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4 Geoarchaeology of prehistoric moated sites and water management in the Middle River Yangtze, China

Duowen Mo and Yijie Zhuang

Abstract

Moated sites appeared very early in the Middle River Yangtze, and their numbers continued to grow throughout Neolithic times, indicating the increasing investment in hydraulic engineering undertaken by prehistoric societies. These hydraulic features formed a robust water-management system that sustained continuous socio-economic growth in the region. We present evidence from our regional geoarchaeological surveys of prehistoric sites in the Middle River Yangtze, focusing particularly on the moats at these sites. We demonstrate how the construction and maintenance of these moated sites were related to and constrained by the changing environmental and socio-economic conditions. Moats became increasingly important in water management, especially flood prevention, and particularly when the settlements occupied large areas of local landscapes, often encroaching upon low-lying areas, because of population growth and migration. By the Qujialing-Shijiahe period (3000–2100 BC), regional competition had become one of the main driving forces that stimulated large-scale infrastructure construction and production of various consumables among large to medium-sized settlements. This not only changed patterns of economic development in the region, a region that was driven and accelerated by ritual activities and associated social gatherings, but also profoundly transformed the local landscape into one that was densely occupied by moats, ditches and other water-management infrastructures. It is this unique entanglement
between social competition, intensification of economic production, and infrastructure construction that needs to be unpacked in future research efforts to demonstrate the long-term water-management practices in this region and their relationship with environmental changes and the corresponding social evolution.

Introduction

Genetic studies and computational simulations have predicted that both the Middle and Lower Yangtze rivers were important places for rice domestication (Silva et al., 2015). While recent research has illustrated the cultivation, domestication and intensification processes of a rice economy in the Lower River Yangtze (Fuller et al., 2009; Gross and Zhao, 2014), the subsequent developmental trajectory of a rice economy in the prehistoric Middle River Yangtze remains unclear. Rice consumption began very early in this region (C. Zhang, 2000; Z. Zhao, 1998), which raises questions about how the transition from possible early cultivation to established rice farming took place and how rice domestication occurred.

In contrast to the uncertainty surrounding the development of the prehistoric rice economy is the early appearance of large moated settlements and the continuous development of hydraulic systems throughout prehistoric times in the Middle River Yangtze. These hydraulic systems were on a large scale compared with earlier periods, consisting of moats, earthen walls and levees, with associated features such as steps, bridges and piers located along the moats and nearby rivers. Together, these features, arguably, formed a robust water-management system that sustained continuous socio-economic growth in the region (see Pei, 2004a, 2004b). Further questions may be asked about the relationship between the changing palaeo-environmental and climatic conditions, the prehistoric settlements, and the associated hydraulic systems. To what extent did these hydraulic systems function as irrigation facilities supplying water to rice farming or as flood protection infrastructures? And how were the construction and management of these systems related to social evolution and economic development in the region? To address these questions we present evidence from our regional geoarchaeological surveys of prehistoric sites and their surrounding environments in the Middle River Yangtze. We focused particularly on the moats and demonstrated how their construction and maintenance was related to, and constrained by, the changing environmental and socio-economic conditions.
Regional environmental settings

The Middle River Yangtze region consists of two large alluvial plains, the Jianghan Plain and the Dongting Plain (Figure 4.1), both of which are encircled by mountains. These plains are low-lying, around 20–40 m above sea level. The low-lying areas are subject to active alluvial activities and prone to flooding, especially during the monsoon season. Many systematic coring surveys have demonstrated that the Holocene stratigraphies are dominated by fine alluvial and lacustrine sediments that have rapidly built up since the beginning of the Holocene (H. Deng et al., 2009). These cores sometimes contain sandy or coarser particle deposits derived from periodic flooding events. Scattered in the middle or along the edges of the alluvial plains are places that have been overlain by Middle to Late Pleistocene loess and red clay, often several metres higher than their surroundings. These places are called by local people ‘slopes’ or ‘tablelands’ (Figure 4.2A). They would have been ideal places for prehistoric occupation, as would the areas transitional between foothills and alluvial fans, which were generally higher than their surroundings.

Figure 4.1  The Jianghan Plain and the Dongting Plain in the Middle Yangtze, and the locations of major archaeological sites mentioned in the text. 1 Yejiamiao; 2 Menbanwan; 3 Shijiahe; 4 Sanfangwan; 5 Futian; 6 Liuguan; 7 Fenshanbao; 8 Zoumaling; 9 Huachenggang; 10 Bashidang; 11 Jijiaocheng; 12 Chengtoushan; 13 Pengtoushan. Source: authors
The studied region has humid, rainy summers and cold, relatively dry winters. The present average annual temperature is 15–18°C, while annual precipitation ranges from 800 to 2,000 mm. Its eastern part, closer to the monsoon front, receives significantly more rainfall than its western areas. As documented in high-resolution stalagmite records, the Holocene climate has slowly but steadily deteriorated from the middle to late Holocene onwards (Y. Wang et al., 2005), meaning that the climate was warmer and more humid during the middle Holocene than during the latter half of the Holocene. It is estimated that the middle Holocene temperatures were 1–2°C higher and precipitation was 200–400 mm greater than at present. However, it is important to note that many decadal and centennial oscillations can also be observed from the reconstructed

**Figure 4.2** A. Typical loess slope at Shiligang, Hunan. B. The Pengtoushan site: the moat, which is still functional, and the site (where the person stands). Source: authors
curves of moisture changes. While this general trend of Holocene precipitation is clear, its impact on the Holocene alluvial hydrology is complicated by the fact that the hydrology is influenced by other factors, such as sea-level fluctuations and sedimentation rates. Generally speaking, in the short term, the peak charge of river water is indeed directly linked to concentrated summer rainfall. However, in the longer term, river flooding regimes are more closely related to landforms and changes in sedimentation rates. This means that it is currently difficult to assess the impact of Holocene climate on flooding regimes in this region.

Prehistoric societies and subsistence

Parallel with the long tradition of rice consumption in the Lower Yangtze River, the earliest rice remains discovered at the Yuchanyan and Xianrendong cave sites in the Middle River Yangtze can be dated to before 8000 cal. BC (C. Zhang, 2000; Z. Zhao, 1998). Together with, or earlier than, this important development was the invention of pottery. The earliest pottery is dated to around 18,000 cal. BC (X. H. Wu et al., 2012). A popular theory is that this pottery was for food processing and thus represents a significant technological leap driven by subsistence change (see Kuzmin, 2013; Shelach, 2012). However, because of the lack of archaeological finds for this chronological gap between 18,000 cal. BC ago, when pottery first appeared, and the early Holocene, when rice first began to be consumed, it is still difficult to understand fully the relationship between the technological advancements, cultural adaptation and the environment. Given that most of these early sites were located in the mountainous areas and were primarily reliant for food on hunting and gathering, the role of rice, as a grassy plant grown in wet habitats, in the local diet was probably minor at this time.

The earliest Neolithic culture found in the Middle River Yangtze is the Pengtoushan, dating to 7100–5600 cal. BC (Hunan Provincial Institute of Cultural Relics and Archaeology, 2006: 617). According to C. Zhang (2015: 207) and Pei (2013), the majority of the Early Neolithic sites were located on river terraces and tablelands, ranging in size from several thousand to three hectares, including some shell midden sites which were situated closer to rivers. The Pengtoushan culture sites were already quite ‘mature’ in terms of their settlement structures. The Pengtoushan site was encircled by a moat (Figure 4.2B). Similarly, the Bashidang site was built next to a river. One side of the site was connected to a lake, the other three sides being enclosed by a moat and earthen walls (Hunan
Provincial Institute of Cultural Relics and Archaeology, 2006; Pei, 2013; C. Zhang, 2015). At Bashidang, single-roomed houses appeared in rows in the north-west and north-east corners of the enclosed area, each containing a fireplace or hearth. Abundant artefacts, and organic remains such as animal bones and seeds, were found next to the residential area. Rice was also present. Some scholars have claimed that the rice was already cultivated (W. X. Zhang, 2006; W. X. Zhang and Pei, 1997; D. L. Zhao and Pei, 2000), with gathered wild plants probably still an important component of the diet. Along with mammal bones, aquatic species including fish and shells were also abundant. This evidence suggests that hunting and gathering were still the main sources of food. However, there is also the suggestion that granaries were built and used to store agricultural surpluses at the site (C. Zhang, 2015: 209). If this was true, it would mean that these granaries were most likely used to store durable grains such as rice or other cereals. Other contemporary or slightly later period settlements, such as Fenshanbao (C. Zhang, 2015: 209), have houses with similar structures but moats are absent at these sites.

The following, Chengtoushan period (5600–3300 BC; we use ‘the Chengtoushan period’ here as a chronological term: the cultural affinities of the archaeological remains of this period are more complicated than for other periods) saw the boom of settlement sites, with expanding residential features in the Dongting and Jianghan plains. Around 300 sites have been found (C. Zhang, 2013: 510). Most sites are 3–5 ha in size, while several reach 5–10 ha (Table 4.1). Inside the enclosed and walled area at Chengtoushan (Figure 4.3), not only have houses been excavated, but a ceremonial feature has also been brought to light through recent excavations. This ceremonial feature is a round-shaped altar built of pure yellow earth, around one metre in height and 200 m² in size. Shallow pits, urn burials and graves have been discovered, along with abundant archaeological remains, including cooking vessels, rice and animal bones. Equally significant was the discovery of paddy fields at this site (He and Yasuda, 2007; Toyama, 2007; Yasuda, 2013). The fields appeared to have already reached a large scale, 20 × 2.7 m, compared to the small field units discovered elsewhere (see Chapter 5 in this volume). This series of new archaeological phenomena indicates that rice farming was further developed and that the farming regimes themselves underwent fundamental changes, such as the planting of rice stands in managed fields. This developed rice economy explains why abundant rice remains were discovered at the aforementioned ceremonial altar. Also worth mentioning are the millet remains discovered at Chengtoushan, along with weedy plants indicative of dry habitats (Guedes, 2011; Nasu et al., 2007). This suggests that millets were being cultivated locally, after being introduced to the area, most
<table>
<thead>
<tr>
<th>Site</th>
<th>Cultural phase</th>
<th>Enclosed area (ha), dimensions</th>
<th>Moat dimension (m)</th>
<th>Wall dimension (m)</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bashidang</td>
<td>Pengtoushan</td>
<td>3.7, 270 m × 180 m</td>
<td>Top width 4, bottom width 2, and depth 2</td>
<td>Bottom width 5, top width 2, height 2</td>
<td>Guo, 2010</td>
</tr>
<tr>
<td>Shanlonggang Pengtoushan</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
<td>Guo, 2010</td>
</tr>
<tr>
<td>Pengtoushan</td>
<td>3,160 m × 190 m</td>
<td></td>
<td></td>
<td></td>
<td>Guo, 2010; Hunan Provincial Institute of Cultural Relics and Archaeology, 2006</td>
</tr>
<tr>
<td>Chengtoushan Mid- to late Daxi</td>
<td>9</td>
<td>Top width 10, bottom width 6.15 and depth 4</td>
<td>Top width 5, bottom width 8, height 1.6</td>
<td></td>
<td>Z. H. Zhang, 1998; Guo, 2007, 2010</td>
</tr>
<tr>
<td>Yinxiangcheng Daxi/Qujialing? (only partially surveyed)</td>
<td>c. 19, 350 m × 580 m</td>
<td>Width 30–40 and depth 4</td>
<td>Width 10–25, height 1–2</td>
<td></td>
<td>Jia, 1998a; H. X. Wang, 2003; Yuan, 1997</td>
</tr>
<tr>
<td>Longzui Daxi</td>
<td>8.2, 305 m × 270 m</td>
<td>Surrounded by lakes on three sides; one side has moat: width 18 and depth 1.5–2.7</td>
<td>Bottom width 17, height 1–3</td>
<td></td>
<td>Hubei Provincial Institute of Cultural Relics and Archaeology, 2008.</td>
</tr>
<tr>
<td>Huachenggang Daxi-Qujialing Shijiahe</td>
<td>4, 200 m × 200 m</td>
<td>Width 10–15</td>
<td>Very low</td>
<td></td>
<td>He, 1983; Yin, 2005</td>
</tr>
<tr>
<td>Shijiahe Qujialing-Shijiahe</td>
<td>c. 120</td>
<td>Width 60–100, depth 2</td>
<td>Bottom width 50, top width 15, height 6</td>
<td></td>
<td>Liu and Yu, 2016; Joint archaeological team of Shijiahe, 1992</td>
</tr>
<tr>
<td>Site</td>
<td>Cultural phase</td>
<td>Enclosed area (ha), dimensions</td>
<td>Moat dimension (m)</td>
<td>Wall dimension (m)</td>
<td>Source(s)</td>
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<tr>
<td>Menbanwan</td>
<td>Qujialing-Shijiahe</td>
<td>20, 550 m × 400 m</td>
<td>Top width 59, depth 1.8–2.5</td>
<td>Top width 13.5–14.7, bottom width c.40, height 6</td>
<td>H. X. Wang, 2003</td>
</tr>
<tr>
<td>Taojiahu</td>
<td>Qujialing-Shijiahe</td>
<td>67, 1000 m × 850 m</td>
<td>Top width 20–45</td>
<td>Bottom width 30, height 1.5–3</td>
<td>Li and Xia, 2001; H. X. Wang, 2003</td>
</tr>
<tr>
<td>Tunzishan</td>
<td>Qujialing-Shijiahe</td>
<td>8</td>
<td>Width c. 30, height 1–5</td>
<td>Jia and Yang, 2005</td>
<td></td>
</tr>
<tr>
<td>Xiaocheng</td>
<td>Qujialing-Shijiahe</td>
<td>9.8, 156–305 m × 250–360 m</td>
<td>Moat connected to lakes encircling three sides of the settlement</td>
<td>Bottom width 23, height 0.6–1.6</td>
<td>W. X. Huang et al., 2007</td>
</tr>
<tr>
<td>Chenghe</td>
<td>Qujialing-Shijiahe</td>
<td>71.8, 600–800 m × 550–650 m</td>
<td>Width 15–50, depth 1–3</td>
<td>Width 8–50, height 1–5</td>
<td>Hubei Provincial Institute of Cultural Relics and Archaeology, 2014; Jingmen Institute of Cultural Relics and Archaeology, 2008</td>
</tr>
<tr>
<td>Wangguliu</td>
<td>Qujialing-Shijiahe</td>
<td>88, 1000 m × 880 m</td>
<td></td>
<td></td>
<td>Zeng, 1990</td>
</tr>
<tr>
<td>Qinghe</td>
<td>Qujialing-Shijiahe</td>
<td>6, 300 m × 200–240 m</td>
<td>Width 30–50</td>
<td>Width 30, height 0.5–2</td>
<td>Jia and Yang, 2005</td>
</tr>
<tr>
<td>Yejiamiao</td>
<td>Qujialing-Shijiahe</td>
<td>15, 870 m × 650 m</td>
<td>Top width 40, depth 2</td>
<td>Top width 27–30, height 2–6</td>
<td>Liu, Hu et al., 2012</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Site</th>
<th>Cultural phase</th>
<th>Enclosed area (ha), dimensions</th>
<th>Moat dimension (m)</th>
<th>Wall dimension (m)</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoumaling Qujialing-Shijiahe</td>
<td>7.8</td>
<td></td>
<td>Width c. 35, depth 2</td>
<td>Bottom width c. 28 and height 5</td>
<td>H. X. Wang, 2003; Z. H. Zhang, 1998</td>
</tr>
<tr>
<td>Jijiaocheng Qujialing-Shijiahe</td>
<td>14, 400 m × 470 m</td>
<td>Multiple rings of moats and ditches, the innermost one 40–70 in width; other moats and ditches c. 20 in width</td>
<td>Width 40–60 and height 2–5</td>
<td>Guo, 2010; H. X. Wang, 2003; Yin, 2002</td>
<td></td>
</tr>
<tr>
<td>Jimingcheng Qujialing-Shijiahe</td>
<td>15, 500 m × 400 m</td>
<td>Width 20–30 and depth 1–2</td>
<td>Top 15 m in width, bottom 30 m in width and 2–3 m in height</td>
<td>Jia, 1998b</td>
<td></td>
</tr>
<tr>
<td>Shijiahe phase at Chengtoushan</td>
<td>8</td>
<td>Width 40–50</td>
<td>Width 20 and height 2–4</td>
<td>Guo, 2007, 2010; Joint Archaeological Team of Shijiahe, 1992</td>
<td></td>
</tr>
<tr>
<td>Zhangxiwan Qujialing-Shijiahe</td>
<td>9.8, 295 m × 335 m</td>
<td>Width 25–35, depth 3–3.5</td>
<td>Width 24, height 1.5</td>
<td>Liu, Guo et al., 2012</td>
<td></td>
</tr>
</tbody>
</table>
likely from the north (Guedes, 2011). Some smaller sites of this period, such as Huachenggang, also had moats and walls. However, these sites either were severely damaged or lacked large-scale excavations, so the full scope of their structures remains unclear.

Dramatic changes in settlement structures can be seen during the Qujialing-Shijiahe period (5000–4100 cal. BP). The number of settlements reached more than a thousand (Table 4.2; C. Zhang, 2015: 227). These settlements can be divided into at least four tiers according to their sizes (C. Zhang, 2013: 514, 2015: 228). The Shijiahe site complex was composed of a large rectangular walled area, with numerous archaeological features inside and outside this enclosed area (Figure 4.4).
Table 4.2  Number of sites from different cultural periods

<table>
<thead>
<tr>
<th>Cultural period</th>
<th>Number</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pengtoushan</td>
<td>c. 30</td>
<td>Pei, 2013</td>
</tr>
<tr>
<td>Daxi-Yangshao</td>
<td>c. 300</td>
<td>C. Zhang, 2015: 210</td>
</tr>
<tr>
<td>Qujialing-Shijiahe</td>
<td>&gt;1000</td>
<td>C. Zhang, 2015: 227</td>
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Figure 4.4  Plan of the Shijiahe site complex (after C. Zhang, 2013)
Excavations at several locations inside the walled area have revealed houses, large graves with rich burial goods, and most significantly, ritual objects and features. The latter include hundreds of thousands of ceramic cups, concentrated in a small area and covered by earth, two pits in the cemetery containing several thousand terracotta figures of animals and humans, and many jars lying horizontally, with one attached to another in row after row (Figure 4.5). Outside the moated area were more than 20 residential areas, each containing houses and living facilities. This spatial relationship between ritual activities and residential areas leads some scholars to think that Shijiahe was a regional centre where important ceremonial events were held and participated in by the populace. Such a central role would have meant that its settlement structure became a model for neighbouring local communities to follow. This may have triggered regional competition, resulting in the construction of large-scale walls and moats by contemporaries. Indeed, settlements

Figure 4.5  An excavated ceremonial feature at the Dengjiawan location inside the walled area (after Yang, 2003)
belonging to the second and third tiers all possessed moats and walls. Several of them also formed into clusters, but their structures are poorly understood because of the scarcity of archaeological data. Behind this emerging regional phenomenon, of intensifying engineering taking place on the local landscape, was a fundamental shift in the agricultural economy and unprecedented population growth. During this phase, not only were the large, central sites able to organise the construction of large-scale infrastructures, but medium or smaller settlements also had the means to build walls and moats.

Archaeobotanical flotation was conducted at a number of Qujialing-Shijiahe-period sites. The predominant plant recovered at both Yejiamiao and Sanfangwan was rice. These results suggest that rice farming had become very important, although millets continued to be cultivated (Deng et al., 2013; C. R. Wu et al., 2010). Though no paddy fields from this period have been found (they are likely to be buried underneath late Holocene alluvial deposits), a kind of dyke has been commonly found ‘all over the Liyang Plain’ and is thought to represent the type of ‘dyke and reservoir works’ used in irrigation practices. This implies that rice farming was practised on a much larger scale to feed the increasing ‘rural and urban population’ (C. Zhang, 2013: 523).

The construction of the prehistoric moats and walls

Unlike the Late Neolithic walled sites in North China, constructed by well-developed earth-pounding techniques and consolidated by standing wooden logs inside the walls (H. Zhao and Wei, 2002: 18), the moats and walls in the Middle River Yangtze were constructed with rather simple technologies that remained largely unchanged during this period. During the early stage, earth dug up from the moats was simply piled up on the same spot to build the walls, without any further treatment. This simple process was sustainable because the construction remained on a small scale, and the size of the moats and walls was also fairly small, and therefore it did not require sophisticated technology to build them. By the Qujialing-Shijiahe period, as the size of the moats and walls grew exponentially, pounding and trampling technology, using wooden sticks or other tools, was occasionally applied at some sites when earth was piled up. This enabled the construction of higher walls, which were more solid and resistant to surface erosion. However, the majority of the walls in the prehistoric Middle River Yangtze were still being built in a very simple manner as the heavy, clayey earth did not require heavy pounding.
Indeed, resistance to surface erosion was a critical factor in this rainy and humid region with abundant surface run-off. Hence, many Neolithic walls have a prismatoid cross-section with a very wide base and gentle slopes to reduce surface erosion (Table 4.1).

The construction of the moats and walls was closely related to changes in social structure and agricultural growth throughout Neolithic times. Table 4.1 shows the size increases in moats and walls from the Pengtoushan cultural period to the Qujialing-Shijiahe period. None of the early-period moats enclosed an area larger than 10 ha. Most of these moats were rounded or irregular in shape. This spatial arrangement was to connect parts of the existing natural water bodies with the artificial moats to save labour costs. Assuming low productivity among the earth workers, Pei suggests that 100 labourers would have needed to work for 20 days to dig the moat at Bashidang (Pei, 2004a). As mentioned above, by the Qujialing-Shijiahe period a clearly ranked system of walled and moated sites had developed, which is inferred from site size estimates.
The largest one was the Shijiahe site, whose enclosed area reached 120 ha. The second-tier sites fell into a size range of 50–100 ha and the third-tier ones measured 10–20 ha (C. Zhang, 2015: 228). In addition, at and around large regional centres such as Shijiahe smaller sites were often concentrated to form one huge site complex, revealing an unprecedented effort by a dense population to transform a landscape into a heavily engineered environment. Completion of these increasingly large moats and walls would have consumed substantial resources. Zhang calculates that at least half a million m³ of earth would have been dug from the moats to build the walls at Shijiahe. This would mean about 1,000 workers working for about 10 years, who ‘had to be fed by probably 20,000 to 40,000 persons’ (Nakamura 1997, cited in C. Zhang, 2013: 519). Labour investment and organisation on such a large scale would have only been possible in a society with a considerable agricultural surplus and advanced organisational skills. Also by the Qujialing-Shijiahe period, some sites, such as Jijiaocheng and Zoumaling, had multiple rings of moats encircling a large area (Chen, 1998; Yin, 2002). This further suggests that sophisticated planning and logistics existed not only at large sites, but also at smaller sites which had economic and cultural connections with them.

Along with these structural changes and the increase in size of the moats and walls came an increasing emphasis on the construction along or next to the moats of associated facilities, which served a key role in their functioning. At Bashidang, from the early period, an initial attempt to connect the residential area with its surrounding water bodies was evidenced by the discovery of pebble stairs descending towards the river (Figure 4.7). In the following period, at the Chengtoushan site, not only were reeds and wooden planks used to consolidate the banks along the moat, but wooden paddles and parts of boats were also discovered inside the moat (He and Yasuda, 2007). The latter suggest that the moat was also used for transport. By the Qujialing-Shijiahe period, in addition to the continuous building of stairs along the moats to facilitate water usage, which can be seen at sites such as Zhangxiwan (Liu, Guo et al., 2012), wooden bridges had been built between the moats and the walled areas. Bridges of this type have been found at the Shijiahe site (Meng et al., 2012; Figure 4.8). Only a few wooden stakes are left, but the construction of such bridges demonstrates a greater investment in the moats. The most significant development was the construction of ‘water gates’ at many Qujialing-Shijiahe walled sites. These gates were often built in the low-lying areas surrounding the moats and connected to rivers and lakes nearby. C. Zhang (2013) speculates that an existing
Figure 4.7  The stone steps discovered at the Bashidang site (after Hunan Provincial Institute, 2006)

Figure 4.8  The excavated bridge remains at the Tanjialing location of the Shijiahe site complex (after Meng et al., 2015)
gap (c. 450 m in width) in the south-eastern corner of the Shijiahe walls was the place where one of those gates was situated (but the precise dimension will remain unknown until the area is excavated), probably fenced with wooden logs. Such gaps have also been found at other sites, such as Menbanwan (H. X. Wang, 2003).

**Water management and landscape engineering**

The functions of these moats and their associated facilities has been much debated. Were they mainly used for flood protection? To what extent did they function as a defensive system? What specific roles did they play in irrigation, in the supply of water for daily use, and in water transport? And did these functions evolve through time? Despite continuing disagreement on these questions, there is a growing consensus that these issues need to be examined within the wider socio-economic and environmental contexts.

As mentioned above, the Holocene landscape in much of the Jianghan and Dongting plains was crisscrossed by natural rivers. In our survey, we have found that the majority of the prehistoric sites were located 35 m above sea level and at least 2 m higher than the plains that were often flooded by the rivers (see also Zhu et al., 2007). These settlements were encircled by moats, which were situated on lower ground and connected to natural water bodies through artificial ditches. The ample rainfall and its uneven temporal and spatial distribution have been a constant challenge to daily life and agriculture in the region in the past and the present. When the rainfall reaches its peak, it quickly gathers in ditches and low-lying areas in the field, becoming a threat to communities living there. On the other hand, however, it is necessary for villages to be connected to natural water bodies to guarantee water availability during dry seasons. Small modern villages in the region indeed rely entirely on small rivers for water for daily use and agricultural irrigation.

The extent to which these prehistoric sites were affected by Holocene floods remains unclear. Evidence derived from regional environmental surveys suggests that, even though the volume of water flow per second of the Yangtze and its major tributaries and associated lakes was higher during the middle Holocene than at present, the water levels of major rivers were actually much lower than now; the rivers benefited from the low silt-laden water and deep and wide river channels with larger volumes (J. Li et al., 2011; Zhou, 1994). Thus, these rivers and lakes would have served to absorb the low- to medium-magnitude
floodwater, mitigating the danger of flooding at the prehistoric sites located on higher ground and not too close to the major rivers. Indeed, there is so far no convincing evidence that archaeological remains were directly overlain by flooding deposits. Rather, excavations of many moats have revealed that they were filled up predominantly by organic-rich, dark, clayey sediments (Hui Liu, personal communication), without the pebbles and sands which are normally deposited in standing water conditions. Such depositional processes suggest either that the local water systems were well maintained and regulated and the flow and velocity of water were well controlled and stable, or that these moats were not flooded on a regular basis, as floods would have resulted in the deposition of much coarser particles than clay.

By the Chengtoushan and Qujialing-Shijiahe periods, though most of the sites were still located on higher ground, settlements were expanding more extensively over the landscape, presumably because of the pronounced increase in population. Associated with this increase was an intensification of the rice economy, which means that substantial areas of arable fields, including the land situated in the low-lying areas, would have been reclaimed for rice farming. The elevations of the Liuguan and Futian sites, for instance, decreased to lower than 20 m above sea level, which put these sites at greater risk of being flooded. Because of increasing deforestation and land clearance (J. Li et al., 2011; Shi et al., 2010; see also Y. Li et al., 2010), the rivers were silting up more quickly than before. These changes in settlement patterns and river hydrological regimes posed a significant challenge to water-management practices at these sites, especially when the growth of rice plants coincided with the peaks of summer rainfall, meaning that rice fields needed to be drained quickly (see Chapter 5 in this volume). One of the most significant efforts to mitigate this potentially detrimental effect was further engineering of the local landscapes to enhance the function of large-scale moats and their associated water-management systems. Surveys at the Jijiaocheng site have revealed a well-developed water-management system (Figure 4.9). This walled area is surrounded by a network of ditches and weirs, some of which have been excavated recently. These ditches and weirs are located in low topographic areas and many of them are still in use for growing aquatic plants such as lotus and for routine activities such as washing. Among the ditches are agrarian fields. These ditches and weirs formed a highly integrated water-management system, which played a crucial role in water drainage and flood mitigation by receiving overflow from the farming fields. Floodwater was most likely diverted before it caused damage to agricultural yields, and quickly discharged into the rivers. The key
to the normal functioning of these combined water-management systems of moats and ditches was ensuring that these ditches were not silted up. This would have involved careful management and maintenance of the ditches by enforcing frequent clearance and related activities, although evidence of such activities has not been found yet. Between the ditches and the moat, sluices, water outlets and other small facilities would have been built to control water flow.

Discussion

Environmental constraints and opportunities in the prehistoric Middle River Yangtze

The moated and walled sites in the Middle River Yangtze were among the earliest and most developed in prehistoric China. The scale of these early moated sites was large and their number continued to increase, with a
pronounced leap during the Qujialing-Shijiahe period. Moats and walls became integral parts of Neolithic sites in this region and played a central role in the socio-economic activities that took place there. The early and consistent emphasis on the construction of moats and walls was an unprecedented phenomenon that was closely related to its environmental context.

High-resolution climate change data, especially precipitation patterns, for the Middle River Yangtze, is lacking. However, the whole region has been very humid throughout the Holocene, characterised by heavy summer rainfall. In this sense, we suggest that rainfall (as a constant variable) was not the paramount parameter for the evolution of prehistoric water-management systems. Rather, as discussed above, it was the combination of geomorphological processes and characteristics of local landforms that played a decisive factor in the planning, expansion and maintenance of these systems. Compared with other regions, the landforms in the Middle River Yangtze are dominated by relatively flat alluvial plains. Variations in the elevations are often less than 5 m. These places were ideal for the construction of mega-scale walled and moated sites such as the Shijiahe site. These sites took advantage of the developed natural water systems in their large-scale engineering works of local landscapes for various purposes. The water system and engineered landscape at Jijiaocheng reached a mature level, characterised by the construction of well-designed moats and ditches for robust channelling ditches with the construction of moats for water management and flood prevention. This mature water-management system shows a sophisticated understanding of the local ecology and an ability to manage micro-topography in the field. Indeed, these moated sites gradually developed multiple functional water-management systems. Irrigation, supplying water for daily use, drainage and flood prevention, water transportation, and other functions which, despite fluctuating water needs (depending on local economic and environmental conditions), make these moats and walls an intrinsic part of both the seasonal and the temporal functioning of these sites. However, the construction and maintenance of these increasingly large water-management systems required large economic resources and a large labour force, as well as managerial skills. This is one reason why moats and walls were only built at medium-to-large sites. This pattern prompts one to ask what the relationship is between the intensification of water management and pathways of social complexity in the prehistoric Middle River Yangtze.
Intensification of water management and social complexity

Variables that determine trajectories of intensification include population and labour, demand and supply patterns, and related key factors such as environmental conditions and availability of natural resources. In many classic studies of intensification (e.g., Boserup, 1965), the importance of environmental conditions has largely been overlooked. As we have discussed above, the construction and especially the expansion of large moated and walled sites were fundamentally constrained by local landforms. On the one hand, the alluvial plains made the construction and expansion possible; on the other, there was always the necessity to choose the optimal space on the plains to avoid floods.

From about the fifth millennium BC onwards, the increasingly large moated and walled sites, by means of their socio-economic impact accumulated sufficient economic resources and knowledge for the dramatic development witnessed during the succeeding Qujialing-Shijiahe period. Indeed, the scale of some of the walled and moated sites during that period was enormous, and the density of cultural and economic activities was so high that it caused a fundamental transformation, both qualitative and quantitative, of prehistoric landscapes. We see a positive correlation between the size of the walled and moated sites and their productivity in terms of water management and other economic functions. When the size of the moats and walls increased $n$ times, the size of the enclosed area increased $n^2$ times. This meant that more space and resources became available for the growing population at these large sites. In turn, this improved economic efficiency accelerated social and economic division, gearing the societies up for further intensification and specialisation of economic production.

An example that illustrates this point is the Shijiahe site complex, which is dominated by a wide variety of functional areas inside and around the enclosed area, as mentioned briefly above (Figure 4.4). The hundreds of thousands of ceramic cups and pottery figurines appear to represent large-scale social gatherings or similar events, which would have been a crucial arena for enhancement of social identity and acquisition of social power. An excavation in 2017 recovered even more ceramic cups and evidence of their production (Hui Liu, personal communication). What was taking place at Shijiahe was imitated by many sites in the region (Table 4.1). This process stimulated regional competition and considerable resources were invested in building walls and moats as well as in the production of consumables such as the ceramic cups. Such competition for space and resources resulted in conflict. This made defence
by means of the walls and moats increasingly vital, a situation that would further encourage regional competition in the building of larger walls and moats and the consumption of more cups as a way of enhancing and increasing social power. We can therefore see another distinctive pathway to intensification, initiated by social-cultural actions, becoming closely related to the acquisition of social power in the society. This pathway might also have provoked a fundamental shift in the use of moats towards multiple functions, in which defence played a key role.

Conclusion

The early appearance of walled and moated sites in the Middle River Yangtze is unparalleled among contemporary Neolithic cultures in different regions of China. Moated and walled sites in this region continued to see quantitative and qualitative growth throughout the Neolithic period. Because the development of a rice economy is not clearly understood at present, it is hard to assess the role of moats in irrigation. Nonetheless, these moats did become crucial in water management, especially in flood prevention, when the settlements expanded into larger areas of local landscapes, including the low-relief areas, because of population growth and migration. In addition, the ability of the ditches to absorb surface run-off quickly during the rainy season makes them especially efficient in water management. The frequent water flow in turn clears away sediments in the ditches, guaranteeing their normal function in flood prevention. These moats and ditches form an extremely effective and unique water management system in the Middle River Yangtze, which is dominated by flat lands and receives heavy summer rainfall. By the Qujialing-Shijiahe period, regional competition had become one of the main driving forces that stimulated large-scale infrastructure construction and the production of various consumables. This competition not only changed the pattern of economic development in the region, one that was driven and accelerated by ritual activities and social gatherings, but also profoundly transformed the local landscape into one that was densely occupied by moats, ditches and other water-management facilities. It is this unique entanglement between social competition and intensification of economic production and infrastructure construction that needs to be further unpacked in future research to demonstrate the long-term water-management practices of this region and their relationship with environmental changes and social evolution.
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