n*	*df*	*p*	*V*	1 σ		2 σ	
							+	-	+	-
C1	Large	11.196	62	10	0.342	0.134	N1	N3, N10		
C2	Large	13.899	76	10	0.178	0.135	N1			**N10**
C6	Large	10.902	21	10	0.365	0.228	N1, N2, N9	N3, N10		
C9	Large	12.487	33	10	0.254	0.195	N2	N1, N4, N10		
C15	Large	16.064	52	10	0.098	0.176	N6	N1, N2		
C3	Small	33.838	77	10	0.000	0.210	N2, N4	N3	**N1**	
C5	Small	32.765	43	10	0.000	0.276	N3, N9	N1, N2, N4		
C8	Small	35.171	30	10	0.000	0.342	N6		**N4**	
C10	Small	22.662	24	10	0.012	0.307	N2	N7, N10	**N5**	
C13	Small	84.488	22	10	0.000	0.620			**N10**	
C7			10							
C11			15							
C12			1							
C14			18							
C16			7							
C17			1							
C18			2							

Distribution of pottery from other production units, on the other hand, was more restricted. Sherds associated with production units C3, C4, C5, C8, C10, and C13 were abundant in some neighborhoods and either absent or found in low frequencies at others. The chi-square values shown for these production units in Table 4.1 show that frequencies of these sherds differed significantly and strongly from the expected, homogenous baseline. Pottery from C3, in particular, was found in especially high quantities in Neighborhood 1, as well as Neighborhoods 2 and 4, pointing to a circulation network that is connected to a production unit that was likely located at Xiaocheng with consumers in Xiaocheng and Taojiahu (especially the southernmost part of Taojiahu). Similarly, pottery from C8 was especially abundant at Neighborhood 4, as well as at Neighborhoods 6 and 2, indicating that the C8 production unit may have been located somewhere just south of the center part of the Taojiahu core, frequently exchanging pottery with households at Neighborhood 2 in Xiaocheng. Circulation of pottery from production unit C10 echoes the structure of C3 and C8 exchange networks, linking together neighborhoods at the southern and southwest side of Taojiahu with those at Xiaocheng (Neighborhoods 2 and 3).

Circulation networks associated with production units C4 and C13 were different from those of C3, C8, and C10. Vessels made by units C4 and C13 were particularly abundant in northern hinterland Neighborhood 10, located east of Taojiahu. Pottery from C4 was also recovered in high quantities in Neighborhood 8, but in lower than expected proportions at Neighborhoods 2, 4, and 6, revealing a circulation pattern that was distinct from those of the C3 and C8 pottery exchange networks. However, the presence of C4 pottery in almost all neighborhoods indicates that although this network had a distinct structure, it was still accessible to other neighborhoods in the region.

The distribution of pottery from production unit C13 tells a different story. Pottery from C13 was considerably more abundant in Neighborhood 10 than anywhere else in the region. This distribution pattern suggests that C13 pottery was both produced and primarily consumed by households in Neighborhood 10. The relatively small numbers of C13 vessels that were circulated regionally were more often exchanged with households residing in other parts of the hinterland (Neighborhoods 3 and 11).

Roughly the same proportion of Qujialing pottery was circulated through small-scale, local networks as was circulated through broad, regional networks. These local networks connected a variety of neighborhoods through the movement of pottery: some connected neighborhoods in core areas of Taojiahu with those in core areas of Xiaocheng (C3, C8, C10), while others connected core areas with households in the hinterland (C4). A third kind of circulation network (C13) linked neighborhoods that were located outside of walled towns, showing that pottery exchange was not necessarily controlled or orchestrated by the populations living in core settlement areas.

Finally, the circumscribed distribution of ceramics from production units C17 and C18 point to yet another form of circulation network. While sherds associated with these production units are rare, their peculiar distribution suggests some possibilities for the nature of their circulation. These production units were represented in just two neighborhoods in low quantities, and may relate to particularly short-lived production units or to sporadic exchanges with production units based much further away from the study region. XRD analysis indicated that C18 was associated with mineralogical Group 2, which was distinct from the majority of pottery recovered in the region, which potentially means it came from outside the study area.

Thus, Qujialing period occupants of the study area were hooked into a variety of ceramic circulation networks. These networks ranged from large-scale systems to smaller-scale, possibly local networks that provisioned some but not all the neighborhoods in the region. Examining the structure of exchange networks not only allows us to focus how access to pottery was similar or different between neighborhoods, it also reveals patterns of interaction between populations that are not otherwise detectable in regional settlement patterns. Neighborhoods 3 and 8 are separated by 8 km and an earthen wall, but the occupants of these areas were in contact with the same group of potters that produced C9 vessels. Economic networks connected populations (whether directly or indirectly) that might otherwise occupy completely disparate social spheres. The result was that Qujialing period populations were connected to one another through local pottery distribution networks as well as with populations much further away through broader, regional networks.

4.1.2 Pottery procurement

Shifting attention away from production units to individual neighborhoods enables the examination of how households in each neighborhood procured pottery. Pottery from all 18 production units are represented in ceramic assemblages dating to the Qujialing period, with pottery from 9 to 15 distinct production units recovered from a given neighborhood. Comparing neighborhood ceramic assemblages reveals a high degree of redundancy in the production units households relied upon for much of their pottery. All neighborhoods consumed pottery from the same three production units (C1, C3, and C9), and the pottery from 8 additional production units was represented across 70% of neighborhoods.

Multidimensional scaling is a powerful means of comparing neighborhood assemblages. This method involves transforming highly dimensional data into two-dimensional plots in which each point represents a case in the dataset, and the distance between points corresponds to the relative similarity of cases. The purpose of multidimensional scaling is to reduce the number of dimensions in which cases vary from one another to more clearly and simply trace the relationship between them. Here, each of the 11 Qujialing neighborhoods is taken as an individual case. These cases vary along 18 dimensions based on the proportion of sherds from the 18 production units that are represented in each assemblage.

As with hierarchical cluster analysis, multidimensional scaling begins with calculating similarity coefficients between cases, which here represent neighborhood assemblages. These similarities are recorded in a symmetrical matrix akin to a table of distances in an atlas, with the exception that a higher value between cases reflects greater similarity. For this analysis, similarity was measured between neighborhoods using two separate similarity coefficients with variables standardized by z-score: Euclidean distance (expressed as a similarity coefficient) and the Brainerd-Robinson similarity coefficient (Peeples 2011). The purpose of repeating this analysis with two different coefficients was to determine the robustness of patterning in the data. Ultimately, multidimensional scaling solutions produced by these two metrics showed very little difference, attesting to the persistence of these patterns. For the sake of simplicity, in this discussion I present only the results calculated with the more commonly-used Euclidean distance metric. The full set of multidimensional scalings can be found online at the Comparative Archaeology Database of the University of Pittsburgh Center for Comparative Archaeology (Sturm 2017).

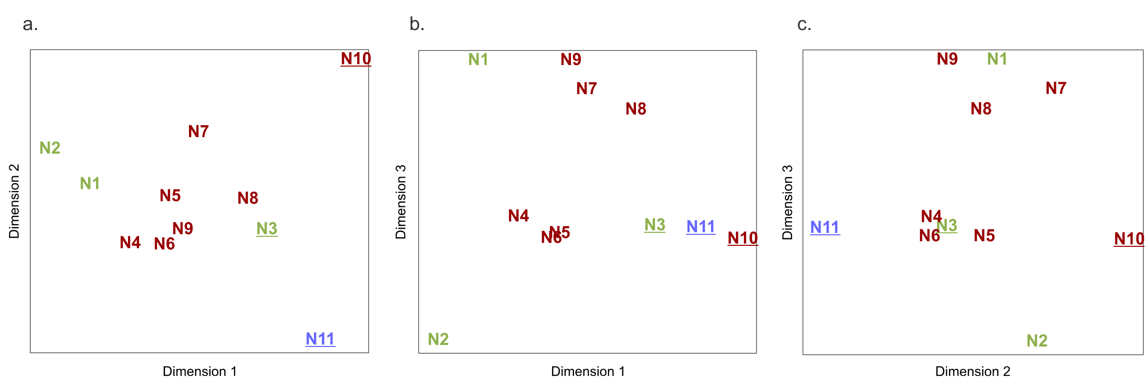

Figure 4.2a-c: Three-dimensional multidimensional scaling solution for the 11 Qujialing neighborhoods based on Euclidean distance. Neighborhoods in green are from the southern zone of the survey area, those in red are from the north, and blue from the middle. Neighborhoods that are underlined are from hinterland areas, those without underlining are from core areas.

The results of a three-dimensional scaling solution of Qujialing period neighborhoods, shown in Figure 4.2, reveal several axes of variation. Neighborhoods in Xiaocheng and Taojiahu core areas clustered separately from one another and from hinterland neighborhoods (Figure

4.2a). These three clusters correspond roughly to the spatial relationship of neighborhoods: Xiaocheng Neighborhoods 1 and 2 are separate from Taojiahu Neighborhoods 4, 5, 6, 7, 8, and 9, which are both in turn distinct from hinterland Neighborhoods 3, 10, and 11.

Plots of Dimensions 1 and 3, and 2 and 3, reveal patterns of clustering that crosscut geographic location. In Figures Figure 4.2b and Figure 4.2c, Taojiahu Neighborhoods 7, 8, and 9 cluster with Neighborhood 1; as Neighborhoods 4, 5, and 6 cluster tightly with southern hinterland Neighborhood 3. Although it can be complicated to determine the specific combination of variables that produced these groupings, we can begin to unravel these patterns by comparing combinations of production units present in each neighborhood assemblage. Neighborhoods 7, 8, and 9 have low proportions of C3, C8, and C10 pottery, but higher proportions of C4 and C5 pottery than Neighborhoods N4, N5, and N6. The ceramic assemblage of Neighborhood 1 is similar to those of Neighborhoods 7, 8, and 9 in that all have higher frequencies of sherds from the first seven production units (C1-C7), and low frequencies of sherds from the next four (C8-C11). By contrast, the assemblages of the Neighborhoods 4-5-6 group and Neighborhood 3 display higher frequencies of the four middle production units (C8-C11), especially C8 and C10, and some combination of the last few production units (C13-C16), particularly C13 and C16. The last three neighborhoods, Neighborhoods 2, 10, and 11, are distinguished from the rest by their particular combination of production units represented in each assemblage. Neighborhood 2 has high proportions of sherds from the first set of production units (C1-C3) and the middle units (particularly C6, C8, C9, C10, and C11), but no sherds from the last set of production units. Neighborhood 10 is characterized by high proportions of sherds from a few production units, contrasting with Neighborhood 11, which has high proportions of sherds from several different production units. As Neighborhood 11 is composed of all the dispersed collection lots that were not included in any of the other 10 neighborhoods, this pattern probably represents an amalgamation of several different consumption patterns found across the region.

Together, the multidimensional scaling results show that while geographic distance between neighborhoods played a role in determining assemblage similarity, other factors impacted the range and combination of pottery production units represented in each neighborhood. This fits well with the conclusions drawn from the analysis of Qujialing pottery circulation networks: mainly that neighborhoods far afield of one another were often linked together by economic networks.

Pooling together ceramic assemblages allows us to identify larger-scale economic patterns that are invisible to us at the level of individual neighborhoods. We can put a finer point on the difference seen in the multidimensional scaling between pottery access and consumption in areas inside and outside walls. I refer to the densely settled areas within the Taojiahu and Xiaocheng walls as 'core' areas, and the more dispersed area of settlement outside these walls as the 'hinterland'. Chi-square comparisons of core and hinterland assemblages shows a significant and strong difference in the kinds of pottery present in these areas (χ^2=112.493, df=14, p<0.0005, V=0.459; calculated for production units with more than five sherds). Much of the difference between assemblages arises from heavy reliance on pottery from production units C1, C2, and C3 in the core area, and an emphasis on pottery from production units C4, C5, and C13 in the hinterland area (Figure 4.3). This difference is further captured in multidimensional scaling plots of neighborhood assemblages, in which hinterland Neighborhoods 3, 10, and 11 cluster consistently together, distinct from core zone neighborhoods (Figure 4.2).

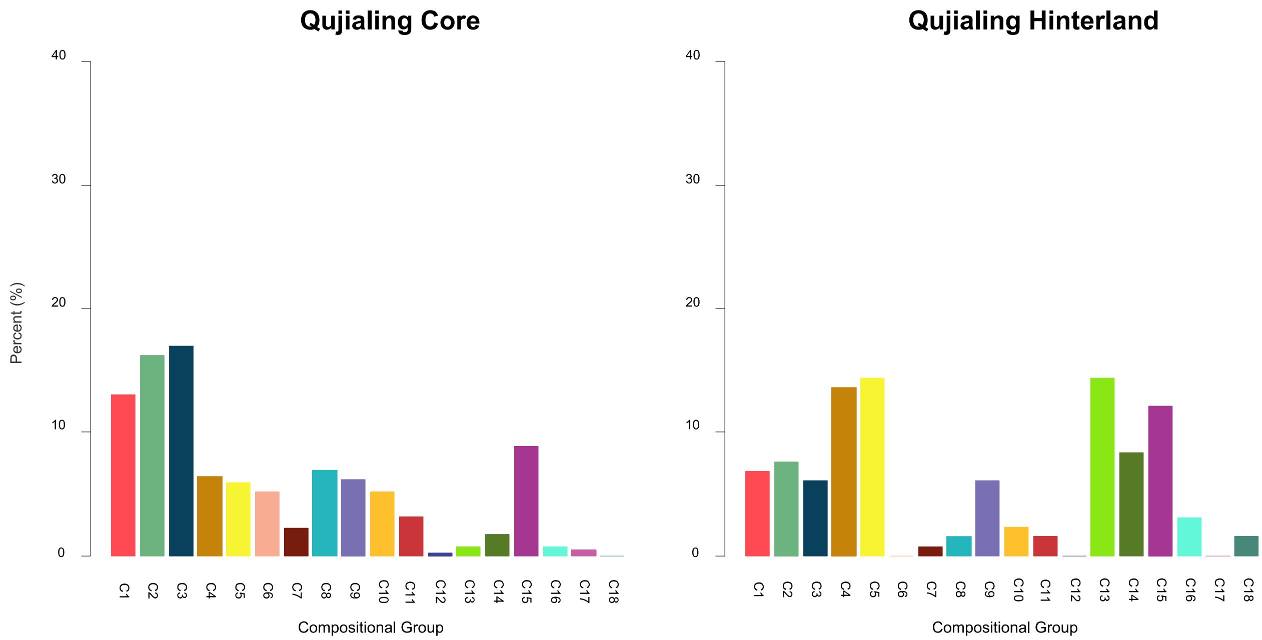

Figure 4.3: Proportion of pottery from the 18 production units recovered in Qujialing core and hinterland ceramic assemblages. Core zones designate all neighborhoods located inside walled areas (Neighborhoods 1, 2, 4, 5, 6, 7, 8, and 9), hinterland zones refer to all neighborhoods located outside walled areas (Neighborhoods 3, 10, and 11).

Comparing pottery assemblages from Taojiahu and its environs north of the Zaoshi River with pottery assemblages from Xiaocheng and its environs south of this river targets potential differences in access to pottery within each supralocal community. Because neighborhood 11 includes dispersed collection lots located both to the north and the south of the Zaoshi, it was excluded from the following comparisons. Visual comparison of the pooled proportions of northern and of southern neighborhoods indicates marked parity in the kinds of pottery consumed in these regions, especially when contrasted with core/hinterland assemblages (Figure 4.4). Although there was a significant difference between these assemblages, this difference was weak (χ^2=29.411, df=14, p=0.009, V=0.239). This difference arose in large part because of the high concentration of pottery from production unit C3 pottery in the south (21.2% ± 5.1% at the 90% confidence interval), and from C15 pottery in the north (particularly at Neighborhood 10; 12% ± 2.9% with 90% confidence). This relationship is also reflected in the multidimensional scaling plots in the separation of Xiaocheng core from Taojiahu core neighborhoods in (Figure 4.2a), and in the overlap of neighborhoods from northern and southern parts of the study zone in the other dimensions (Figure 4.2b and c).

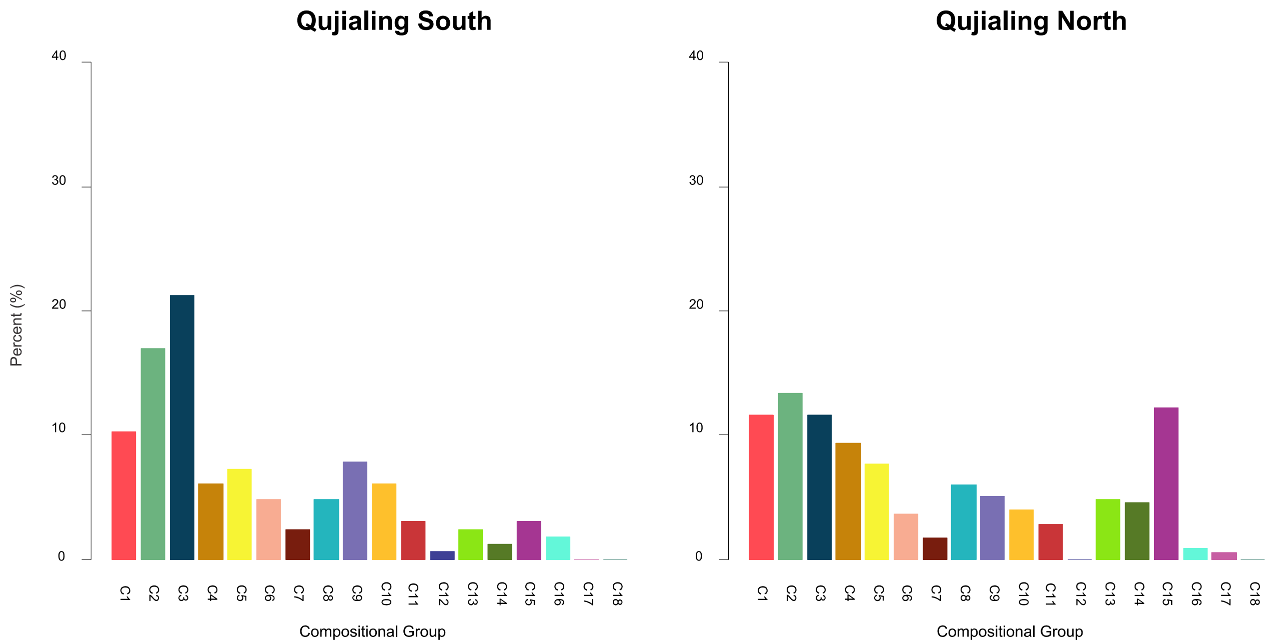

Figure 4.4: Proportion of pottery from the 18 production units recovered in northern and southern areas of the survey zone. The south zone includes assemblages from Neighborhoods 1-3; the south zone includes assemblages from Neighborhoods 4-10. Note that Neighborhood 11 is not included because it represents dispersed areas of settlement across both the northern and southern zones.

Several key features of pottery consumption practices emerge through this analysis of Qujialing period ceramic assemblages. First, occupants of each neighborhood relied on pottery from many of the same production units, with slight variations in the combination of groups and the frequency with which particular pots were consumed. Second, pooling these neighborhoods into larger spatial-social units revealed significant differences in the pottery assemblages of core and hinterland settlements. Pottery from certain production units was better represented in core areas than in hinterland areas, and vice-versa, a pattern that was also observed in the results of multidimensional scaling results. Finally, and contrastingly, patterns of pottery consumption in the north and south of the study area were significantly but weakly different. These data demonstrate that whether a household was in a core or hinterland settlement had a larger impact on the kinds of pottery it consumed than whether that household was situated closer to Taojiahu or to Xiaocheng.

Consumption patterns do not only involve the range of goods people rely upon, but also encompass the strategies people use to acquire goods. For example, consumption patterns may be determined by the kinds of acquisition strategies used by groups of households to provision themselves, which might vary from neighborhood to neighborhood, from settlement to settlement, and through time. Did households in each neighborhood accumulate pottery from largely the same sets of production units, or from a wide range of producers? In order to address these questions, I calculated and utilized assemblage diversity as a proxy for patterns of pottery accumulation. Diversity is a measure of assemblage richness (the absolute number of production units represented) and evenness (the frequency with which each production unit is represented). I used Simpson's D as an index of assemblage diversity (symbolized in the following discussion as *D*). The index ranges from 0 to 1, where 0 indicates that all sherds are from the same production unit (no diversity) and 1 indicates that all sherds are from different production units (total diversity).

Bullet graphs of Simpson's Index and bootstrapped confidence intervals for neighborhood and pooled, supra-local zones are shown in Figure 4.5. At the level of individual neighborhoods, Qujialing consumers amassed pottery from a wide range of pottery production units. Some minor differences in diversity point to local variations in the ways that groups of households provisioned themselves. Ceramic assemblages of populations living in Neighborhoods 1, 4, and 10 had the lowest diversity scores, which fell between 81% and 86%, whereas Neighborhoods 5 and 7 had some of the highest diversity scores at 93% and 91%, respectively. While some neighborhoods exhibited significantly different diversity scores, the strength of these differences was extremely low. Even the diversity scores at the far ends of the spectrum amount to saying that there is an 80% chance that two sherds selected at random belong to different production units versus a 95% chance: both indicate that populations at all neighborhoods acquired pottery from many different production units in substantial quantities. This finding complements earlier observations that pottery circulated freely during the Qujialing period and that access to production units was not restricted.

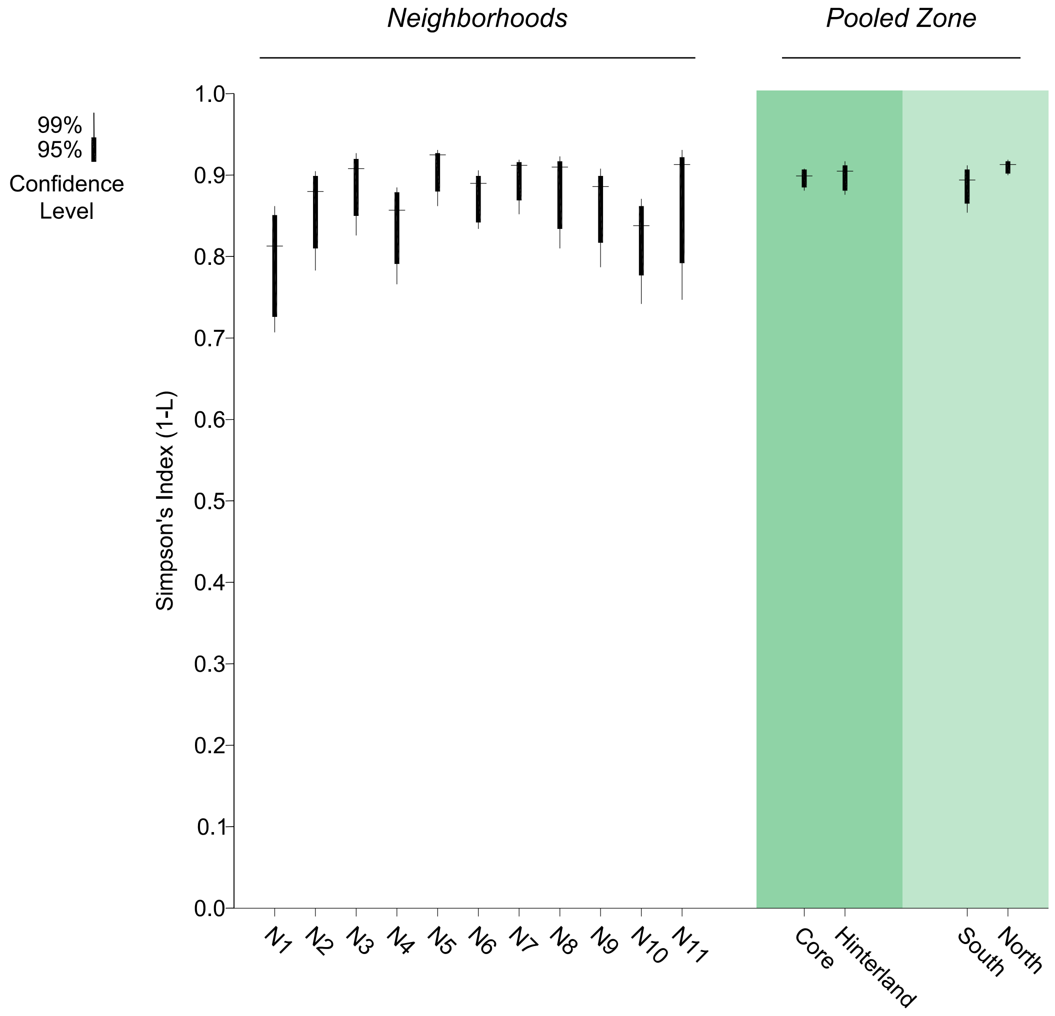

Figure 4.5: Diversity scores of Qujialing neighborhood assemblages (left) and regional zones (right) with bootstrapped error ranges for the 95% and 99% confidence levels.

Pooling together neighborhood diversity data revealed higher order patterns in how populations acquired pottery. Northern settlement outside the walls of Taojiahu were the least diverse, with a 77% - 87% chance, respectively, that two sherds from this area chosen at random came from different production units (*D*=83.8%, at the 95% confidence interval). A similar pattern emerged from the core area of Xiaocheng (*D*=85.4%; 79.9% - 88.1% at the 95% confidence interval). Slightly higher diversity indices were seen in settlement areas outside the Xiaocheng walls (*D*=90.8%; 84.8% - 92.0% at the 95% confidence interval) and inside the Taojiahu walls (*D*=90.4%; 89.0% - 91.1% at the 95% confidence interval). As previously noted, there was a very high level of diversity in dispersed hinterland settlement represented by Neighborhood 11 (*D*=91.3%, 78.8% - 92.2% at the 95% confidence interval).

These diversity scores emphasize the high level of ceramic diversity present across the region in the Qujialing period. Yet, even in the setting of such high levels of diversity, meaningful patterns of distribution are present. First, settlement in and around Xiaocheng tended to be less diverse than that in and around Taojiahu. Second, the relative diversity of settlement inside and outside walls was reversed in the north and south. In the south, the ceramic assemblage inside Xiaocheng walls was slightly less diverse than that outside the walls. In the north, however, the ceramic assemblage inside the Taojiahu walls was more diverse than that outside the walls.

While the absolute differences in ceramic diversity are weak, they highlight variations in how populations living across the region acquired pottery. These patterns tell us that some households, particularly those in Neighborhoods 1, 4, and 10, and more broadly in the southern half of the study area, relied on slightly fewer production units for a larger proportion of their pottery. For other populations of the region, especially those in Neighborhoods 5, 7, and 8, and in the north more broadly, pottery acquisition strategies involved a large number of production units, from which smaller amounts of pottery were obtained.

Consumption patterns between the settlements areas described here align more closely with an ‘extensive’ consumption, but not all areas are equally so. By noting where consumption is slightly less and slightly more extensive offers insight into variation in the strategies and conditions that impacted pottery acquisition practices in the Qujialing period.

4.2 POTTERY EXCHANGE AND PROCUREMENT IN THE SHIJIAHE PERIOD

4.2.1 Pottery exchange

Pottery from the 18 production units was distributed in a visibly different manner among neighborhoods of the Shijiahe period than it was in the preceding Qujialing period (Figure 4.6). Shijiahe ceramic assemblages reveal more inter-neighborhood variation than was observed for Qujialing assemblages. Households in Neighborhood 18, for example, procured pottery from a wider range of production units than did households in Neighborhood 13. There are also several instances in which adjacent neighborhoods had very similar ceramic assemblages, as in the case of core neighborhoods at Xiaocheng (Neighborhoods 12 and 13) and in areas on either side of the Taojiahu wall (Neighborhoods 16 and 22). These pairs of neighborhoods acquired similar proportions of pottery from the same production units. These general observations suggest that the structure of pottery circulation networks changed between the Qujialing and the Shijiahe period.

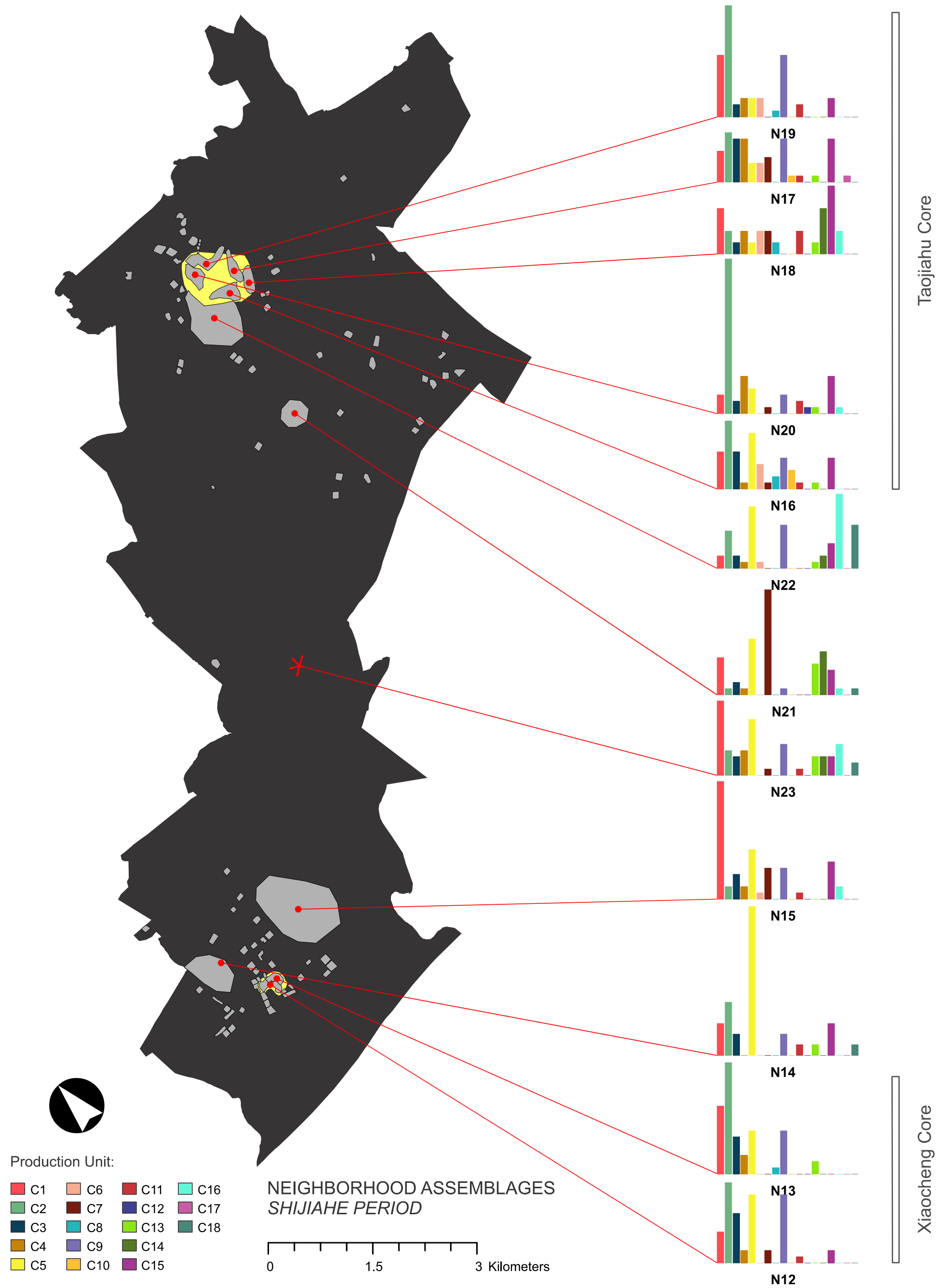

Figure 4.6: Shijiahe neighborhood ceramic assemblages showing the frequency of pottery from each production unit.

To characterize the pottery circulation networks of the Shijiahe period, I again rely on chi-square tests of homogeneity. These tests compare the observed frequencies of sherds from each production unit with expected, even frequencies of sherds by neighborhood to determine network size. Only pottery production units with more than 20 sherds were included in this analysis (C1, C2, C4, C5, C5, C7, C9, C15, and C16).

The distribution of three pottery production units, C3, C4, and C15, did not differ significantly or strongly different from an expected even distribution (Table 4.2). A closer examination of the ceramic assemblages depicted in Figure 4.6 reveals that pottery from C3 was found in all neighborhood assemblages in relatively low frequencies. Circulation networks for C4 and C15 pottery may have been slightly smaller than that of C3 because sherds from these production units were slightly more abundant in northern neighborhoods than in southern ones, meaning these vessels may have been circulating from a point slightly closer to Taojiahu. These differences were minor, however, and did not significantly limit southern neighborhoods' access these production units. About 20% of all Shijiahe pottery was circulated through these broad, large-scale networks.

Pottery from two production units was distributed in a way that deviated significantly and strongly from theoretical expectations (Table 4.2). Pottery from production unit C7 was especially abundant in N21 but completely absent from N19, N22, N14, and N13, and present in very low quantities at N20, N16, N23, and N12. This suggests that the C7 production unit was located in or near N21, and exchanged pottery most frequently with households in the Xiaocheng hinterland (N15) and the southeastern edge of Taojiahu (N17, N18). Similarly, pottery from production unit C16 was especially well represented at N22, as well as at N23 and N18. The C16 production unit was likely located in or near N22 and exchanged pots most frequently with other households living in the hinterland. Thus, both localized networks were primarily focused in hinterland areas of the study area, and were responsible for circulating just under 10% of Shijiahe pottery.

Table 4.2: Relative scale (large, intermediate, or small) of Shijiahe pottery circulation networks from 18 production units. Individual neighborhoods with χ^2 residuals that were one or two standard deviations from the mean are noted here and indicate areas with higher than expected frequencies (or lower than expected frequencies) of pottery for a given production unit.

Production Unit	**Distribution Scale**	χ^2	***n***	***df***	***p***	***V***	**1 σ**		**2 σ**	
							+	-	+	-
C3	Large	13.037	45	11	0.291	0.162	N12, N17			
C4	Large	15.755	32	11	0.150	0.212	N17		**N20**	
C15	Large	14.918	49	11	0.186	0.166	N17, N18	N12		**N13**
C1	Intermediate	31.199	86	11	0.001	0.182		N20, N22	**N15**	
C2	Intermediate	57.779	113	11	<0.0005	0.216	N13, N19	N15, N21	**N20**	
C5	Intermediate	32.087	88	11	0.001	0.182		N17, N19, N20	**N14**	
C9	Intermediate	18.225	63	11	0.077	0.162	N12, N20	N18, N22		
C7	Small	83.106	33	11	0.000	0.478			**N21**	
C16	Small	65.212	23	11	0.000	0.508			**N22**	
C6			14							
C8			5							
C10			4							
C11			12							
C12			1							
C13			16							
C14			16							
C17			1							
C18			11							

Nearly 60% of Shijiahe pottery was circulated through networks larger than those of C7/C16 but smaller than those of C3/C4/C15. The distribution of pottery from production units C1, C2, C5, and C9 differed significantly from expected distributions, but the strength of this difference is fairly low. Pottery from C1 was found in all neighborhoods, but was especially abundant in N15. This pattern suggests that the C1 production unit was located somewhere in or around the center of the survey zone near Neighborhood 15. Similarly, sherds from production unit C2 were recovered in all neighborhoods, but were represented in much high proportions in core areas of Taojiahu and Xiaocheng and in much lower quantities in hinterland areas. Based on these distribution patterns, C2 pottery was probably produced in the north zone of the Taojiahu core (N20 and N19) and exchanged frequently with households in Xiaocheng Neighborhoods 12 and N13, and slightly less frequently with households from other Taojiahu core neighborhoods. Production unit C5 was likely located in or around southern hinterland neighborhood N14 and exchanged pottery more frequently with households in nearby neighborhoods than more distant ones. Pots from production unit C9 were circulated through slightly more complex networks that connected households in the Xiaocheng core with those in the north and east of the Taojiahu core (N19, N17).

The development and proliferation of mid-scale pottery circulation networks in the Shijiahe period highlights a shift away from the patterns of economic interaction of the Qujialing period. Populations were no longer integrated at the same regional scale as suggested by the way pottery from Qujialing production units C1 and C2 were circulated, but rather interacted more frequently with populations within a 10 km or smaller radius. This is demonstrated by the fact that we can detect fall-off curves for many pottery circulation networks within the 58 km^2 of the study area, which were not evident for broader circulation networks in the preceding period. Residents of the study area did continue to have access to a wide range of circulation networks in the Shijiahe period. As with the Qujialing period, the fact that neighborhoods procured pottery from an array of production units that were circulated through a variety of networks suggests centralized control of pottery exchange was minimal.

4.2.2 Pottery procurement

We now turn from examining how pottery from one production unit was circulated across the region to compare the ways in which households in Shijiahe neighborhoods procured pottery. Pots from four production units were represented in all 12 Shijiahe neighborhood assemblages

(C1, C2, C3, and C5), with five additional production units represented across 70% of neighborhoods.

Multidimensional scaling of Shijiahe neighborhood assemblages shares some similarities with the results of scaling on Qujialing neighborhoods (Figure 4.7). There is a clear tri-partite separation of neighborhoods from the Taojiahu core (N16, N17, N19, N20), from the Xiaocheng core (N12, N13), and from more dispersed settlement areas outside the walled areas (N14, N15, N21, N22, N23).

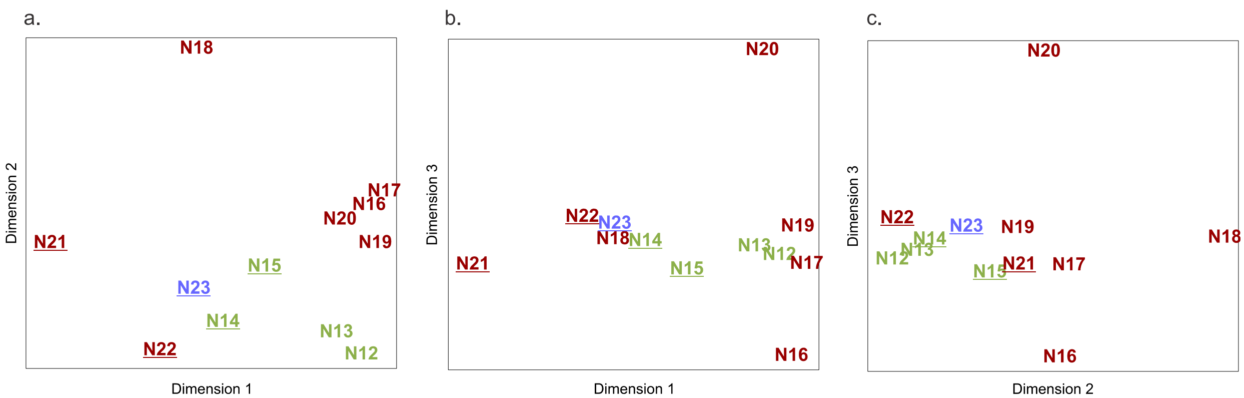

Figure 4.7a-c: Three-dimensional multidimensional scaling solution for the 12 Shijiahe neighborhoods based on Euclidean distance. Neighborhoods in green are from the southern zone of the survey area, those in red are from the north, and blue from the middle. Neighborhoods with underlining are from hinterland areas, those without are from core areas.

We can better understand the similarities and differences between neighborhoods shown in these solutions by comparing their ceramic assemblages as shown in Figure 4.7. Southern neighborhoods both inside and outside walled areas cluster together in all three solutions. These four neighborhoods acquired pottery from noticeably fewer production units other neighborhoods, especially those in the Taojiahu core. In the multidimensional scaling solution depicted in Figure 4.7b, neighborhoods from both core areas – Neighborhoods 12, 13, 17, and 19 – are grouped closely together. As mentioned in the previous section, all four of these neighborhoods share elevated proportions of pottery from C9. Neighborhood 18 stands out from other core area neighborhoods, either isolated from other all other neighborhoods (Figure 4.7a and c) or clustering closely with hinterland neighborhoods (Figure 4.7b). This may be due to higher frequencies of pottery from production units C13, C14, and C16 which are rare in core neighborhoods but common in hinterland neighborhoods. Yet, like the other northern core neighborhoods, it has high assemblage richness and evenness.

Although the multidimensional scaling solution of Shijiahe neighborhoods distinguishes between northern core, southern core, and hinterland neighborhoods, these groupings are not conserved across all three dimensions. This suggests that while pottery procurement practices in these three zones were distinct in certain ways, they overlapped in others. The close clustering of Neighborhoods 12, 13, 14, and 15 indicate that households in southern neighborhoods relied on pottery from many of the same production units in similar frequencies.

Pooling together ceramic assemblages highlights some of these higher-order economic patterns. Chi-square comparisons of assemblages from neighborhoods within walled areas with those of neighborhoods located outside walls indicates a significant and strong difference in pottery use (χ^2=118.203, df=15, p<0.0005, V=0.440; Figure 4.8). Pottery production unit C2 contributes most directly to this difference: it accounts for more than a 25% of pottery in core areas (26.4% ± 3.8%, 90% confidence interval) but only 7% of pottery in hinterland areas (7.1% ± 2.6%, 90% confidence interval). Additionally, pottery from production unit C5 was more abundant in the hinterland, representing 20% of the hinterland ceramic assemblage (20% ± 4%, 90% confidence) and only about 10% of the core assemblage (11% ± 3.2%, 90% confidence). These patterns echo observations made earlier for differences in circulation networks of C2 and C5 pottery, and in the separation of core from hinterland neighborhoods in the multidimensional scaling solutions.

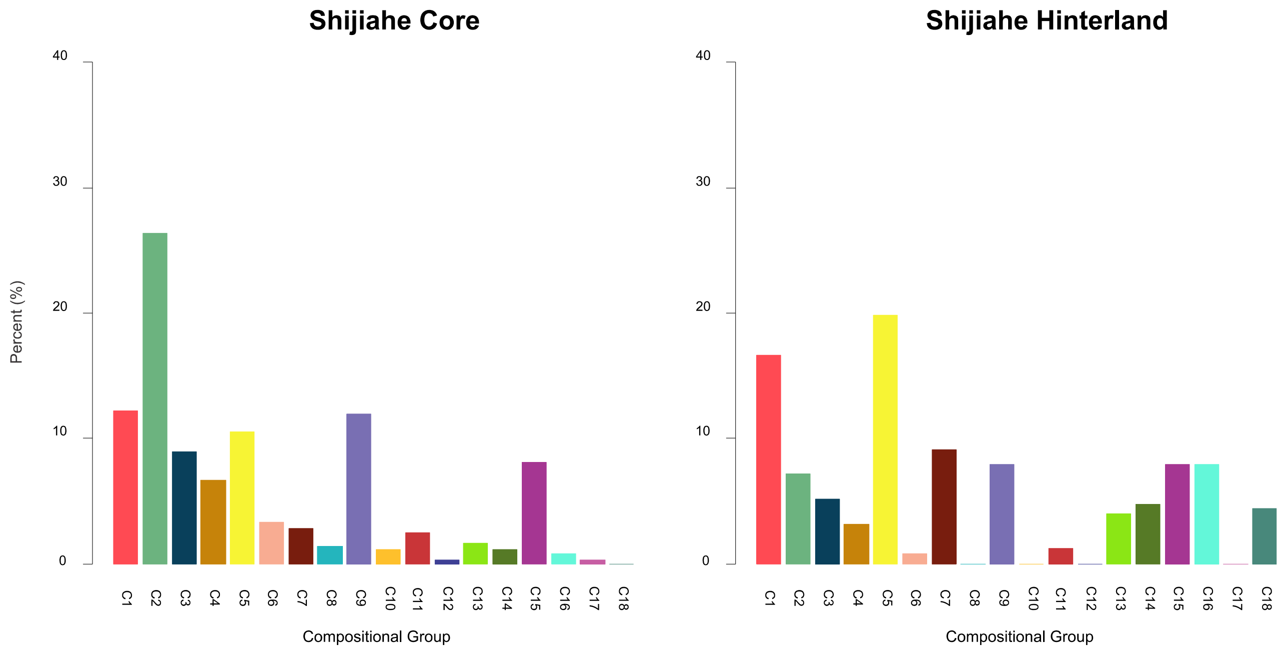

Figure 4.8: Proportion of pottery from the 18 production units recovered in Shijiahe core and hinterland ceramic assemblages. Core zones designate all neighborhoods located inside walled areas (Neighborhoods 12, 13, 16, 17, 18, 19, 20), hinterland zones refer to all neighborhoods located outside walled areas (Neighborhoods 14, 15, 21, 22, 23).

Comparison of northern and southern ceramic assemblages reveals a significant but weaker difference than that between core and hinterland assemblages (χ^2=49.855, df=15, p<0.0005, V=0.300; Figure 4.9). Southern neighborhoods had slightly higher proportions of pottery from production units C1 (19% ± 4.5%, 90% confidence) and C5 (20% ± 4.6%, 90% confidence) than did northern neighborhoods (CG1: 10% ± 2.6%; CG5: 11% ± 2.7%, both at the 90% confidence interval). A much clearer difference between these assemblages lies in their diversity. Households in the south procured most of their pottery from a few sources. Pottery from production units C1, C2, and C5 account for more than 60% of the southern ceramic assemblage. The most abundant pottery production unit represented in the north is C2, which only accounts for about 20% of the ceramic assemblage.

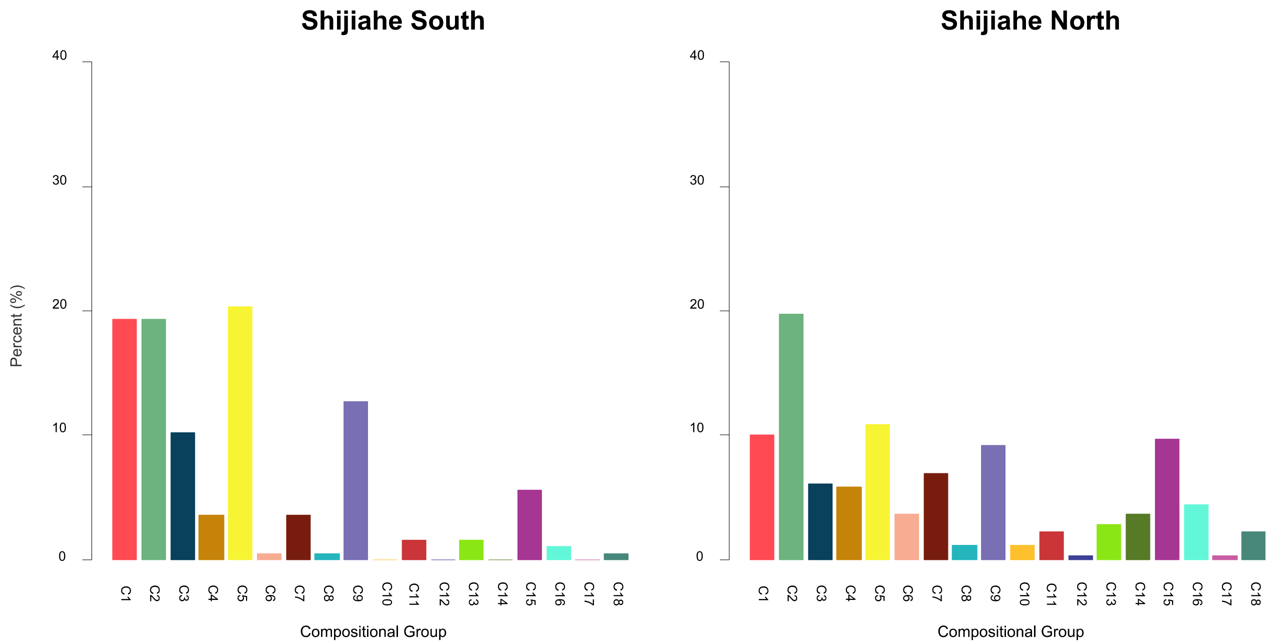

Figure 4.9: Proportion of pottery from the 18 production units recovered in northern and southern areas of the survey zone. The south zone includes assemblages from Neighborhoods 12, 13, 14, and 15; the south zone includes assemblages from Neighborhoods 16, 17, 18, 19, 20, 21, and 22. Note that Neighborhood 23 is not represented here because it includes dispersed areas of settlement in both northern and southern zones.

In sum, patterns of pottery procurement were affected by both settlement context (core or hinterland) and by location (north or south). Core and hinterland ceramic assemblages continued to be quite different in the Shijiahe period, but this distinction was slightly less strong than it had been in the Qujialing period. Consumption practices were less affected by settlement location, however the difference between northern and southern assemblages was significant, and stronger than in the previous period. This evidence points to the rising importance of settlement location and declining importance of settlement context to pottery procurement patterns.

Diversity scores further clarify differences in pottery procurement in the Shijiahe period. Bullet graphs with bootstrapped confidence intervals of Simpson's D scores are presented for neighborhood, supralocal, and regional ceramic assemblages in Figure 4.10. Diversity scores were lower in the Shijiahe than in the Qujialing period, with scores for Neighborhoods 14 and 20 falling to 78% (60% - 85%, 95% confidence) and 77% (64% - 84%, 95% confidence), respectively. Neighborhoods 16, 17, and 18 were most diverse with scores hovering around 90% (N16: 84% - 91%; N17: 87% - 92%; N18: 84% - 93%; all at the 95% confidence interval). Yet, even with these lower scores, the difference in ceramic diversity between neighborhoods is not terribly strong.

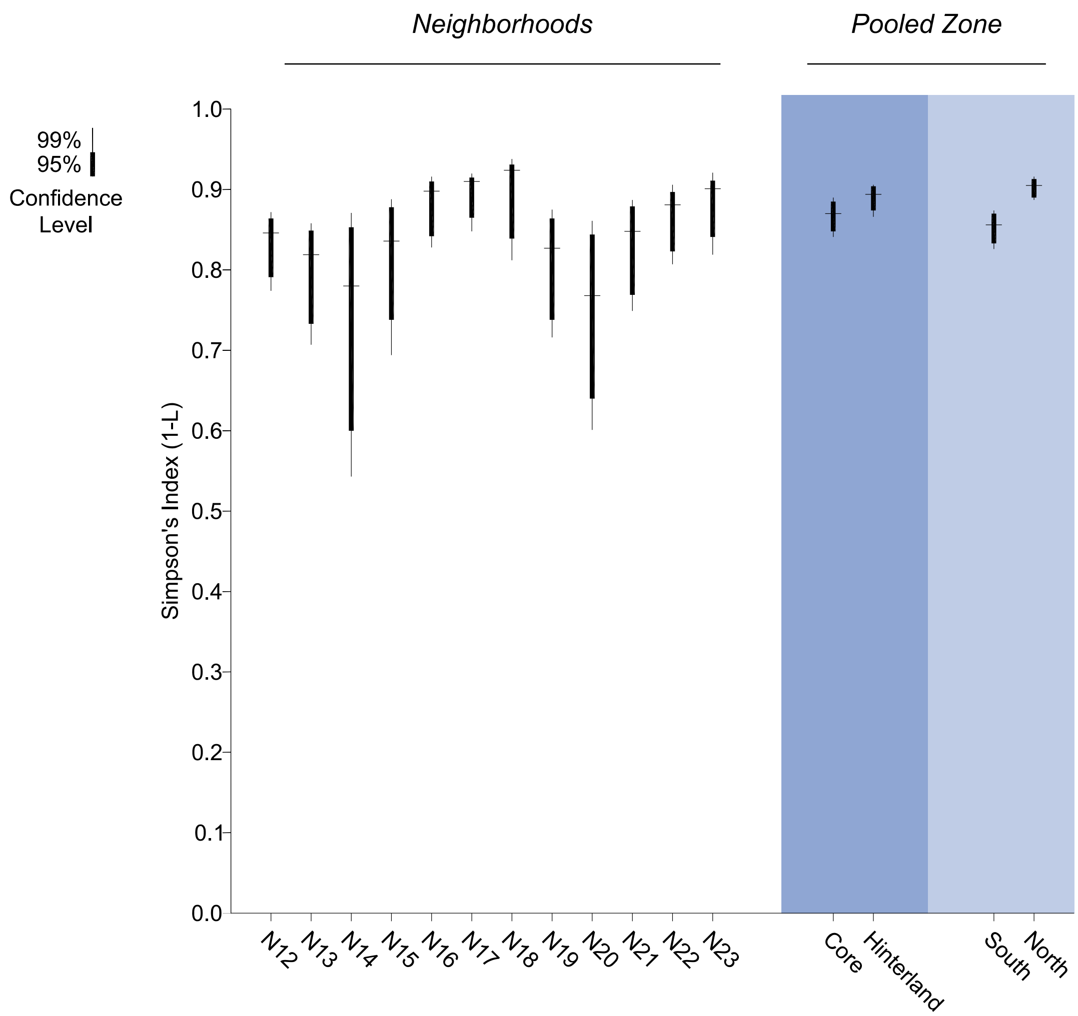

Figure 4.10: Diversity scores of Shijiahe neighborhood assemblages (left) and regional zones (right) with bootstrapped error ranges for the 95% and 99% confidence levels.

Clearer differences in ceramic diversity emerge between settlement areas on a supralocal scale. Both southern core and hinterland areas were less diverse than northern core and hinterland areas; the difference in diversity between the two core areas was significant at the

95% confidence level. In other words, populations in the south of the study area tended again to rely on slightly more intensive patterns of pottery procurement, in which households relied on a few production units for a larger portion of their pottery. Populations in the north practiced fairly extensive procurement practices, consuming low amounts of pottery from a large number of production units.

Interestingly in this period, we see a consistent relationship between ceramic diversity and settlement context which was not present in the Qujialing period. Although northern assemblages are, on the whole, more diverse than southern ones, the ceramic diversity of both hinterland areas is relatively higher than that in the core areas. This perhaps indicates the development of consistently structured relationships between core and hinterland populations.

4.3 CHANGE AND CONTINUITY IN LATE NEOLITHIC POTTERY ECONOMIES

This chapter has thus far focused on the structure of economic relationships within each period of the late Neolithic. I have described how Qujialing and Shijiahe populations circulated and procured pottery by comparing the distribution of pottery from each production unit across neighborhoods, and the combination and frequency of various production units in each neighborhood's ceramic assemblage. This final section takes a keener look at how these systems changed through time by directly comparing the pottery circulation networks and neighborhood procurement strategies for each period.

There was a clear change in the structure of pottery circulation networks over the duration of the late Neolithic. In the Qujialing period, roughly half of the pottery available to local populations was circulated through large-scale, regional networks, while the other half was circulated through small, localized networks. The Shijiahe period saw a decline in the circulation of pottery through both regional and local networks, and an increase in the amount of pottery exchanged via sub-regional networks that were about 10 km in radius. The pottery production units associated with each scale of network changed though time as well. The scale of circulation of pottery from production units was reduced from regional networks in the Qujialing to mid-range networks in the Shijiahe period. However, pottery exchange networks of three other production networks, C3, C4, and C5, expanded through time, from local circulation in the Qujialing period to regional (C3, C4) and sub-regional (C5) in the Shijiahe period. Only C15 remained stable through time, and was consistently associated with a regional pattern of distribution that was slightly more focused in the north of the region than the south. These dynamics point to an economic decoupling of the settlements in this study area from large-scale, regional exchange networks, and an increasing reliance on smaller exchange networks, perhaps between one or two neighboring settlements.

These changes in regional economic relationships also impacted consumers' access to and reliance on pottery production units. Though many of the same production units are represented in the ceramic assemblages of both Qujialing and Shijiahe neighborhoods, their frequency and configuration alters through time. This is in part linked to the reorganization of pottery circulation networks, but it also reflects shifting relationships between producers and consumers.

We can examine variation in procurement strategies through time by comparing the ceramic assemblages of all Qujialing and Shijiahe period neighborhoods together. Figure 4.11 depicts the results of a three-dimension multidimensional scaling analysis of the 23 neighborhoods. The first feature that becomes clear in this diachronic analysis is that Qujialing neighborhoods plot together in a loose cluster that is distinct from the cluster of Shijiahe neighborhoods, despite the presence of the same 18 production units in both periods (Figure 4.11a). The partition of neighborhoods by period calls attention to overarching differences in pottery procurement strategies through time. A chi-square comparison of Qujialing and Shijiahe pottery echoes this result, revealing a significant and fairly strong difference in ceramic assemblages by period ($\chi^2 = 104.022$, $df = 17$, $p<0.0005$, $V = 0.301$).

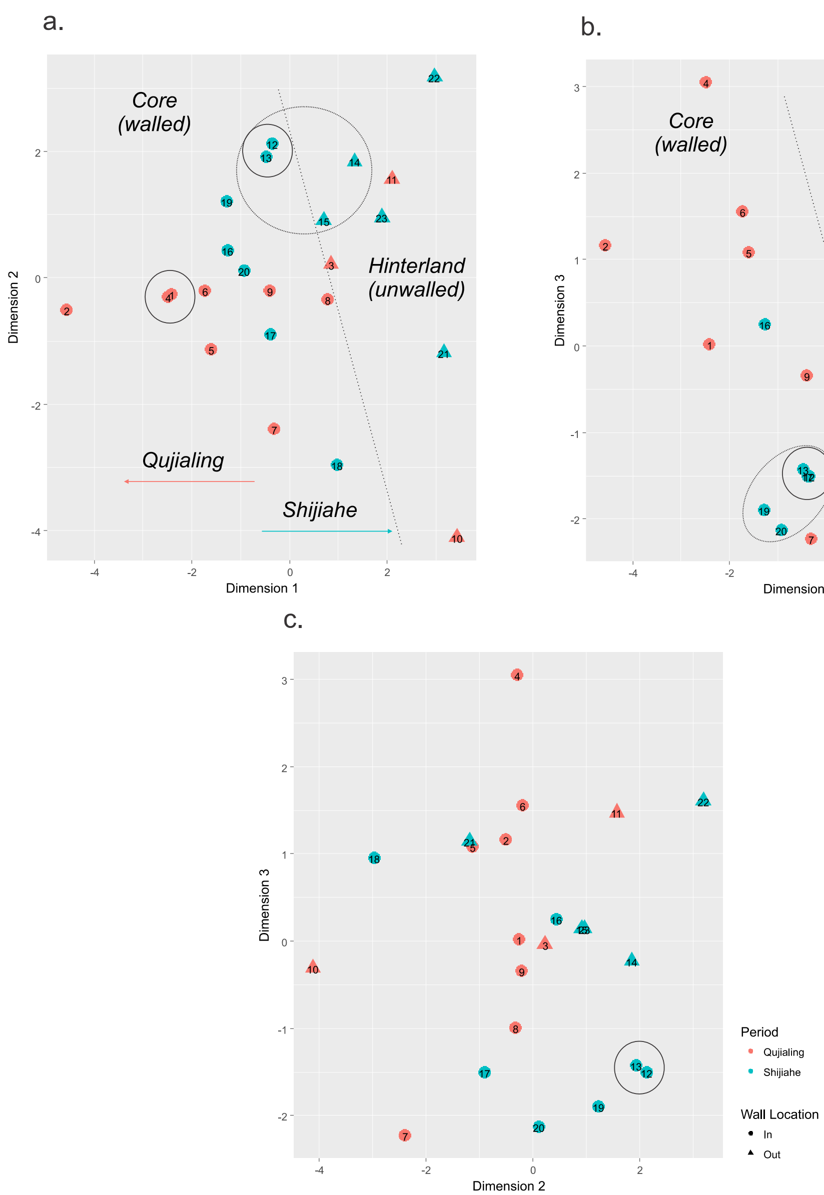

Figure 4.11a-c: Three-dimensional multidimensional scaling solution for all 23 neighborhoods based on Euclidean distance. Key patterns are marked and annotated.

The multidimensional scaling plots also show a separation of core and hinterland neighborhoods—those located inside and outside walled areas—across both periods. This pattern is very clear and well-preserved in two configurations (Figure 4.11a and b), which complements chi-square comparisons between core and hinterland assemblages by period.

These plots draw a much murkier picture of the relationship between northern and southern neighborhoods. In Figure 4.11a, Qujialing southern neighborhoods are scattered across Dimension 1: Neighborhood 1 is plotted closer to northern Neighborhoods 4 and 6 than to geographically adjacent Neighborhoods 2 or 3, while Neighborhood 3 is plotted closer to northern Neighborhood 8 than to either N1 or N2. By contrast, Shijiahe southern neighborhoods N12 and N13 group closely together in all three dimensions and often appear in the proximity of northern N19 and N20. These patterns suggest that pottery procurement patterns of southern Qujialing neighborhoods were quite variable and were often more similar to neighborhoods located further away than to those they were immediately adjacent. This dynamic changed in the Shijiahe period, as core Xiaocheng neighborhoods had extremely similar ceramic assemblages showing common reliance on the same pottery production units; moreover, southern hinterland assemblages were much more similar at this time, as seen in the proximity of Neighborhodds 14 and 15 to Neighborhoods 12 and 13 in Figure 4.11a. Yet, this relationship between southern and northern core areas was preserved, as evidenced by the clustering of Neighborhoods 12 and 13 with 19 and 20. In sum, multidimensional scaling analysis provides a more detailed version of the story told earlier through chi-square comparisons of northern and southern assemblages: increasing similarities in pottery procurement patterns at Xiaocheng resulted in clearer distinctions between ceramic assemblages of the north and south through time. Said in slightly different terms, southern residents cultivated increasingly similar sets of economic relationships and practiced more homogeneous procurement strategies.

This final point is complemented by trends in ceramic diversity. At the neighborhood level patterning in diversity scores was largely obscured, but at the settlement level several trends emerged. First, southern assemblages were persistently less diverse than northern ones, and second, diversity in the south decreased through time. While these differences in diversity scores are slight—assemblages across the region were objectively quite diverse throughout the late Neolithic—relative differences between scores point to two regional modes of pottery procurement. In the south, residents as a whole tended to acquire pottery in larger frequencies from fewer production units whereas in the north, residents acquired pottery in smaller frequencies from a wider range of production units. Turning back to the results of multidimensional scaling, we see this partially reflected in the proximity of southern neighborhoods and northern neighborhoods to one another. In the Qujialing period, both sets of neighborhoods are widely distributed, while in the Shijiahe period, we clearly see southern neighborhoods group together while northern neighborhoods remain much more dispersed (see, for example, the proximity of N12, N13, N14, and N15 in Figure 4.11a).

The investigation of the distribution of pottery from 18 production units across 23 neighborhoods and two temporal periods undertaken here has revealed key changes in the structure of pottery exchange networks during the late Neolithic period of the northern Jianghan Plain. The next chapter investigates these patterns more closely in tandem with the research questions outlined in Chapter 1.

5.0 CONCLUSIONS

The research presented in this dissertation examines the organization and structure of utilitarian pottery economies in the context of population growth and dispersal at two late Neolithic walled towns. Chapter 2 described changes in demography and settlement patterns in the northern Jianghan Plain that were documented in the Taojiahu-Xiaocheng Regional Settlement Survey. Chapter 3 outlined the geochemical methods and sampling strategy employed to characterize patterns in compositional variability of 1,150 Qujialing and Shijiahe period pottery sherds, ultimately identifying 18 pottery production units. Chapter 4 analyzed the distribution of pottery from these 18 production units between clusters of households, or neighborhoods, across the span of a millennium (3100 – 2000 BCE). In the discussion that follows, I connect these results to each of the five research questions posed in Chapter 1.

5.1 ADDRESSING THE RESEARCH QUESTIONS

5.1.1 Research Question 1: How do pottery exchange networks compare among small local communities (e.g. neighborhoods)?

During the late Neolithic, households living in the Taojiahu-Xiaocheng study area cooked, stored, and consumed food from pots that were made by a common set of production units. Each production unit represents a group of potters who used similar raw material resources and clay paste recipes to produce ceramic vessels. As a result, pots made by a single production unit have geochemical and mineralogical signatures that are more similar to one another than to those made by other production units. Pottery sherds with different compositional signatures were recovered from each neighborhood in the study area, indicating that local households acquired pottery from 18 different production units.

This final count of production units merits a brief discussion. The 18 production units I have identified in this dissertation do not reflect absolute counts of every pottery source in the area. Rather, this number provides us with a good indication of the scale at which pottery was being produced during the late Neolithic. On the one hand, it tells us that pottery was not regularly made by each household for its own private use. If households produced vessels for their own consumption, we would expect to see a clear correlation between neighborhood location and compositional group. Thus, households in Taojiahu would have relied on local clays for their pots while households in Xiaocheng would have done the same with clays close to them. The result would be two compositionally-distinct clusters of pottery that were cleanly divided by neighborhood location. These patterns also tell us that pottery was also not manufactured by one or a few centralized workshops and redistributed to all households. This would produce an even distribution of pottery with the same compositional signature across the study region. Instead, the compositional data points to a level of production somewhere between these extremes. Pottery was likely produced by individuals or family groups who focused on producing wares for exchange. There may have been 10 or 25 groups at any particular time specialized in making pottery.

To more closely examine pottery procurement practices at each neighborhood, I used multidimensional scaling to compare neighborhood ceramic assemblages by period. Results of this analysis revealed a complex set of economic relationships across the study area: in some cases, neighborhoods that were directly adjacent to one another acquired pottery in distinct ways, while in other cases, neighborhoods 10 km distant had similar pottery procurement strategies. During the Qujialing period, residents of Neighborhood 3, located just outside the walled area at Xiaocheng, acquired pottery from a similar combination of production units and in similar frequencies as the residents of Neighborhoods 4, 5, and 6 in the Taojiahu core area. However, Neighborhood 3's acquisition strategies were distinct from those practiced in Neighborhoods 1 and 2, both of which were a mere 200 meters away. Similarly, neighborhoods in the northern section of the Taojiahu core (Neighborhoods 7, 8, and 9) procured pottery in a similar way, which diverged from the procurement strategies of neighborhoods in the southern Taojiahu core (Neighborhoods 4, 5, and 6).

This sort of complex variability in neighborhood pottery procurement strategies continued into the Shijiahe period. Neighborhood 18, for example, was located in the core area of Taojiahu, but its residents obtained pottery in way that was more similar to the residents of northern hinterland Neighborhoods 22 and 23, and southern hinterland Neighborhood 14 than to other neighborhoods in the Taojiahu core.

Neighborhood procurement patterns highlight several key aspects of the consumer side of utilitarian economies. First, no two neighborhoods procured pottery in precisely the same way. Each neighborhood had access to many different pottery production units from which residents obtained pots in differing combinations and frequencies. Second, the similarity (or dissimilarity) of two neighborhoods' procurement practices is not clearly correlated with the distance between them. Sometimes the residents of adjacent neighborhoods obtained pottery in similar ways, while in other instances neighborhoods with similar procurement strategies were located at opposite ends of the study area. These observations offer compelling evidence that access to utilitarian goods was not controlled by a central authority during either the Qujialing or the Shijiahe period.

On the other side of the economic coin from pottery procurement is pottery circulation. While analyses of procurement patterns showed that neighborhood residents acquired pottery from different combinations of producers, it was unclear whether all production units circulated their pottery at the same scale and with the same intensity. To address these questions, I used chi-square test of homogeneity. This test allowed me to differentiate between the production units that were available and consumed across all parts of the survey area and those that were present in only limited zones within it. Ultimately, such comparisons can clarify the structure and evolution of economic interactions between pottery producers and consumers in the study area.

During the Qujialing period, vessels made by production units C1, C2, C9, and C15 represented a similar proportion of the pottery in all neighborhoods, indicating that they were equally available to populations living across the survey area. One interpretation of this pattern is that it was caused by centralized redistribution or administered exchange. However, it seems unlikely that the circulation of some utilitarian pottery was controlled by political elites, while the circulation of other, seemingly interchangeable pottery was not.

An alternative explanation is that potters living throughout the region used the same raw materials and production methods to manufacture ceramic vessels. This would mean that although the physical exchange of pots occurred locally, potters maintained common production traditions through regular interactions and a regional ‘circulation’ of practices. The results of the XRD analysis argue against this interpretation, however, as the mineralogy of C1 pottery did not appear to be not local to the region. While neither this nor the previous explanation are completely refuted by the evidence at hand, they are each fairly unconvincing.

A more satisfying explanation is that vessels from these four production units circulated through large-scale exchange networks. These networks would have been large enough that characteristic fall-off curves (decline in the abundance of a good as a function of distance from its source) are too slight to be detected across the 58 km^2 area of the study area (*sensu* Hodder 1974; Renfrew 1977). In other words, the distance between neighborhoods was negligible given the overall scale of the circulation network itself. Transporting pots by boat would have reduced effective distance between communities and could easily have produced these broad distributional patterns. There is evidence that populations living in the middle Yangzi River valley did rely on rivers for transport to some extents: dock-like structures and remains of boats offers direct evidence that late Neolithic populations relied on rivers for transportation (Hunan 1999:17–30; Hunan 2007).

However, not all Qujialing period pottery moved long distances to consumers. The other half of the pottery present in the region was recovered from fewer neighborhoods in higher proportions, which was likely the result of a more constrained, local pottery circulation network. This was particularly true of pottery associated with production units C4, C5, C8, C10, and C13. C13 offers the most extreme example of such local circulation: it was probably produced in Neighborhood 10 where it represents 27% of the ceramic assemblage, but only 5% of the assemblage of Neighborhood 3, where it is next most abundant. Often, neighborhoods with high proportions of pottery from the same production units are not immediately adjacent to one another. The two neighborhoods with the highest proportion of C10 sherds were Neighborhood 2 in the Xiaocheng walled area, and Neighborhood 5 in the Taojiahu walled area. Similarly, pottery from C8 was abundant among neighborhoods in the southwestern corner of Taojiahu (Neighborhoods 4, 5, and 6) and in Xiaocheng (Neighborhood 2). This implies that 'local' circulation should not only be thought of in geographic terms, but also in social terms. Potters may have chosen their trading partners (or, alternatively, households may have chosen potters) on the basis of kinship, acquaintanceship, or reputation.

Ethnographic studies of traditional potting communities have shown patterns of pottery exchange to be impacted by a number of social factors, including kin relationships and a history of trade partnerships. In the Philippines, Kalinga potters prefer to exchange their wares with individuals in their extended kin group (Graves 1991; Stark 1994), particularly in towns that are further away from the potter's own home. Potters feel that selling vessels to family (and buying vessels from family) reduces the risk of being cheated. The very act of exchange thus reinforces social ties between producers and consumers by referencing shared lineage. Regular customers may be inherited by potters' children once they themselves become potters, producing stable sets of economic relationships through generations (Stark 1994:178). The translation of economic relations into social terms has been described in other parts of the world as well. Guderman writes that in many parts of Latin America, "small-scale market exchanges are given stability and longevity by being sealed to *compadrazgo* [shared godparenthood] bonds that are formed before or after the market relationship" (2001:137–138). Long-lasting economic partnerships also emerge without the specific reference to kinship: Arnold identifies several potters in Yucatan who, at the time of observation, had cultivated 30-year commercial relationships with their customers (Arnold 2008:137). These brief examples illustrate that the identities of both pottery producers and consumers play an important role in determining the frequency and timing of exchange. Similar social factors likely impacted economic relationships at Taojiahu and Xiaocheng as well, resulting in distant neighborhoods having similar ceramic assemblages.

Pottery exchange networks shifted slightly during the Shijiahe period. Instead of large or small-scale networks, most pottery circulated through networks of a size somewhere between the two. These intermediate-scale networks seem to have covered areas roughly 10 km in radius, meaning that the pottery that circulated through them was available to households across the study area but in clearly declining quantities. For example, pottery from production unit C5 is present in every Shijiahe period neighborhood, yet is especially abundant in Neighborhood 14 in the southern hinterland. This suggests that C5 pottery may have been produced and distributed from Neighborhood 14 to households as far away as Taojiahu, but that a larger quantity of vessels were exchanged with households located more closely. Pottery from production units C1, C2, and C9 also appear to have been exchanged through such intermediate-scale networks.

Replacement of regional and local exchange networks in the Qujialing period by sub-regional, ‘intermediate’ networks in the Shijiahe period reflects a slight change in the nature of interactions between Taojiahu and Xiaocheng, and with other settlements in the Jianghan Plain. Households in Taojiahu and Xiaocheng were not closely connected with a regional circulation network in the Shijiahe period as they were in the Qujialing period, but they also did not rely as heavily on local pottery networks. Instead, Shijiahe period populations have fostered relationships with other, neighboring settlements with which they exchanged pottery. This pattern can be explored more fully by expanding the current survey area and studying the composition of sherds from other, nearby walled towns like Menbanwan, Shijiahe, and Qujialing.

In summary, occupants of the Qujialing and Shijiahe neighborhoods acquired their pottery from a range of production groups rather than provisioning their own households with vessels made on their own. The majority of vessels were exchanged through either regional or local exchange networks in the Qujialing period, and via sub-regional networks in the Shijiahe period. Neighborhoods were connected to one another through pottery exchange networks, but areas with similar access to and consumption of pottery were not always adjacent. Through time, neighborhoods in core areas of Taojiahu and Xiaocheng share particularly similar ceramic assemblages, insinuating the presence of a strong and persistent social link between these communities, or at the very least that households in these areas were engaged in similar sets of relationships.

5.1.2 Research Question 2: How similar or different were the networks through which the inhabitants of Taojiahu and Xiaocheng obtained their pottery?

Comparing the combined ceramic assemblages of Taojiahu and surrounding settlement with that of Xiaocheng and its environs revealed patterns of pottery circulation and consumption that were not evident at the level of individual neighborhoods. To examine these trends, I consolidated the ceramic assemblages of northern and southern neighborhoods by period. I omitted ceramic data from Neighborhoods 11 and 23, which included collection lots scattered across both the north and south of the survey area. These dispersed 'neighborhoods' will be more closely examined in section 6.3, while here I focus on the supra-local communities centered at the two walled towns.

During the Qujialing period, the presence of the same 18 pottery production units in northern and southern ceramic assemblages indicates that consumers in both areas had access to the same range of pottery sources. There were, however, significant but weak differences in the proportions of pottery from each production unit present in the two regions, including a higher abundance of C3 pottery in the south and of C15 in the north (χ^2=29.411, *df*=14, *p*=0.009, *V*=0.239). In the Shijiahe period, differences between northern and the southern ceramic assemblages grew stronger (χ^2=49.855, *df*=15, *p*<0.0005, *V*=0.300). Pottery from C1 were C5 were both more abundant in the south, whereas pottery from C6, C14, and C16 were more abundant in the north. Thus through time, residents of Taojiahu and Xiaocheng had access to and used pottery from increasingly dissimilar sources. This trend is highly significant albeit weak, telling us that slightly different economic and social forces were at play at each walled town community.

Diversity scores offer another point of comparison in economic activities in the north and in the south. For both the Qujialing and Shijiahe periods, southern assemblages were significantly less diverse than northern ones, and this difference intensified through time. Populations in the north acquired pots from a wide variety of sources without relying too heavily on any single producer, whereas populations in the south relied more intensively on a smaller number of pottery sources. These differences are again small in magnitude but highly significant, indicating that they were almost certainly created by some force that operated differently (but not *very* differently) in the north and south.

Differences in ceramic diversity might be related to population size, as larger populations are likely to rely on a larger number of producers to meet their outsized consumer demands. However, population estimates indicate that southern populations actually *increased* in the Shijiahe period as ceramic diversity *decreased* (D. Li 2016). At the same time, populations in the north *decreased* while ceramic diversity stayed the same (or decreased very slightly). It thus appears that ceramic diversity in the Taojiahu-Xiaocheng was not positively correlated with population size.

Such differences in diversity may also be tied to the organization of local market systems. In hierarchically-arranged market systems, higher-order centers (i.e. loci of economic exchange) have greater access to a wider range of goods than do lower-order centers in the same economic system. This means that as a whole, the community that relies on the higher-order center will have a more diverse assemblage than the community that relies on the lower-order market center (see discussion in Minc 2006). Within either of these communities, however, individual households or neighborhoods could have more or less diverse assemblages depending on local acquisition practices. If settlements with high assemblage diversity can be linked to higher-order market centers than settlements with low assemblage diversity, then Taojihau (or the northern region of the study area) would be associated with a higher ranked market center than Xiaocheng (and the southern zone of the study area). This interpretation is consistent with the picture drawn by settlement patterns in the Qujialing period, which show Taojihau as the larger and more powerful political unit of the two. It is, however, at odds with patterns of Shijiahe settlement, where population growth and centralization at Xiaocheng indicate that it was actually *rising* in regional prominence, not declining as its falling diversity scores would suggest.

These explanations spotlight some of the many factors that could have produced the small difference in ceramic assemblage diversity that was observed at Taojiahu and Xiaocheng. Without additional lines of evidence or ceramic data from a wider region, it is hard to convincingly argue for one of these explanations over another. But what underlies these explanations is the premise that ceramic diversity reflects a group's range of social or economic interactions. Drawing on this basic principle, we can take the differences in diversity to indicate that northern and southern populations had slightly different interaction patterns with pottery production units. Lower diversity scores in the south indicate that residents had more frequent interactions with fewer pottery producers, whereas higher diversity scores in the north point to less frequent interactions with a wider range of producers. The stability of these patterns through time suggests these patterns of interaction developed locally and continued to structure local economic networks even as demographic and settlement patterns changed.

To summarize, differences in northern and southern pottery economies became marginally more pronounced through time. This slow divergence can be seen in the particular sources of pottery that were used in each area as well as in the structure of networks through which residents obtained pottery. Yet, projected across the span of a millennium, these changes become exceptionally small compared to the kinds of economic transformation we might otherwise expect to find. The most remarkable finding of this analysis is not that patterns of northern and southern pottery exchange changed, but undoubtedly that they changed so little over so long a time.

5.1.3 Research Question 3: How similar or different were the networks through which inhabitants living inside walled areas and inhabitants living outside walled areas procured their pottery?

The late Neolithic saw several differences in the kinds and variety of pottery consumed by occupants of core and hinterland areas. These differences declined through time, but remained stronger than those observed between the northern and southern ceramic assemblages. Despite these differences, however, the exchange of pottery between households in core and hinterland neighborhoods was quite active at both Taojiahu and Xiaocheng. In fact, the occupants of these two contexts relied on many of the same sources of pottery in slightly different ways.

In the Qujialing period, there was a significant difference between core and hinterland ceramic assemblages (χ^2=112.493, *df*=14, *p*<0.0005, *V*=0.459). People living in core settlements—that is, within the walled areas of Taojiahu and Xiaocheng—had higher quantities of vessels associated with certain production units (C2 and C3) than did populations living outside the walls. The hinterland, inversely, had higher proportions of pottery from other production units (C5 and C13). For all four pottery types, there was a difference of about 10% between core and hinterland assemblages, a large enough disparity to indicate meaningful behavioral differences in how residents of these areas acquired pots and relied on each production unit. One pottery type, C6, was completely absent from hinterland assemblages and was only recovered in low quantities in core areas. Vessels from C6 include a variety of shape classes, and the sherds themselves are visually indistinguishable from sherds associated with other production units. The restricted distribution of this pottery type to Taojiahu and Xiaocheng core areas suggests that some production units circulated pottery to only core areas. The low number of C6 sherds indicates that such core-specific circulation networks were extremely limited and represented only a small fraction of the pottery that was available to consumers.

In the Shijiahe period, differences in the content of core and hinterland pottery assemblages remained significant, but became slightly less strong than they were in the Qujialing period (χ^2=118.203, *df*=15, *p*<0.0005, *V*=0.440). As in the Qujialing period, particular production units were more abundant in core or in hinterland areas: C5 was more abundant in hinterland communities whereas C2 was strongly associated with core areas. Thus, counter to the patterns observed for northern and southern areas, core and hinterland assemblages actually became more similar through time.

Diversity scores for core and hinterland assemblages reveal a slightly different picture of the pottery economy (Figure 5.1). During the Qujialing period, the Xiaocheng core and in the Taojiahu hinterland were each 5% less diverse than the Xiaocheng hinterland and Taojiahu core (at about the 95% confidence interval). Northern and southern core areas became less diverse than their respective hinterland areas. This pattern held true even though as a whole, the Xiaocheng community had a lower diversity score than the Taojiahu community. As I discussed previously, it is unclear what social or economic factors were responsible for these variations in ceramic diversity. What is clear is that over time, these forces began to act more consistently on core and on hinterland areas, resulting in a 'uniform' format of economic interactions within each supralocal community.

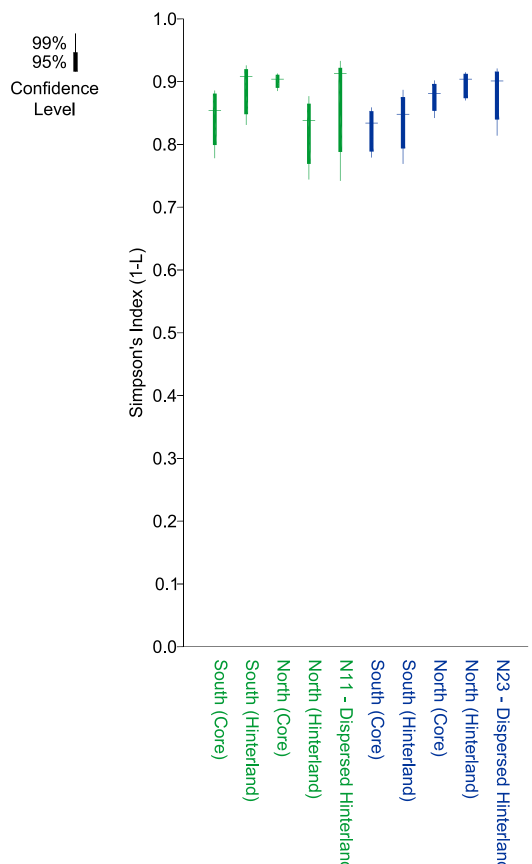

Figure 5.1: Diversity scores for each settlement context through time.

In summary, while there were differences in the kinds and combinations of pottery that were present in core and in hinterland areas, access to pottery production units was not restricted to one settlement context or the other (C6 in the Qujialing period is the sole example). Core and hinterland pottery assemblages became less dissimilar, and patterns of ceramic diversity at core and hinterland areas stabilized through time. Interestingly, as more people settled the landscape outside walled areas—producing a settlement pattern that more closely approximates a true 'hinterland'—the difference in economic networks inside and outside these walls became smaller. The most substantial difference in pottery circulation and procurement at core and hinterland settlement areas occurred in the Qujialing period when only a fraction of the regional population lived in a 'hinterland' setting.

5.1.4 Research Question 4: Did the organization and accessibility of these distribution networks change between the Qujialing and Shijiahe periods of the late Neolithic?

The research presented in this dissertation has documented several subtle ways in which the organization of and access to of pottery exchange networks changed throughout late Neolithic. These changes affected both the content and diversity of pottery assemblages, and are summarized in Figure 5.2.

One way in which pottery exchange networks changed is how consumers accessed, or procured, vessels from producers. Households living throughout the study area slowly altered which production units they relied most on for pottery, as well as the frequency with which they obtained pots from one producer over another. Though we cannot trace these economic decisions for any single household, they are captured in the aggregate by the content of neighborhood ceramic assemblages. Seen at the settlement level, pottery procurement strategies became increasingly distinct between northern and southern communities, and more similar across communities in core and hinterland zones.

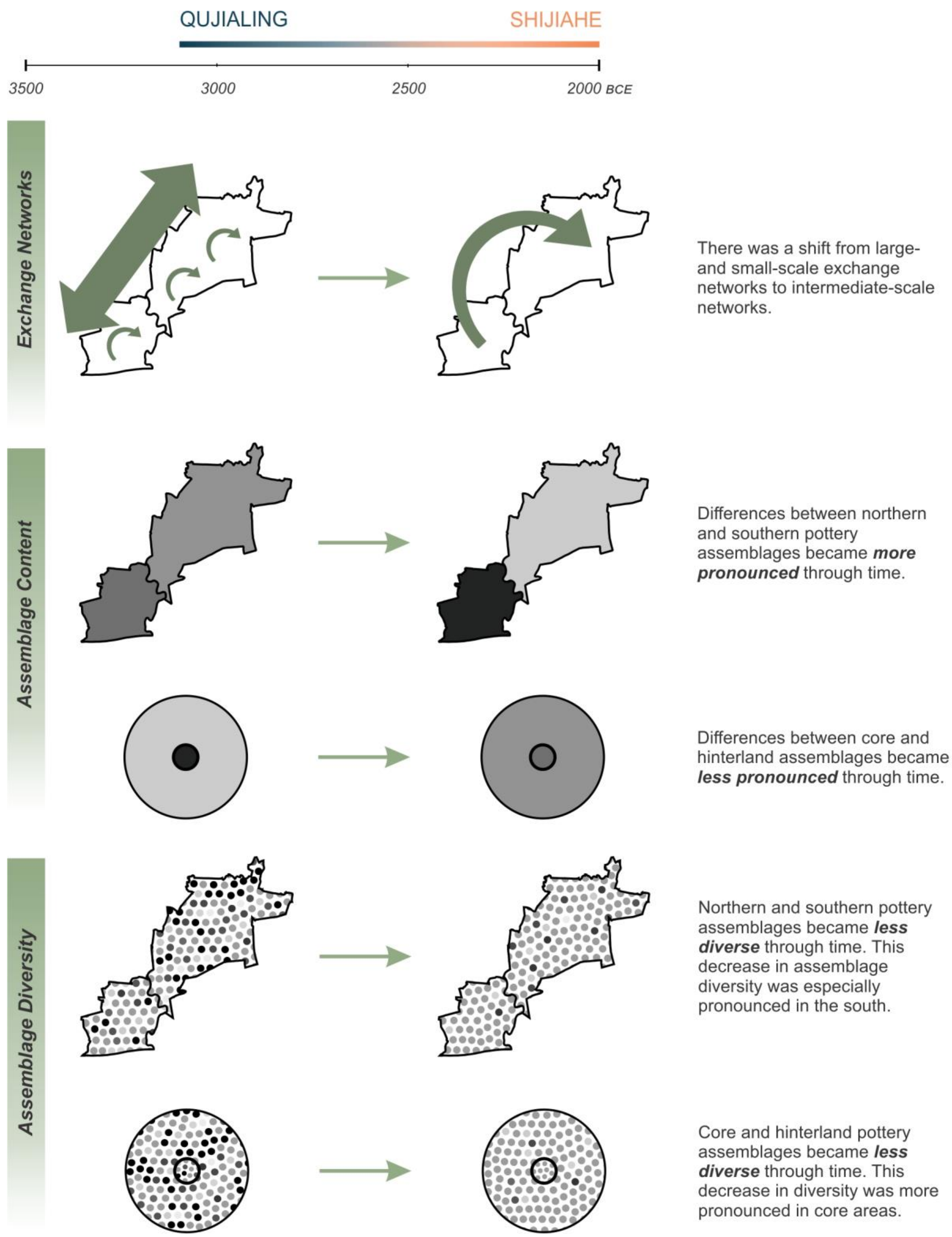

Figure 5.2: Summary results of this research.

Similarity in ceramic assemblages reflects the nature of the relationship between communities. Whether similarities are produced through direct contact (i.e. trade, migrations, or gifting) or indirect influences (emulation, identity signaling, similar sets of economic relationships or trade partners), greater similarities in assemblages indicate a higher probability of economic and social interactions between communities (Mills et al. 2013:39; Minc 2006). Ceramic assemblages were very similar at Taojiahu and Xiaocheng in the Qujialing period, pointing to a strong connection between the two communities. This connection weakened in the Shijiahe period as assemblages at each settlement became increasingly dissimilar. At the same time, social and economic ties between core and hinterland settlement were fairly weak in the Qujialing period but they grew in strength through time.

Alongside changes in procurement practices, the organization of pottery circulation networks also shifted over time. In the Qujialing period, pottery circulated through either large-scale, regional networks that were much larger than the study area or small-scale, local exchange networks. Ceramic vessels flowed through large-scale networks to Taojiahu and Xiaocheng, as well as communities far outside of the study area, possibly including nearby walled towns such as Menbanwan and the Shijiahe and Qujialing settlement complexes. The large geographic extents of these networks may have been facilitated by river transport. Qujialing pottery also circulated at a smaller scale between producers and consumers at a local level. These networks connected neighborhoods that were spatially close to one another as well as more distant neighborhoods that may have been 'socially local' through bonds of kinship, friendship, etc.

By the Shijiahe period, most pottery was circulated through networks of an intermediate size. These networks would have connected communities that were about 10 km apart, but were noticeably smaller than the regional networks of the previous period. It may be that this change from the regional-local network combination in Qujialing times was a reflection of a growing number of walled towns in the Jianghan Plain at consequently closer spacing (Guo 2008, cited in Zhang 2013:539).

Shifts in pottery procurement strategies and circulation networks point to an underlying change in the scale of economic and social interactions within the study area. Where populations had previously engaged in relationships with other inhabitants of walled towns—at Taojiahu, Xiaocheng, and likely other walled towns elsewhere in the Jianghan Plain—these relationships turned slightly inward in the Shijiahe period as stronger connections were forged between populations inside and outside the walls of each town. Though towns maintained economic relationships with other walled towns, these connections were not as intense as they had been in the Qujialing period.

Yet, as I have previously mentioned, these changes are remarkably subtle for a period of 1,000 years. The scale of these interactions may have contracted through time but the basic structure of the utilitarian pottery economy remained effectively the same. A similar number of production units manufactured and circulated pottery to households across the region. The residents of each neighborhood continued to have access to ceramic vessels from 10 or 15 production units, not just one or two. These patterns ultimately show that utilitarian exchange networks operated outside of the political sphere, and continued to do so for the duration of the late Neolithic. They also reveal that economic networks were flexible and could accommodate changes in settlement patterns without being completely restructured.

5.1.5 Research Question 5: How did this change correspond chronologically with the founding, growth, centralization, and disintegration of walled towns?

The results of the Taojiahu-Xiaocheng Regional Settlement Survey outlined distinct demographic trajectories for the two walled towns during the late Neolithic. Settlement patterns average occupational history of the region. Taojiahu developed into a large, nucleated settlement shortly after its founding and the construction of its walls in the Qujialing period. Approximately 65% (4,500 – 9,000 individuals) of the regional population lived within the walled area at Taojiahu, and another 20% (1,500 – 3,000) lived in the north outside of these walls. In the Shijiahe period, however, regional populations stayed steady, but only 45% (2,500 – 5,000) of the population lived in the walled core of Taojiahu as 20% (1,200 – 2,400) continued to occupy the northern zone outside the walls. Thus, at Taojiahu, population growth and the construction of walls occurred swiftly and in short succession in the Qujialing period. Yet in the following Shijiahe period, Taojiahu's population shrunk and dispersed to settle other parts of the study area.

Xiaocheng followed a much slower developmental trajectory than Taojiahu. In the Qujialing period, only about 8% (550 – 1,100 individuals) of the regional population lived in the walled area there, and 6% (450 - 900) of the population lived in the southern zone of the survey area outside the Xiaocheng walls. The population of these areas grew substantially in the Shijiahe period as 8% (900 – 1,800) of the regional population lived inside the Xiaocheng walls and another 8% (900 – 1,800) outside them. Xiaocheng's growth was less dramatic than Taojiahu's but much steadier, with populations doubling in size long after its walls were constructed. These distinct settlement trajectories led Li to argue that the centripetal forces that caused vast numbers of people to settle together at Taojiahu were very strong but relatively short-lived; by contrast, centripetal forces at Xiaocheng were less acute but persisted for nearly twice as long as those at Taojiahu.

Taojiahu emerged so suddenly and with such massive population growth that it is difficult to determine how pottery distribution changed alongside it. Xiaocheng's slower growth, however, makes it possible to view such changes, and the most impressive feature of the pottery economy at Xiaocheng is how little it changed. Though the scale and focus of economic interactions did shift slightly, the fundamental organization of pottery networks remained consistent. This overarching stability of pottery production and distribution within the study area indicates that the economy had little to do with the emergence of walled towns and the consolidation of political power they are thought to represent.

Yet analysis of the economy can provide insight to how people interacted with one another in mundane, everyday contexts. Anthropologists Mary Douglas and Baron Isherwood observe that the circulation and consumption of goods has a "…double role in providing subsistence and in drawing the lines of social relationships" (1996:39); and, moreover, that the "…choice of goods continuously creates certain patterns of discrimination, overlaying or reinforcing others" (1996:44). The decision to obtain pottery from one producer over another for whatever reason, simultaneously acknowledges one relationship while rejecting another. Compounded through time, these choices "make visible and stable the categories of culture" (Douglas and Isherwood 1996:38). For instance, observed differences in the diversity of ceramic assemblages at each settlement may represent two slightly different forms of social network construction. At Taojiahu, populations acquired pottery from a slightly wide array of production units in relatively low quantities, creating a more 'extensive' network composed of numerous weak connections between individuals. On the other hand, at Xiaocheng, populations obtained pottery from fewer production units but did so in slightly higher frequencies, producing a more ‘intensive’ network of few, strong connections between individuals. While the magnitude of the difference in diversity these strategies represent is small, these network patterns remained stable at each settlement despite fluctuations in local population size and settlement density.

One reason why understanding the structure of social networks may be important is that it could have affected how well or efficiently communities were able to accommodate demographic changes. More extensive networks tend to be redundant and thus are resilient but not especially efficient. More intensive networks, on the other hand, may be more hierarchical, less resilient, but more efficient. Rapid population growth at Taojiahu could have been facilitated in part by extensive-trending social networks, but may have soon gone too far for the population to be efficiently integrated, triggering a disintegration of community structure. Slow but steady population growth at Xiaocheng may have been maintained through time by intensive-leaning social networks, which allowed for new populations to be readily integrated into its existing structure. These are rudimentary hypotheses that could be fully tested with large-scale comparison of ceramic diversity data from a range of settlements with documented demographic trajectories. However, I offer them as brief illustrations of other, less direct ways in which economic networks might affect settlement dynamics, community structure, and even opportunities for political power.

Comparing the demographic trajectories of the Taojiahu and Xiaocheng settlements with changes in pottery exchange networks shows that political power was not based in management or control of utilitarian economies in the northern Jianghan Plain. Indeed, the production and circulation of pottery operated independently and quite stably for a millennium.

5.2 WALLED TOWNS IN REGIONAL PERSPECTIVE

Taojiahu and Xiaocheng are two of many walled towns in the Jianghan Plain, which itself was one of many places where walled towns emerged across Neolithic China. Historically, these sites have garnered significant attention from scholars working in East Asia, in part because of their visual similarity with walled capital of later Chinese states. The presence of architecturally similar walls at Neolithic and at important state cities has encouraged many prehistorians to propose that the earlier walled sites were the precursors of later walled capital cities. This view was further promoted by discoveries of prestigious items at walled towns as well as by burial data that pointed to the contemporaneous development of sociopolitical inequality.

A consequence of the comparison between Neolithic and Shang (and later) walled towns is that it masks the variation across walled towns present within each period. Thus ‘walled towns’ are massed together in one analytical group whether they are located in the middle Yellow River, in northeastern China, or in the Jianghan Plain. Recently, archaeologists have been working to change this by attempting to identify the diverse functions walls had in disparate geographical, climatological, and social contexts. There are three major forces that archaeologists have associated with the emergence of walled towns in different parts of China. First, walls are seen as fortifications designed to defend residents from violent attacks by competitive neighbors or warriors from other regions (Guo 2005:301; Meng 1997; Wang 2004; Yang 1994; Zhang 2013). Second, walls are seen as protecting locals not from invaders but from floodwaters (He 2002; Wang 2003; Yasuda 2013). Third, walls are interpreted as monuments that conspicuously marked the economic and political power of local elites, or alternatively acted as symbols of heterarchy and community participation (Dematte 1999; Liu 1996; Liu 2004:115; Priewe 2012; Zhang 2000).

The walls at Taojiahu and at Xiaocheng were clearly important to their inhabitants: the survey data reveals that walls actively influenced where populations chose to settle for at least 500 years. Yet, unlike the tall, stone walls of Xiajiadian hilltop forts in northeastern China, earthen walls in the Jianghan Plain were gently sloping and enclosed settlements that were made unnecessarily large by the inclusion of unoccupied spaces. This observation has led Li to argue that the walls at Taojiahu and Xiaocheng would not have made efficient defensive structures and were probably not initially built to serve this purpose (D. Li 2016; see also Shelach et al. 2011). The results presented in this dissertation offer additional support to his argument. The fact that Taojiahu and Xiaocheng participated in the same distribution networks and that residents procured pottery in broadly similar ways argues against the presence of conflict of warfare between them as a force driving their emergence. This is underscored by the fact that evidence for economic interaction between settlements was strongest in the Qujialing period, when the vast majority of the regional population lived within the enclosures of each settlement. This is not to say that the Taojiahu and Xiaocheng walls never served a defensive function, but rather that it is unlikely that the two communities were involved in the kind of endemic warfare typically associated with the large-scale construction of wall fortifications elsewhere in the world (see for example, Arkush and Stanish 2005). Expanding our settlement survey to include neighboring walled towns will allow us to build a more comprehensive picture of the nature of the relationship between these walled communities, and to determine just how variable settlement patterns were in and around the walls.

Determining the function of Neolithic walls addresses only part of the deeper anthropological issues about the roles they played in regional settlement systems. To date, several full-coverage, systematic surveys have documented the emergence of Neolithic walled towns elsewhere in China, the results of which can be used to address these anthropological questions. This comparative approach can also highlight variation among walled towns by emphasizing the particular mix of political, economic, and social forces driving both their development and disappearance. This involves identifying not only the ways in which the trajectories are similar, but also noting where their developmental paths diverge. I begin this process by comparing walled settlements in the northern Jianghan Plain with those in two regions of the Yellow River Valley.

The Yiluo River Survey Project (Liu 1996; Liu 2004; Liu et al. 2004) documented settlement patterns along tributaries of the middle Yellow River from the late Peiligang to the Eastern Zhou periods (6500 – 200 BCE). The survey showed that the region was first occupied in the late Peiligang period (c. 6500 – 5000 BCE) by a small number of people who lived in dispersed farmsteads and hamlets. Populations grew slightly in the subsequent Yangshao period (c. 3500 – 3000 BCE), resulting in a slightly higher number of sites but the general settlement pattern remained the same. Liu Li attributes the appearance of more and larger Longshan-era (c. 2900 – 1900 BCE) sites in the middle Yellow River to the immigration of populations from adjacent regions. She argues that these migrations sparked conflict between local communities and resulted in the creation of the first walled settlements. The largest among these was Taosi, located just upstream of the Yiluo River in the Linfen Basin, which is thought to have been a regional center. Liu contends that growth and centralization at Taosi was tied to its primary role as an economic center (Liu 1996; Liu 2004; Liu et al. 2004; Liu and Chen 2012). Supporting this is the discovery of numerous lithic tool blanks at Taosi, which were prepared using stone similar to that found at the nearby Mount Dagudui quarry (Liu and Chen 2012:226). Liu posits that elites maintained power by monopolizing access to this quarry, thereby controlling access to agricultural tools and food production. Other more prestigious items such as jade, white pottery, and small bronzes that were found in burials at walled sites are thought to have been produced by craft specialists beholden to local elites (Liu 2003).

The development of large, nucleated settlements in the nearby Yuanqu basin followed a similar trajectory to that of the Yiluo valley. Dai Xiangming (2006) documented a progressive increase in the number and size of settlements across the region throughout the middle and late Neolithic, ostensibly relating to population growth and settlement nucleation. Sites larger than 8 or 10 hectares briefly emerged in the Yangshao period but did not persist. Interregional conflict in the Longshan period seems to have spurred the development of a new central place settlement at Fengcun. Ultimately, Fengcun disappeared in the Erligang period following the expansion of Nanguan, which itself was enclosed by a ditch. Kilns excavated at these larger sites suggest that they served economic functions like those of the central settlements in the Yiluo river region. Using metric analyses of Yuanqu pottery aimed at identifying standardization and specialization, Dai argued that increasing sociopolitical complexity in the region caused the reorganization and centralization of pottery production and distribution (Dai 2006).

One major difference in the emergence of walled towns in the Yellow and Yangzi River valleys is in the role that warfare played in their development. Liu Li strongly contends that walled towns initially emerged across the middle Yellow River valley in response to conflict and local violence (Liu 1996b; Liu et al. 2004; see also Underhill 2002:34). Though this has been argued for the emergence of walled towns in the Yangzi River as well, our data indicates this was not the case for Taojiahu and Xiaocheng. It would be enlightening to compare evidence of warfare and fortification construction in the Central Plains with that in other parts of the world. Analysis of burials in Illinois, for example, offer compelling evidence of regularized conflict and surprise, targeted attacks between late prehistoric Oneota villages, with an estimated 1 in 3 deaths attributed to inter-village hostilities (Milner et al. 1991). These villages were either fortified or situated in easily defendable locations like bluff-crests (Milner et al. 1991:592; Milner et al. 2013:98). In contrast to the intermittent violence of the Illinois River valley, bioarchaeologists have identified a mass-killing event of at least 486 individuals at the palisaded site of Crow Creek in South Dakota in which 90% of the skulls had signs of been scalped (Willey and Emerson 1993). The site itself was enclosed by a later outer ditch and bastions, and an earlier inner ditch with palisade that connected terrace bluffs on the west and south sides of the settlement. The settlement was apparently destroyed before the outer ditch could be completed (Willey and Emerson 1993:230). In the Andes, widespread construction of walled *pukara* hillforts is accompanied by a small but growing body of bioarchaeological data pointing to endemic warfare (Arkush 2008). The hillforts had much more elaborate fortifications than the villages in the US Midwest. Located on peaks between 3,900 and 4,600 masl, pukaras included multiple defensive walls made of double-faced, rubble-filled stone, which were 1 to 2 m thick and between 1.5 and 5 m in height. In some cases, double sets of walls were built so that defenders could draw their enemies into a restricted space where they could be more easily wounded or killed (Arkush 2008:347). These three cases describe increasingly intensive forms of violence and warfare and the defensive structures that were built in response. Bringing data from the Central and Jianghan Plains into this mix will put a finer point on our understanding of the degree to which conflicts contributed to the construction of walled towns in each region.

Liu and Dai both view walled towns as the economic centers of the Yiluo and Yuanqu regions. They argue that elites who lived in these towns orchestrated the flow of staple goods and raw materials from the hinterland to the core, and finished goods from the core back to the hinterland. Thus, it was control over the economy that acted as the material foundation for elites' political power. My research has shown this not to be the case in walled towns of the northern Jianghan Plain. While pottery was probably produced within the walled areas of both Taojiahu and Xiaocheng, as was the case at Nanguan and Taosi, neither its production nor circulation seems to have been controlled by local elites. In fact, the stability of pottery exchange networks in the face of fluctuating population growth and nucleation suggests that the pottery economy operated largely outside the political sphere. Hence, to the extent that pottery distribution serves as an indication of how the distribution of other basic goods was organized, this research demonstrates that the political power of Jianghan Plain elites was not founded on control of the utilitarian economy.

The evidence behind the often-voiced idea that elites living in walled towns along the middle Yellow River wielded great economic power merits careful and critical examination. In fact, Anne Underhill argues that in the region downstream from Yiluo and Yuanqu, potters made eggshell cups and other labor-intensive forms for use in high-status burial rituals not because elites required them to but because there was high market demand for these forms (2002). We know remarkably little about the range of economic structures that were present across early complex societies in China. How integrated were political and economic spheres? Were different kinds of economic mechanism in operation at the same time within a single polity (i.e. market exchange and centralized redistribution)? It is also crucial to determine how existing systems of craft production and exchange were restructured (or not) as increasingly complex and bureaucratic political organizations developed. The middle Yellow River is one place in China where such questions could be answered with an approach like the one developed in this dissertation. Critical to the success of this endeavor is the selection of a large, statistically representative sample of sherds dating to Neolithic and Bronze Age periods, taken from a full-coverage, systematic regional settlement survey. This is easily accomplished using sherds from any number of surveys in the Yellow River valley, including but not limited to the Yiluo, Yuanqu, Yuncheng, Rizhao, and Huaitucheng regions (Drennan and Dai 2010; Ren 2008; Underhill et al. 1998; Underhill et al. 2008b).

Another key difference between walled towns of the Yellow and Yangzi River valleys is their relationship with hinterland populations. Along the Yellow River, large settlements emerged by drawing in populations from nearby hamlets and villages to their core, producing a settlement landscape of complex, ‘core area’ sites surrounded by small agricultural villages. In the Jianghan Plain, walled settlements developed through *in situ* population growth, meaning there was never a pre-existing hinterland population for Taojiahu or Xiaocheng to draw from (a pattern which is found at other Neolithic walled sites in the Jianghan Plain; see Zhang 2013 for a review).

Though I have referenced the ‘hinterland’ populations throughout this work, I use the term as a shorthand to describe the households that lived outside the walls of either town. The actual percentage of the total population that lived outside the walls was small, and they were not organized into distinct satellite communities of the sort seen in the Yellow River and other regions with a true settlement hierarchy. The absence of this latter kind of hinterland in the northern Jianghan Plain means that, by default, Taojiahu and Xiaocheng did not emerge as economic centers for the hinterlands. It also means that farmers, craftspeople, and elites all lived together in the same settlements, implying that the nature of social interactions in these communities was fundamentally different than those in which producers and leaders lived in separate areas. This proposition can again be tested by applying the same approach used in this dissertation to a region with a differentiated settlement hierarchy and comparing the results against mine.

The full impact of living in a settlement without a ‘true’ hinterland comes into focus when we translate archaeological periods into human generations. At Taojiahu and Xiaocheng, roughly 2,000 generations of people would have lived together inside the walls, most of whom would have lacked even institutional memories of living in another type of settlement. This, coupled with the fact that there was virtually no occupation of the land outside the walls until the Shijiahe period calls to question whether it makes sense to talk about demographic centralization at Taojiahu and Xiaocheng in the same way that we do for sites like Taosi and Nanguan. It perhaps makes more sense to ask what finally disrupted this stable pattern of nucleated living rather than focus as much on its origins.

This leads to the question of what factors contributed to the eventual abandonment of walled towns in the middle Yangzi River valley. Two thousand generations is a period twice as long as the history of the United States which lacks the major demographic shifts that the US has experienced since its founding. What would it have taken to upset such a steady system? Warfare, climate change, and flooding have been variously proposed as the direct sources of the abandonment of walled towns (curiously, these forces are the very same prime movers argued to have sparked the development of these settlements in the first place). Yet none of these factors are likely to have been the underlying cause of this sudden change in settlement. These changes are better accounted for by structural rifts in the political fabric of these societies, a glimpse of which we may have seen in the shrinking of economic interaction networks of the Shijiahe period.

Coupled with the deterioration of local political systems, factors like flooding or climate change may have served as immediate causes for the changes in settlement patterns. Li Dongdong's analysis of agricultural catchment zones in the Taojiahu-Xiaocheng region shows that good farmland might have been in short supply in the north of the study area during the Qujialing period. As the political structure of Taojiahu declined, households may have chosen to move closer to Xiaocheng to take advantage of the less occupied land there (2016:137–144). Flooding or changes in climate would have placed an even tighter strain on available farmland and might have accelerated settlement of zones outside the town walls. Another potential proximate cause for population dispersal is the sanitary conditions of walled settlements. With 2,000 generations of families, population levels in the high thousands, a moat filled with standing water (and possibly sewage), the presence of barnyard animals, and an occupational density similar to that of major modern cities, parasites and diseases were probably a ubiquitous part of life for the residents of walled towns. At Chengtoushan, for example, various species of beetles (Carabidae, Staphylinidae, *Aphodius* sp., *Onthophagus* sp.), flies (Muscidae, Calliphoridae), and parasites (*Trichuris*) were recovered from soils dating to the Qujialing period (Yasuda et al. 2004:156). Though these conditions were likely not sufficient to change such stable settlement patterns alone, as the political infrastructure of these communities unraveled, poor sanitation may have hastened migration away from the settlement centers to less populated areas.

The large-scale abandonment of walled towns and settlements along the length of the Yangzi River, referred to as the post-Shijiahe "collapse", may finally be somewhat exaggerated by an overreliance on the ceramic chronology. I do not deny that regional populations declined and settlement patterns changed dramatically after c. 2000 BCE. However, based on what this research has told us about pottery economies, it seems likely that the populations who remained in the Jianghan Plain continued to make pottery in the same way they did during the Shijiahe period. Without confirming the age of these contexts with radiocarbon dates, any such later occupations areas are folded into Shijiahe period contexts. The clear next step towards understanding the dynamics of settlement abandonment in the Jianghan Plain is for archaeologists to make a collective effort to compile all the chronometric dating information that exists for the region into a common database—and to continue to add dates to this database from future projects. This will allow us to more productively target research towards those places and times where the scantiness of the archaeological record reflects large-scale changes in the occupation of the middle Yangzi River region, rather than incomplete sequences in our own data.

Comparing walled towns from the middle Yellow River with those from the middle Yangzi River shows that their visual similarity (they all have earthen walls) masks significant variation in their sociopolitical trajectories. It also raises questions about the assumed contribution of economic control to the consolidation of political power in these settlements. Considerably more research is needed to examine the relationships between utilitarian economies and the development of social complexity in China, at both the local and regional scales (some scholars have begun to address these questions, notably Bennett 2002; Bonomo 2017; Cunnar 2007; Flad 2004; Hung 2011; T. Li 2016; Peterson 2006).

In this dissertation, I have described the structure and evolution of pottery exchange networks at two Neolithic walled settlements in the Jianghan Plain. I used a suite of geochemical methods to identify variation in pottery sherds collected from a regional settlement survey to reconstruct patterns of pottery exchange and procurement. These patterns were examined at both local and supra-local levels, among neighborhoods and within and between walled towns. I argue that despite their proximity, Taojiahu and Xiaocheng had slightly different developmental trajectories that corresponded with their participation in regional- and intermediate-scale economic networks. I have also suggested that differences in the organization of economic interaction at Taojiahu and at Xiaocheng may have contributed to rapid population growth and decline at Taojiahu, and to slow, steady population growth at Xiaocheng. Finally, I compared the development of social complexity and emergence of walled towns in the Jianghan Plain to those in other parts of China to emphasize that very different factors led to the appearance of morphologically similar sites. Ultimately, this study demonstrates the value of pairing systematic study of settlement patterns with targeted geochemical investigations. Future research could usefully increase the extents of the Taojiahu-Xiaocheng regional survey to encompass nearby walled towns, expanding our understanding of Neolithic settlement patterns and economic networks in the Jianghan Plain.

APPENDIX

Electronic Access to Datasets and Images

Access to the geochemical and mineralogical datasets collected for this research can be found online in the University of Pittsburgh Comparative Archaeology Database at <www.cadb.pitt.edu>. These databases are intended to be used for comparative purposes or for additional exploratory data analysis by researchers interested in the methods of geochemical pottery sourcing adopted in this project.

Geochemical and mineralogical datasets from both the pilot study and the full sample are available as tabular data in .xls and comma-delineated ASCII text files. These datasets document the elements (or mineral phases) and their intensities (or concentrations and weight percentages) measured in each sherd alongside its archaeological provenience. Raw spectral data for the four Bruker Tracer pXRF readings taken of each sherd is also available for download in comma-delineated ASCII text format. Finally, results of supplementary analyses of the datasets, including hierarchical cluster analyses and Brainerd-Robinson similarity coefficients, are available online as .pdf or .xls and .txt files as well.

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