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Interaction, Fragmentation, and Resilience: Rethinking Collapse in the Longshan World

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by

Zichan Wang

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ABSTRACT OF THE DISSERTATION

Interaction, Fragmentation, and Resilience: Rethinking Collapse in the Longshan World

by

Zichan Wang

Doctor of Philosophy in Archaeology

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Professor Lothar von Falkenhausen, Co-Chair

Professor Min Li, Co-Chair

This dissertation reconceptualizes the Longshan Transformation (ca. 2400–1800 BCE) as a multi-scalar, network-driven process that reshaped North China at the end of the Neolithic. Rather than a uniform "collapse" triggered by climate change, the transformation is interpreted as a regionally diverse reconfiguration produced by the interplay between local developments and intensifying interregional connectivity. Using settlement pattern analysis, ceramic and mortuary data, and social network analysis (SNA), this study investigates the pace, variability, and systemic implications of these changes at both transregional and site-specific scales.

At the macroregional level, the dissertation reassesses the climatic and subsistence conditions of the late third millennium BCE. While climatic instability and food stress occurred in places, Chapters 1–2 show that neither pattern aligns consistently with the timing or geography of societal decline. Chapter 3 synthesizes settlement surveys across multiple basins and demonstrates that the Longshan Transformation unfolded not as a single synchronous collapse but as a sequence of regionally staggered contractions and reorganizations spanning roughly two centuries.

The second half of the dissertation focuses on Taosi in the Linfen Basin. Chapter 4 traces shifts in ceramic production and mortuary practice, documenting a movement from diverse, elaborated repertoires to more standardized, Highland-oriented forms. Elite strategies likewise shifted from conspicuous feasting and prestige goods to ritual performances involving animal and human retainers. Quantitative analysis of grave assemblages confirms a broader transition from material display to ceremonial authority. Chapter 5 applies SNA to elite interaction networks, revealing Taosi's changing position: early centrality, shared prominence with Shimao in the Middle Phase, and subsequent decentralization in the Late Phase. Despite fluctuations in centralization, overall connectivity remained high. I argue that this dense interconnectivity—initially a catalyst for cultural florescence—also magnified local disruptions into macroregional crises, producing the Longshan Transformation as a network-wide phenomenon.

This dissertation advances three conclusions: (1) climate and subsistence stress were contributory but not primary drivers; (2) the transformation was regionally variable rather

than a uniform collapse; and (3) interregional interaction, functioning as a prehistoric form of globalization, generated both opportunities for sociopolitical complexity and systemic vulnerability.

The dissertation of Zichan Wang is approved.

Aaron A. Burke

Arlene Rosen

Lothar von Falkenhausen, Committee Co-Chair

Min Li, Committee Co-Chair

University of California, Los Angeles

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CURRICULUM VITAE

EDUCATION

MA. School of History and Culture, Shandong University, China, 2018.

BA. School of History and Culture, Shandong University, China, 2015.

PUBLICATION

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CONFERENCE PRESENTATION and Invited Lectures

August 2025. "Not a Sudden Collapse: Beyond Sudden Collapse: Reconceptualizing the Longshan-Erlitou Transformation based on Settlement Data. 10th Conference of The Society for East Asian Archaeology, Aberdeen, Scotland, UK.

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October 2023. "Selective Continuity of Material Culture and Role of Longshan Interaction Networks in Memory Preservation." Invited guest lecture in *Art and Material Culture, Neolithic to 210 BC*, UCLA.

May 2023. "Shamans and the Invisible Metal Workers in Early China: An Ethnohistorical Perspective," UCLA Center for Chinese Studies event: *Comparative Studies of Religious Communication and Political Power in Early Chinese and Mayan Civilizations*, Los Angeles, California.

April 2022. "An Integrated Approach to Migration and Power during the Longshan Period" (co-authored with Kirie Stromberg and Andrew MacIver), SAA 87th Annual Meeting, Chicago, Illinois.

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Introduction

The Longshan Era (2400–1800 BCE), variously referred to as the terminal Neolithic (e.g., Zhongguo 2010) or the Chalcolithic (e.g., Su 1991), immediately preceded the rise of China's first state in the Erlitou period (1800–1600 BCE). Toward its end, complex societies in the middle and lower Yellow River regions experienced widespread decline, manifested in social destratification, depopulation, site abandonment, fragmentation, and even destruction. The relative simultaneity and broad scope of these changes strikes many archaeologists as a sudden, macroregional "collapse."

This dissertation, however, reconceptualizes the phenomenon as a transregional, medium-term conjuncture lasting at least two centuries. Rather than a single catastrophic event, it consisted of a mosaic of regional disruptions that temporarily interrupted the longue-durée trajectory toward state formation. To examine this process, I explore, on the one hand, how an individual society transformed during the Longshan–Erlitou transition using Taosi—one of the most developed Longshan polities and a representative case of apparent "collapse"— as a case study, and on the other hand also propose hypotheses for why diverse polities across North China experienced drastic transformations at roughly the same time, through a relational, network-oriented perspective.

Before turning to these arguments, however, we must first ask: What does the so-called Longshan collapse entail? What archaeological signatures allow us to identify it? And what

concepts, theories, and methods are most useful for understanding it? This introduction briefly addresses these questions.

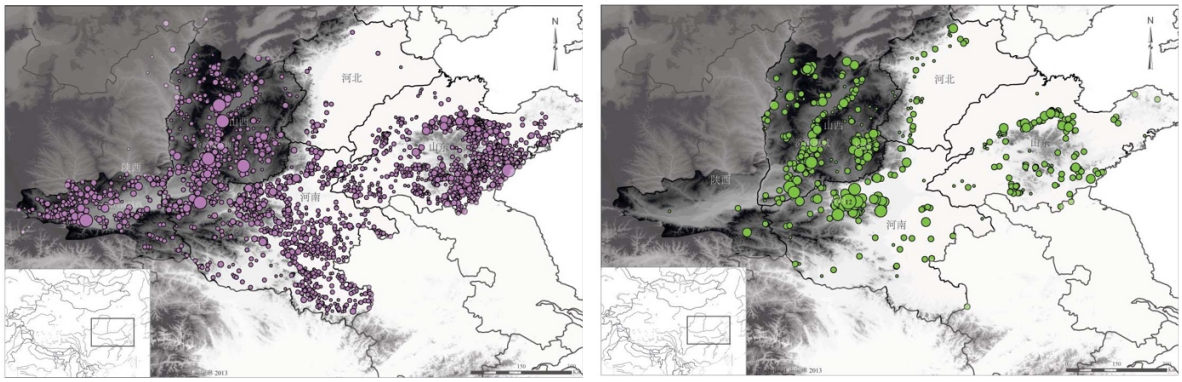
1. The Longshan "Collapse": an Overview of Archaeological Signatures

The Longshan "collapse" is generally characterized by a sharp reduction in settlement numbers, size, and density; the decline of craft production; the disappearance of elite cultural expressions; and, in some cases, the destruction of major landmarks. Below will briefly summarize the most frequently cited archaeological indicators of the collapse, while later chapters provide more detailed analyses.

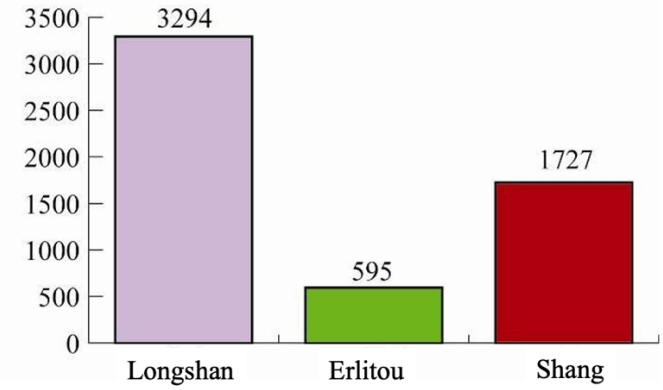
Settlement Decline

From the second half of the third millennium BCE to the first quarter of the second millennium BCE, settlement patterns underwent significant changes with considerable temporal and spatial variability. In the Lower Yangzi, occupation thinned markedly as early as 2450 BCE (Zhang et al. 2015), and by 2300–2200 BCE most Liangzhu sites had been abandoned (Renfrew and Liu 2018; Zhang 2021: 68). In the Middle Yangzi, the Shijiahe Culture began to decline around 2300 BCE as well (Zhang 2013). These developments collectively shifted the political center of gravity northward toward the Yellow River basin. In the middle and lower Yellow River regions, settlement numbers and densities reached an unprecedented peak during the last quarter of the third millennium BCE, followed by a sharp contraction in the first quarter of the second millennium BCE. The scale of this decline ranged from drastic—up to 90 percent in southern Shanxi—to moderate, with roughly one-third reductions elsewhere (see Chapter 3). By

contrast, settlements of the Qijia Culture in northwestern China (Flad et al. 2021) and those of the Lower Xiajiadian Culture in northeastern China (Chifeng 2011) remained stable or even expanded during the same period.



a. site distribution in the Longshan Era b. site distribution in the Erlitou Era



c. number of site count in Longshan, Erlitou, and Shang periods
(Sebillaud 2014: Appdendix 6, map 19 and map 20; P83, fig. 9)

Figure 1. Site distribution and number of sites between 2500-1000 BCE

This overview highlights the regionally divergent trajectories of settlement change: an early and pronounced decline in the Yangzi River region, a later contraction in the Yellow River basin, and continued stability or growth further north and west. It is the contraction of settlements in the middle and lower Yellow River region during the first quarter of the second millennium BCE that signals the Longshan Transformation. Data from the *Zhongguo Wenwu Dituji* (Atlas of

Chinese Cultural Relics) show that settlement numbers, size, and density in this region declined by an estimated 50–90 percent (Figure 1), reflecting major demographic contraction and/or social reorganization (Sebillaud 2014: 82). This pattern is corroborated by systematic regional surveys (Zhang 2017; Zhang 2018), which further demonstrate that the timing and intensity of decline varied from region to region. Further details are discussed in Chapter 3.

Discontinuity in Pottery Making Traditions

Ceramic production underwent dramatic discontinuity. High-fired black wares, which were characteristic of Longshan, were abruptly replaced in many regions by lower-fired, unevenly finished ceramics, suggesting poorer firing control. This was first observed at Dongxiafeng 东下冯 in southern Shanxi (Liu 1992), and comparable shifts appear in the Haidai 海岱 region (Jin and Zhao 1994; Luan 1992: 77-78; Zhang 1989)[1] and around Mt. Song 嵩山 (Zhang 2012: 175). While it remains debated whether these changes represent entirely new pottery-making traditions or a drastic transformation of earlier ones (e.g., Luan 1992 and Zhang 1989), scholars generally agree that the use of the pottery wheel decreased and that firing temperature became less stable.

[1] For different opinions, see Luan (1992) who argues that the Yueshi Culture in Shandong developed out of the local Longshan tradition. However, even under this interpretation, he acknowledges the reduced use of the pottery wheel in ceramic production.

"Disappearing" Elite Culture and Declining Social Differentiation

During Late Dawenkou 大汶口 and Longshan times, social inequality was clearly expressed through tomb size, construction, and grave goods. In contrast, many Erlitou-period cemeteries—especially those linked in the Yueshi 岳石 and Dongxiafeng Cultures—show diminished differentiation, suggesting weakened material displays of hierarchy. Yet this was not universal. The Dadianzi cemetery of the Lower Xiajiadian 夏家店 Culture exhibits clear stratification (Zhongguo 1998), while Erlitou burials also reveal distinctions in wealth and artifact categories (e.g., Xie *et al.* 2020: 312), even though the highest-ranking tombs have not yet been discovered. These regional variations highlight different paces of regeneration during this transitional era.

Destruction of Elite Tombs or Palaces

Unlike in other collapse cases worldwide, evidence of deliberate destruction is relatively rare in the Longshan case. At sites such as Taosi (Gao 2017; Zhongguo and Shanxi Sheng 2015), Qingliangsi (Shanxi Sheng *et al.* 2016), Xiajin (Shanxi Sheng and Shanxi 2022), and Yinjiacheng (Shandong 1990), elite tombs or palatial structures were damaged, but these incidents caused temporary disruption rather than total site abandonment.

Summary

The overview of the archaeological evidence indicates two characteristics of the Longshan collapse: broad geographical scale and clear regional variation. While changes in settlement, ceramics, and elite display occur throughout history, those marking the end of the Longshan Era are distinctive for their simultaneity and breadth across numerous polities. The challenge, then,

is to explain why so many communities in such a broad space experienced upheaval at roughly the same time. The following section outlines on what timescales we can understand the Longshan-Erlitou transition and explains how I conceptualize the Longshan collapse within the long-durée history of state formation.

2. Conceptualizing the Longshan Transformation: Events and Conjunctures and the Long-Term Process

2.1 The Longshan Transformation: Not a Short-Term Event

In the fourth edition of *The Archaeology of Ancient China*, K. C. Chang (Chang 1986: 234) points out:

> [T]he known regional prehistories show two developmental trends very clearly. The first is that all regional cultures in time became more extensively distributed and interaction between them was intensified, resulting, during the fourth millennium B.C., in a sphere of interaction that set the geographic stage for the first historical Chinese civilizations. The second trend is that each region's Neolithic cultures became increasingly complex, diversified, and stratified, socially and culturally, and this trend led to the foundation of the civilizations in these regions. The two trends were probably not unrelated.

Nearly forty years later, these observations still capture the essence of Late Neolithic China: a longue durée process of institutional change, in which rising social complexity and growing interregional networks paved the way for the formation of early states and the consolidation of a

Central Plains–centered core-periphery system in the Early Bronze Age (Li 2018; Liu and Chen 2003; Liu 2004; Tang 2018; Zhongguo 2003).

Within this long-term trajectory, the Longshan Era represented both the peak of Neolithic social complexity and connectivity and the beginning of their unraveling. By the early second millennium BCE, a landscape once marked by nearly a hundred walled polities had contracted dramatically, a pattern earlier scholarship described as the Longshan "collapse" (e.g., Li 2018: 176-179; Zhang 2017; Zhang 2018). The so-called Longshan collapse disrupted, but did not terminate, the broader movement toward state formation. Following this disruption, the long-term trend toward increasing social complexity quickly resumed in the Erlitou and Erligang periods.

The brief summary of archaeological evidence of the collapse above as well as the chapters follow suggest that the so-called collapse was not a monolithic process, but one of great regional diversity consisting of a series of regional upheavals. In other words, while earlier studies often cast the various changes during the Longshan-Erlitou transition as a sudden and eventful collapse, I conceptualize them as a medium-term conjuncture within the long-term trajectory of institutional change towards state formation. Therefore, I refer to this process as Longshan Transformation, instead of "collapse" to highlight the complexity of this process. Also, by adopting a tripartite framework of short-term events, medium-term conjunctures, and long-durée process, I hope to situate the Longshan Transformation in a flexible framework that allows us to see the varied timescales at which changes on different spatial scopes, in different social institutes, and in different geographical regions took place.

2.2 From to Collapse to Transformation: A Discussion on Terms

Current definitions of *collapse* vary significantly in perceiving what it was that collapsed (level of complexity, political organizations, ideologies, civilizations, etc.), how fast they collapse, or even whether "collapse" is applicable at all. Joseph A. Tainter (1988: 4) provides one of the most cited definitions of collapse, framing it as "a rapid, significant loss of an established level of sociopolitical complexity." In his systems-theoretical framework, complexity includes centralized institutions, specialized roles, economic networks, monumental architecture, and record-keeping. Collapse occurs when these features contract or disappear, often because the energy and resources required to maintain complexity exceed the benefits it yields. Tainter's model emphasizes internal structural pressures and diminishing returns as primary drivers and also explicitly emphasizes that the collapse he refers to is political.

Similarly, Timothy Earle, from a political-economy perspective, sees collapse as the failure of leaders to sustain control over economic resources and social. In *How Chiefs Come to Power* (1997), he argues that political authority is dependent on the ability to extract resources and redistribute them in a way that legitimizes power. Collapse ensues when these mechanisms falter, and leadership can no longer be justified or maintained.

Drawing from his work on the ancient Maya, Arthur Demarest (2011), also defines collapse as a political transformation, rather than the disappearance of entire populations or cultures. In addition, he emphasizes that political changes results from the structural problems in elite ideologies and integrative mechanisms. He focuses on the erosion of political and religious

institutions that once unified large territories. Demarest (*ibid*) emphasizes that collapse is often ideologically driven, manifesting in the loss of centralized control and legitimacy, even as local communities persist in altered forms.

Norman Yoffee and his colleagues challenge the utility of the term "collapse" altogether, arguing that it often oversimplifies complex historical processes. Drawing on sociologist Shmuel Eisenstadt's (1988) observation that true social collapse—defined as the complete end of political systems and their civilizational frameworks—is rare, Yoffee (1988a: 18) contends that the demise of states should be analytically separated from the persistence of civilizations. While he initially suggested Mesopotamia might be an exception (Yoffee 1988b: 46), he later revises this view in *Myths of the Archaic State* (Yoffee 2004: 153-154), emphasizing that Mesopotamian civilization endured through its language, rituals, institutions, and material culture—even under foreign rule. This perspective, which foregrounds resilience, transformation, and local agency over narratives of systemic failure, is further developed in *Questioning Collapse* (McAnany and Yoffee 2010: 10–11) and *The Evolution of Fragility* (Yoffee 2019), where he argues that while complex societies are inherently fragile, total collapse is exceedingly rare.

The variation in definitions of collapse reflects the complexity of understanding the phenomena broadly labeled as “collapse.” Given this complexity and the conceptual problems associated with the term, recent scholarship increasingly favors the use of “transformation” instead. This shift aims to highlight the diverse and multifaceted nature of what was previously framed as collapse, and to reframe such events as processes of negotiation, reinstitution, and

reorganization that occurred over relatively short periods of time (e.g., Faulseit 2016; Middleton 2017; Yoffee 2019).

I believe the term "transformation" more accurately characterizes the nature of the Longshan case and therefore adopt the term "Longshan Transformation" throughout this study. That said, I also use the phrase "Longshan collapse" when referring specifically to interpretations that view the Longshan–Erlitou transition as a sudden and eventful process, as well as to specific cases in which local political structures fragmented and came to an end in a deastic manner. By adopting transformation instead of collapse, I do not intend to downplay the severity of demographic decline and the reduction in social complexity during this period. There is no doubt that in many regions of the Longshan world, the transition was indeed devastating and marked by downward social change. Rather, by shifting from collapse to transformation, I aim to highlight that the Longshan case was complex—unfolding along diverse trajectories across different aspects of social life and in different regions—rather than representing a single, abrupt, and uniform collapse. This terminological shift is not merely semantic; it reflects a fundamentally different research approach. The distinctions between the "transformation" and "collapse" perspectives are discussed in greater detail below.

2.3 Different Approaches to the Longshan Transformation and the Longshan "collapse"

To see the Longshan-Erlitou transition as a collapse or a transformation also determines the research approach one takes. I categorize previous studies on the Longshan Transformation into *descriptive* and *explanatory* approaches. These two approaches are not mutually exclusive; in

most cases, explanation is built upon fine-grained description, and descriptions are often provided with the intent of interpreting the phenomenon. Nevertheless, there are discernible differences between the two approaches.

The descriptive approach has increasingly emphasized the regional variation within the so-called Longshan "collapse." For example, Sebillaud (2014) divides the Central Plains into ten macroregions and separately delineates the settlement history in the Longshan, Erlitou, and Shang periods in each region. In these ten macroregions, built upon the settlement data retrieved from the National General Surveys, she identifies five different patterns of change based on the level of complexity of the Longshan settlement system of the region under discussion and whether the declining trend continued uninterruptedly from Erlitou to Shang. Zhang Chi (2017), for another example, based on regional systemic survey results reveals except for the Yiluo 伊洛 region, all other regions in the Central Plains declined during the Longshan Transformation while the areas on the Crescent-Belt (defined by Tong Enzheng [1987]) flourished at the same time. In general, descriptive research is typically conducted at a trans-regional scale and is more sensitive to local historical differences and the complexity of change processes (Sebillaud 2014; Shelach and Jaffe 2014; Xu 2001; Zhang 2017; Zhang 2018).

As a result, these studies tend to interpret the transition from Longshan to Erlitou as a complex *transformation* rather than a straightforward collapse. Through descriptions of how societies were constructed and how power was consolidated, research that adopts a descriptive approach often views the "collapse" of a society as the result of inherent flaws in its strategies of

power consolidation—what Resilience Theory would describe as *path dependence* (for the definition of path dependence and its potential application in archaeology, see Hegmon 2017).

The interpretive approach aims to identify causality to the Longshan collapse. These studies are conducted at multiple scales—from regional to macroregional and transregional levels. The explanatory frameworks typically focus on factors such as global climate change (Guo *et al.* 2014; Liu and Feng 2012; Sun *et al.* 2017; Yu *et al.* 2000) and the frequent flooding events associated with the climate change (Gao 2015; Huang *et al.* 2010; Huang *et al.* 2011; Yuan 2000; Xia and Yang 2003; Xia *et al.* 2004;), warfare and conflict (He 2017; Xiaoyi Wang 2018; Han 2020), internal turmoil (Li 2019), as well as pandemic (Zhang 2017: 56). While this approach offers valuable insights when applied to specific case studies, it becomes less effective when it attempts to identify a single overarching cause capable of explaining the collapse of the entire Longshan world. No single factor adequately accounts for the considerable regional variability within this broad cultural sphere. Moreover, the search for one definitive cause—whether envisioned as a broad-scale driver or as the initial "domino" in a chain reaction—ultimately limits the explanatory power of the interpretive approach.

This interpretative and descriptive approaches should complement one another. Proposed causes—whether climate change, local environmental shifts, and the rise or fall of competing polities—each possess their own dynamic histories. These should be examined in tandem with the transformation of the complex societies under study in order to understand the interactions between these parallel historical trajectories. Only through this integrated perspective can we

construct a meaningful descriptive narrative capable of interpreting the complexity of sociocultural change.

3. **Theories**

When we disaggregate the Longshan Transformation into a series of regional events occurring at different times and across varied temporal and spatial scales, it becomes clear that this phenomenon demands a research framework capable of moving fluidly between site-specific or regional case studies and large-scale, transregional analysis. Such a framework must also allow for the integration of observations across different scales into a complex and interconnected system.

Systems theory, as introduced by Renfrew (1984) in his *Approaches to Social Archaeology*, Resilience Theory (RT) (Gunderson and Holling 2002; Holling 1973; Holling and Gunderson 2002; Walker 2012), and the theoretical contributions of the Annales School (Braudel 1966; 1979) are particularly useful in both disaggregating and synthesizing the multi-scalar changes associated with the Longshan Transformation. While each of these theoretical approaches has its own disciplinary origin and history, it would be beyond the scope of this dissertation to review them in full. However, what is rarely addressed in existing literature is the way in which these three frameworks intersect and complement one another. The following section aims to demonstrate that, despite their disciplinary differences, these theoretical traditions share a common foundation in systematic, multi-scalar thinking, making them especially well-suited for understanding complex processes of social change such as the Longshan Transformation.

3.1 Resilience Theory and Systems Theory

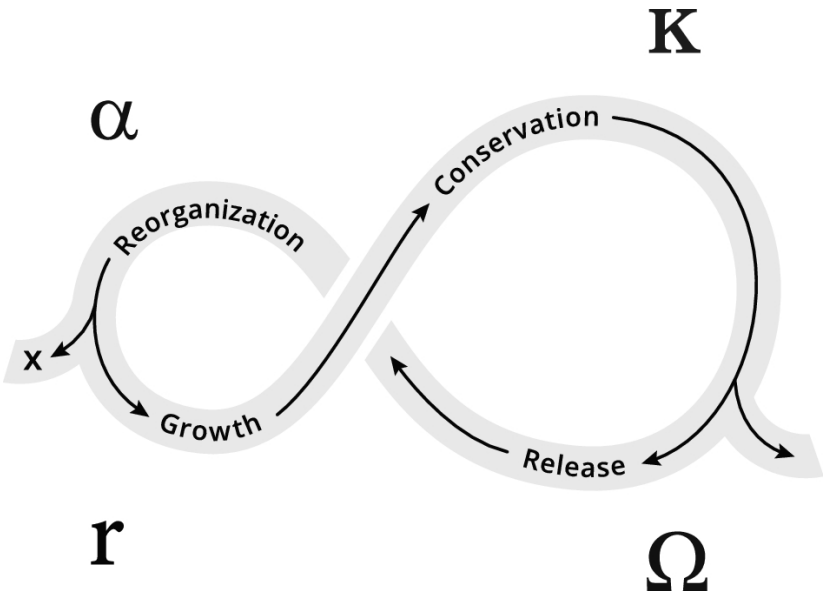
Rooted in structural-functionalism, the *general systems theory* assumes that an entire system could be understood if one identified its different parts and relations between them (for a brief history of general systems theory, see Davis 2024). General systems theory aligns with the processual movement in its pursuit of quantifiable, generalizable patterns about the past through the study of archaeological materials, aiming to uncover the mechanisms of past human societies (Flannery 1972; Thomas 1972; Watson *et al.* 1971). Later, with the emphasis on the distinction between emic and etic perspectives as well as the historicity and particularity of individual cases, scholars increasingly turned to complex systems theory. This framework views complex systems—as defined by Ladyman, Lambert, and Wiesner (2013: 57), "an ensemble of many elements which are interacting in a disordered way, resulting in robust organization and memory"—as complex, adaptive and historically situated. By emphasizing the complexity inherent in the system, the complex systems theory calls for a historical and multiscalar perspective and analytical flexibility to engage with different levels of the system.

RT is a common framework in the complex systems theory (Holling 1973; Redman and Kinzig 2003; Walker *et al.* 2004; Bradtmöller *et al.* 2017). Since RT is rooted in complex systems theory, a separate discussion of their overlap would be redundant. In the following review, therefore, systems theory specifically refers to the general systems theory, while I focus the discussion on complex systems theory on RT as an operational framework. While it has been pointed out that the popularity of complex systems theory was gained at the post-processual

turn (Davis 2024), as many scholars have noted, the distinction between processualism and post-processualism constitutes a false dichotomy (e.g., Hegmon 2003; Bentley and Maschner 2017). Similarly, I argue that general systems theory—as advanced by processualists such as Renfrew and Flannery—shares significant common ground with the RT in complex systems theory and both compatible with the *Annale* temporality.

At their core, both systems theory and RT view systems as dynamic, nonlinear, and composed of interdependent components. They challenge linear, deterministic models of change, instead embracing complexity, feedback loops, and emergent properties. Systems theory has its roots in cybernetics and engineering, and a central idea is *homeostasis*—the tendency of systems to maintain stability through self-regulation in response to internal and external changes (Renfrew 1984: 249). Renfrew characterizes *negative feedback* as the phenomenon that systems strive to return to a state of equilibrium after disturbance (Renfrew 1984: 265) and he terms *positive feedback*, following Kent Flannery (Flannery 1968: 80) as the "self-catalyzing" situation where "the faster a reaction is taking place, the faster its rate increases (Renfrew 1984: 273). In contrast to negative feedback, which could be understood as reactions to exogenous changes, positive feedback shifts focus on the inherent and internal motivation for cultural development: a small deviation from the habitual and regular tradition could lead to substantial changes or even transformation as the deviations could be amplified through processes such as "vicious circles" and "compound interest" (Renfrew [1984: 266] borrowed the terms from Maruyama [1963: 64]).

RT—emerging from ecological science, particularly through the work of C. S. Holling (originally in 1973)—similarly investigates the capacity of systems to absorb disturbances and adapt without collapsing into qualitatively different states. This is also the definition of *resilience* (Holling and Gunderson 2002: 28). In this sense, the concept of resilience is comparable to Renfrew's negative feedback. While RT considers resilience as being an inherent function of a system, it also perceives that systems may have multiple stable states, and crossing a threshold can result in a fundamental reorganization of the system (Holling 1973; Gunderson and Holling 2002; Walker *et al.* 2004).



Originally illustrated by Holling and Gunderson (2002: fig. 2-1)
and restylized by Sundstrom *et al.* (2023: fig. 2)

Figure 2. A stylized representation of the adaptive cycle

Compared to systems theory, RT emphasizes that systems are often not in equilibrium but instead undergo phases of growth, accumulation, collapse, and reorganization (Gunderson and Holling 2002). The four phases are integrated in the *adaptative cycle* (Figure 2). The adaptive

cycle framework emphasizes that systems respond to shocks or stresses not merely by returning to a previous stable state, but by potentially transforming into an entirely new regime. The concept of resilience, therefore, differs from the traditional notion of negative feedback, which assumes that systems tend to return to their original equilibrium after disturbance. Instead, resilience theory highlights that the outcome of absorbed changes may be the emergence of a new equilibrium, rather than a restoration of the previous one.

Rather than categorically labeling the tendency to maintain stability or to amplify change as positive or negative feedback, RT does not explicitly distinguish between these effects in the same way. Instead, it emphasizes two key system capacities: adaptability—the ability to absorb change while maintaining the existing structure—and transformability—the ability to absorb change through structural reorganization (Walker *et al.* 2004). At its core, however, this dialectical view of balancing change and stability is conceptually similar to the framework found in systems theory, highlighting a shared interest in how systems manage disturbance and persist or evolve over time.

Another significant overlap is in the study of social-ecological systems (SESs). Both systems theory and RT emphasize the interaction between and the integration of human society and the environment and criticize the dichotomy between human beings and the natural environment (e.g., Renfrew 1984; Redman and Kinzig 2003; Folke 2006a). Together, they shift the paradigm of human-ecological systems research from a mono-scalar, reductionist, and linear approach that neglects complexity and unpredictability to a multi-scalar, holistic, and non-linear framework. This new approach emphasizes the exploration of complexity, webs or networks of

relationships, rather than relying on strong causality within a predictable, chain-like model (Müller and Li 2004).

Although the two theories are similar in their conception, systems theories are usually more commonly adopted by scholars whose focus are on the social, cultural, and political changes in a given society (e.g., Watson, LeBlanc, and Redman 1971; Flannery 1972; Renfrew 1984), where those who adopt RT have more heavily focused on the ecological system and resource management (Nelson *et al.* 2007; Gil-Romera *et al.* 2010; Butzer 2012; Butzer and Endfield 2012; Lentz *et al.* 2018). That said, in most cases, the overlaps outweigh the differences when exploring the complexity and integration of human-ecological systems.

3.2 Resilience Theory and the Long-term Social History in Annales School

Resilience Theory and the long-term social history approach of the Annales School (particularly as developed by Fernand Braudel [1972; 1979]) share several intellectual affinities, especially in their rejection of event-centered history and in their embrace of deep, structural change over time. Although they originate from different disciplines—ecology and history, respectively—they converge in important ways when applied to the study of long-term human dynamics, especially in archaeology, environmental history, and socio-ecological systems research.

Central to both approaches is a focus on the diversity of temporal scales through which a case study could be viewed. Braudel's famous tripartite model distinguishes between *l'événementiel* (short-term events), *la conjoncture* (medium-term cycles), and *la longue durée*

(long-term structures such as geography and social institutions) (Braudel 1972). Resilience Theory similarly considers time through the lens of the adaptive cycle as discussed above. These cycles unfold over varying time scales and are often embedded within one another (panarchy, see below). In both frameworks, slow-changing structures play a crucial role in shaping the conditions under which faster processes occur.

The multi-scalar point of view is best captured in the notion of "panarchy" (Gunderson and Holling 2002). Panarchy in resilience theory refers to a framework of nested adaptive cycles operating at different scales and speeds, where changes at one level can influence others through cross-scale interactions (Holling, Gunderson, and Peterson 2002: 74–75). For example, the *revolt* dynamic refers to the situation where a smaller, faster system (e.g., a local crisis) triggers change in a larger, slower system by pushing it across a threshold (e.g., local unrest sparking regional collapse) (*ibid*) and the *remember* dynamic refers to the situation where a larger, slower system influences how a smaller, faster system reorganizes after disturbance—by providing stability, resources, or institutional memory (*ibid*: 76). With these concepts explained, the overlap between the RT and the Annales School becomes increasingly clear. As Holling, Gunderson, and Peterson wrote (2002: 76): "The fast levels invent, experiment, and test; the slower levels stabilize and conserve accumulated memory of past successful, surviving experiments. The whole panarchy is both creative and conserving." This understanding corresponds to the *longue-durée* perspective and the notion that long-term structures shed fundamental shaping effects on short-term and medium-term events and conjunctures.

3.3 Systems Theory and Braudel's long-term history

Systems theory, as introduced by Colin Renfrew, and Fernand Braudel's long-term historical approach within the Annales School share substantial intellectual ground, particularly in their focus on structure, process, and temporality. A key convergence lies in their shared emphasis on structure over events. Braudel critiques historians for paying exclusive attention to traditional event-driven history (*l'histoire événementielle*), advocating instead for the study of geography as the setting that shapes historical trajectories, along with slow-moving forces such as demography, and institutional frameworks (Braudel 1972). Similarly, Renfrew (1984) uses systems theory to shift archaeology toward a processual approach, employing models of inputs, outputs, feedback loops, and equilibrium to investigate the internal dynamics of ancient societies. Both approaches highlight how long-term structures underpin short-term developments. Since the 1980s, scholars have been advocating the application of Annales' methodology to archaeology and suggests that such methodology could situate processual and post-processual archaeology as well as history and prehistory in complementarity (Bintliff 1991; Knapp 1992; Peebles 1971 and 1991; Snodgrass 1991).

Their treatment of time as multi-layered further aligns the systems theory and *Annales*. Braudel's tripartite model—events (short-term), conjunctures (medium-term), and *la longue durée* (long-term structures)—offers a framework for understanding historical rhythms. Renfrew's systems thinking likewise accounts for processes operating on different temporal scales, allowing short-term changes to be contextualized within broader, slower-moving

transformations. Scholars adopting complex systems theory more explicitly highlights the intersection between various levels of organization, spatial scopes, and temporal scales as highlighted in the discussion of panarchy (for reference, see above).

Finally, both theories model interconnected social and economic systems. Braudel's *Civilization and Capitalism* (2004) implicitly adopts a systems view, tracing flows of goods, labor, and capital across regions over centuries. Though he did not formalize these relationships mathematically, the logic of interrelated subsystems parallels Renfrew's formal modeling of early state formation and social complexity. In both cases, society is conceptualized as an integrated whole shaped by systemic interdependencies.

In summary, Braudel and Renfrew converge in their structuralism, their interest in long-term processes, and their multi-scalar understanding of time and change. Braudel provides a historical framework for interpreting enduring societal patterns across centuries, while Renfrew offers formal tools to model those dynamics in archaeological contexts. Both approaches illuminate the deep forces shaping human history and offer valuable perspectives for understanding complexity, transformation, and continuity in the human past. Situating the Longshan Transformation in the multi-dimensional theoretical frameworks above, I move interactively between the transregional survey of the Longshan world and fine-grained analysis of site-specific transformative history.

3.4 Social Network Analysis: Viewing Complex Systems through a Relational Perspective

The three groups of thoughts mentioned abvoe—resilience theory, systems theory, annale school—adopt comprehensive approaches to studying complex systems and are well suited to understanding both the overall system and individual societies, though in practice they are more often applied to individual polities or regional systems. Social Network Analysis (SNA), by contrast, emphasizes the relational structures within a complex system, making it especially suitable for examining the Longshan world where individual communities were highly interconnected. Again, I do not wish to fully cover the research history of SNA but focus on highlighting how it overlaps with other complex theories that have been introduced above.

SNA is best understood not as a unified theory but as a relational orientation within sociology (Emirbayer 1997; Emirbayer and Goodwin 1994). It provides vocabularies, measures, and analytic tools that can be integrated with diverse theoretical frameworks without being confined to any single paradigm. In this sense, SNA is a flexible, theoretically informed method that operationalizes relational sociology and offers new insights into the structure and dynamics of social systems (Scott 2017: 6-8). Increasingly applied in archaeology, SNA is particularly valuable for analyzing the Longshan network. Rather than treating actors as isolated units, it focuses on ties of kinship, exchange, communication, or conflict, shifting attention from individual attributes to connections and positioning networks as the key medium through which social complexity emerges (Wasserman and Faust 1994).

Borgatti *et al.* (2009: 892-893) observes that in line with Durkheim's view that the causes of social regularities lie not in individual intentions but in the structure of social environments, network analysts emphasize that system behavior emerges from patterned interactions rather than from the properties of constituent actors. Networks generate emergent properties such as clustering, density, centralization, and modularity, which condition processes of cooperation, innovation, and inequality. For example, small-world networks—characterized by both high clustering and short path lengths (Watts and Strogatz 1998)—demonstrate how relational structure can yield system-level efficiency not predictable from individual ties alone (Borgatti *et al.* 2009; Watts and Strogatz 1998).

Networks also provide a means of conceptualizing the multiscalar nature of complex systems. Under a relational perspective, transregional research can proceed not only in a *comparative* manner, identifying similarities and differences among the objects of study, but also through a *connective* approach, examining how mobility and connectivity reshape social relations and contribute to changing forms of social complexity. Social relations are often nested—households within communities, communities within polities, and polities within interaction spheres—and SNA allows researchers to map both the cohesion of these nested structures and the bridging ties that connect them. This relational approach foregrounds the importance of multi-level networks and cross-scale interactions, central to both resilience thinking and archaeological accounts of sociopolitical organization (Brughmans 2010; Mills *et al.* 2013).

A relational perspective also highlights how resilience and transformation depend on the configuration of ties. System robustness is reinforced by redundancy, diversity, and flexible pathways of connection, while vulnerability often arises from over-centralization or the loss of bridging nodes (Borck *et al.* 2015). Collapse can thus be understood not simply as population decline or resource depletion but as the fragmentation or reconfiguration of relational patterns, while transformation corresponds to the emergence of new clusters, hierarchies, or modes of interaction (Janssen *et al.* 2006; Peeples 2018).

In sum, whether focused on the attributes of individual parts of the system or on the relations between them, these theoretical perspectives help conceptualize the Longshan world as a complex system that transverse multiple time scales and contains voluted internal relations. The changes took place at varied temporal and spatial scales, in unpredictable and nonlinear manners, with individual communities as well as with the relationships between different actors. Building on these approaches, I propose to unpack the Longshan Transformation according to the following outline.

4.**Chapter Outline**

As mentioned above, the rise and decline of polities are common throughout history, but not all changes are labeled as "collapse." What distinguishes the Longshan case is its breadth and relative simultaneity. Although each region manifests the transformation in a different way, across much of the Yellow and Yangzi River regions, walled settlements and village sites were abandoned, and distinctive material cultures transformed or disappeared around 1800 BCE.

While these shifts played out over two centuries—a substantial span in absolute terms—their overlap across diverse regions created the impression of suddenness and lent the transformation an exceptional character. This raises two guiding questions for the present study: (1) how did individual societies within the Longshan world reorganize themselves during this transformation, and (2) what factors account for the partial synchrony of these changes? Here, "synchrony" does not imply simultaneous events but rather broadly overlapping trajectories spanning two to three centuries. To address these questions, I use Taosi as a case study of polity-level decline and analyze the broader Longshan interaction network to explore the mechanisms of regional convergence.

Following this introduction, the chapter titled "Time and Space" outlines the temporal and spatial scope of this research and defines key terms used in the dissertation. The five body chapters then present transregional and macroregional surveys of different aspects of the Longshan Transformation. These chapters affirm both the broad scale and relative suddenness of the transformation, while also highlighting its regionality and temporal gaps within what may otherwise appear as a sweeping phenomenon.

Chapter 1 begins with climate change at the turn of the third to second millennium BCE, which has long underpinned environmental-collapse models of the Longshan Transformation and collapse studies more generally (Middleton 2012). It demonstrates the temporal and spatial variability of the 4.2 ka BP climate event during the Longshan Era and explores its possible correlations with cultural change in the archaeological record.

Chapter 2, Food (In)security, builds on this discussion of climate. Climate-driven hypotheses often assume that climate change impacted human societies primarily through agricultural failure and resulting food insecurity. To evaluate this assumption, the chapter surveys faunal, floral, and human skeletal evidence for dietary stress. The results indicate that existing evidence does not substantiate claims that the Longshan collapse was triggered by food scarcity. Thus, the common but rarely tested idea that climate change led to societal collapse via agricultural failure cannot be confirmed in this case.

Chapter 3 turns to settlement data, further elaborating the regional nature of the Longshan Transformation. Whereas past research often characterized the collapse as a sudden, uniform phenomenon, this chapter—drawing on systematic survey data from Shandong, Shanxi, and Shaanxi—demonstrates that it was instead a long-term, multi-scalar, and multi-staged process. The transformation began in the Late Longshan Phase around 2000 BCE, peaked at the end of the Longshan Era, and in some regions continued through the Erlitou (1900–1600 BCE) and Erligang (1600–1200 BCE) periods. Moreover, rather than a single monolithic collapse, it consisted of a series of regionally distinct transformations over roughly two centuries. Each region followed its own trajectory—whether population dispersal, concentration, restricted mobility, or monument destruction—each reflecting different sociopolitical changes.

This transregional survey of climate, food security, and settlement change sets the stage for the case study of the rise and fall of the Taosi polity in the Linfen Basin of the Jinnan region, one of the most representative examples of the Longshan collapse. Chapter 4 examines ceramic traditions to trace shifts in cultural affiliation and mortuary practices that reveal changing

strategies of value and status construction. The analysis shows that Early and Middle Taosi elite mortuary practices rested on two pillars: the reconstruction of feasting scenes and the display of elites' ability to connect to the broader Longshan network. In the Middle Phase, the latter became increasingly important, reflecting strategic responses to deeper involvement in transregional networks and the growing cultural and demographic diversity within Taosi. In the Late Phase, amid internal crisis and the decline of the Longshan network, mortuary practice shifted from affirming the deceased's status to facilitating power negotiation among the living.

While Chapter 4 focuses on site-specific transformations, Chapter 5 shifts back to the transregional scale, employing a relational and connective perspective to reconstruct the broader social network in which Taosi was embedded. Using Social Network Analysis of the circulation of prestige goods, the chapter shows that from Early to Late Taosi the Longshan network became less centralized yet more resilient, while remaining highly connected throughout. This high degree of connectivity allowed local disturbances to be transmitted and amplified, contributing to the scope and relative abruptness of the Longshan Transformation.

The Conclusion summarizes the revisions this project proposes to the conventional narrative of the Longshan "collapse" and connects the series of transformations observed at Taosi with the broader transregional network. It explores how transregional dynamics interacted with regional developments, reconstructing a multi-scalar narrative of the Longshan Transformation. By integrating site-specific changes with network-wide shifts, the conclusion offers a comprehensive interpretation of how localized processes and broader structural transformations were deeply interconnected.

Time and Space

1. Time

1.1 The Longshan Era

The definition of the "Longshan Era" and similar concepts has gone through constant refinement. Yan Wenming introduced the concept of the "Longshan Era" in 1981. Named after the Shandong Longshan Culture, this term designated the period during which most archaeological cultures in the Yellow and Yangzi River regions coexisted with the Shandong Longshan. Yan included the Shandong Longshan, Hougang II, Zaolütai, Wangwan III, Keshengzhuang II, Guihuashu III (roughly equivalent to what we call the Shijiahe Culture now), Liangzhu, and early Qijia cultures (Yan 1981). By analyzing the local trajectories of how each of these Longshan Era cultures originated, he in fact constructed three horizons—the Dawenkou-Miaodigou II horizon, the Longshan horizon, the Erlitou-Yueshi. He further emphasized that the various archaeological cultures of the Longshan Era maintained diverse contact with one another. Given such shared contact, Yan suggested that the time during which thease archaeological cultures occupied shall be named the Longshan Era.

Similar, K. C. Chang (1986: 238) conceptualized the "Longshanoid horizon" as "a spatial integrating device crosscutting a number of regional sequences," highlighting the similarities in material culture that resulted from interaction among different communities and regions. Although each region had its own developmental trajectory and cultural tradition, they became

increasingly similar through intensified inter-community and interregional exchanges within and between interaction spheres.

The Longshanoid horizon describes the phenomenon where multiple regions share similar traditions and the archaeological cultures in these regions formed and ended around the same time. Based on the radiocarbon data then available and ceramic similarities, Chang (*ibid*) proposed that the Longshanoid horizon had formed by the mid-fourth millennium BCE. He viewed it as encompassing the Shandong Longshan Culture, the Liangzhu Culture, various middle Yellow River Longshan traditions (including the Meishan, Hougang II, Wangyoufang, Keshengzhuang, and Taosi cultures), as well as the Qijia Culture and the Qinglongquan (now generally referred to as Shijiahe) Culture.

These two schemes laid the foundation for our understanding of the Longshan Era—emphasizing contemporaneity, interaction, and the resultant similarity in material culture—but further revisions are still needed. During the 1980s, both Chang's and Yan's schemes assumed that the Liangzhu Culture overlapped with the Shandong Longshan Culture, which was the prevail understanding of the time (e.g., Wu 1989). However, subsequent research has altered this view. Luan Fengshi (2000) demonstrated that while Liangzhu often coexisted with the Dawenkou Culture (the precursor to Longshan) at sites in northern Jiangsu, it never coexisted with Longshan itself. This indicates that Liangzhu was contemporaneous with Dawenkou, but its temporal overlap with Longshan was minimal. In addition, improved chronological frameworks revealed that earlier phases of the Shijiahe Culture largely coincided with Liangzhu and preceded most Longshan traditions, while only the late Shijiahe and post-Shijiahe were

contemporaneous with Longshan cultures (for a recent synthesis of this issue, see Liu and Yi 2014). As a result, both Liangzhu and Shijiahe Cultures, although sharing similarities with the archaeological cultures in the middle and lower Yellow and Huai River valleys, should be excluded from the Longshan Era on chronological grounds, although various post-Shijiahe traditions should be considered part of the Longshan world.

In addition, the Shimao Culture in northern Shaanxi, knowledge of which was not available to Chang and Yan, has become increasingly visible with the discoveries of the past 20 years (e.g., (Sun *et al.* 2020a). Based on the similar ceramics it shares with the Taosi Culture and its numerical dates (2300-1800 BCE), the Shimao Culture should be seen as part of the Longshan Era.

As such, building upon Chang and Yan's original frameworks and the recent revisions by later scholars, I define the horizon of various Longshanian cultural traditions—including the Shandong Longshan 山东龙山 Culture, various post-Shijiahe 后石家河 cultures, Wangwan 王湾 III Culture, Hougang 后岗 II Culture, Sanliqiao 三里桥 Culture, Taosi 陶寺 Culture, Keshengzhuang 客省庄 Culture, Shimao 石峁 Culture, as well as the early stage of the Qijia 齐家 Culture as the *Longshan Era*.

It should be noted that in current scholarship, many researchers adopt a broader interpretation of the Longshan Era (e.g., Shao 2019; Yang 1984: 69; Zhang 2020: 107), which includes the cultural remains contemporaneous with the later phases in the Miaodigou II Culture, as these represent the transitional phase between the Yangshao and Longshan periods in the Central Plains. Under this broad definition, the period corresponding to the Late

Miaodigou II Culture (ca. 2500-2300 BCE) is referred to as the "Early Longshan," while the phase contemporaneous with the Shandong Longshan (ca. 2400–1800 BCE) is termed the "Late Longshan" (e.g., Dai 2022; Zhang and Zhao 2021).

To clarify, in this dissertation I employ the narrower definition of the Longshan Era, which excludes the Miaodigou II Culture. That said, the transition in pottery styles and settlement patterns from the Miaodigou II to Longshan periods was remarkably smooth in most regions. Moreover, the intensification of social stratification and interregional interaction—defining characteristics of the Longshan Era—had already begun during the Late Miaodigou II and Late Dawenkou phases. Therefore, it is important to bear in mind that the beginning of the Longshan Era, and the transition from the Miaodigou II/Dawenkou periods to Longshan, was not a clear-cut boundary but rather a gradual process.

Different regions entered the Longshan Era at different times. The Taosi Culture began around 2450 BCE (Zhongguo and Shanxisheng 2015: 114–115), and its Early Phase was in fact contemporaneous with the late phase of the Miaodigou II Culture. The Shandong Longshan Culture and the Wangwan III Culture began around 2400 BCE (for the dates of the Shandong Longshan Culture, see Zhongmei Lianhe Kaogudui 2016; Luan 2006: 410; for the dates of Wangwan III, see Zhang 2021: 112). Other Longshan cultures, such as Shimao (2300–1800 BCE; Sun *et al.* 2017), Sanliqiao (2200–1900 BCE; Dong 2020), various post-Shijiahe cultures

in Hunan and Hubei (2200–1800 BCE; Zhang 2021), and the Keshengzhuang Culture (2100–1700 BCE[2]) in southern Shaanxi, formed slightly later.

Similarly, the end dates of these cultures vary by region. The Taosi site was abandoned around 1900 BCE (Zhongguo and Shanxisheng 2015: 115), although other sites associated with the Taosi Culture may have persisted until approximately 1750 BCE (Zhongguo, Shanxisheng, and Yunchengshi 2015: 59). The Shandong Longshan Culture declined by 1800 BCE (Luan 2006). The Wangwan III culture ended at different time in different microregions. In the Middle Luo River, it is dissolved around 2000 BCE, and in other parts of the Zhengluo region, where the Wangwan III Culture was distributed, it ended around 1800 BCE (Zhang 2021: 116). The Keshengzhuang Culture ended sometime around 1700 BCE. The chronology of Shimao remains debated. However, recent consensus suggests that after its initial abandonment around 1800 BCE, the site was reoccupied by a different group and remained in use until approximately 1600 BCE, overlapping with the Erlitou Culture (ca. 1900/1750–1530 BCE; for further discussion on the chronology of Erlitou, see Xiashangzhou 2022) by about 200–300 years (Sun *et al.* 2020).

[2] The radiocarbon dates were collected and calibrated by the author. Previous studies have dated the Keshengzhuang Culture to 2400–2000 BCE (Liang 1994: 412) or 2600–2000 BCE (Zhongguo 2010: 581); however, almost all of the samples were charcoals, which could have introduced Old Carbon effects into the results. The radiocarbon dates presented here are based on more recent ^{14}C samples from the Shuang'an (双庵) (Beijing daxue et al. 2024) and Taiping (太平) (Zhongguo et al. 2025) sites. These samples consist of animal and human skeletons as well as annual plants, which should more accurately reflect the time of burial. The results accordingly suggest a much later chronological span for the Keshengzhuang Culture. This range, of course, is subject to revision as more radiocarbon data become available.

Given that most Longshan cultures began and ended within the range of 2400 to 1800 BCE, I use this range to define the span of the Longshan Era. However, it is important to emphasize that the numerical dates of the Longshan Era differ region by region, and the term may refer to distinct temporal frameworks depending on the local archaeological sequence.

1.2 Era, Period, and Phase

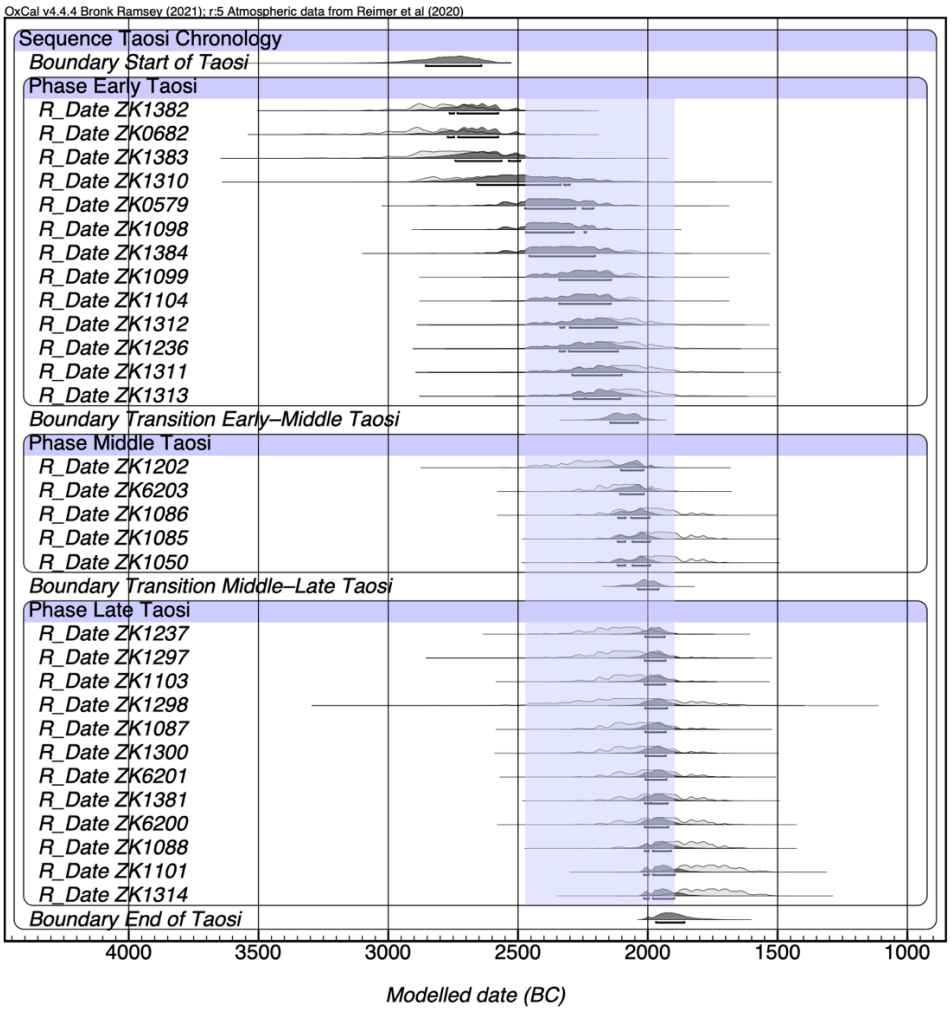
In this dissertation, I use the term "era" to refer to a *transregional horizon* comprising multiple archaeological cultures. The cultures associated with the Longshan Era have been listed above, while the Erlitou Era refers to a horizon that includes the Erlitou Culture, Dongxiafeng 东下冯 Culture, Yueshi 岳石 Culture, the later phases of the Qijia 齐家 Culture in the Yellow River, the Maqiao 马桥 Culture in the Lower Yangzi, and the Lower Xiajiadian 夏家店下层 Culture in northeastern China.

In contrast, I use the term "period" to refer to *regional* chronologies, such as the Taosi period for the Jinnan region, the Longshan period for the Haidai region, and the Qijia period for the Ganqing region. Each period is typically subdivided into phases. For example, the Taosi period is divided into Early, Middle, and Late Phases. In some cases, these phases can be further broken down into sub-phases, depending on the resolution of the archaeological data.

1.3 The Chronology of Taosi

As the focus of this dissertation, the radiocarbon dates for Taosi requires further elaboration. In 2004, He Nu published an influential paper discussing the pottery typology, periodization, and dates of the Taosi site. In this paper, he dated Early Taosi to 2300–2100 BCE,

Middle Taosi to 2100–2000 BCE, and Late Taosi to 2000–1900 BCE (He 2004). Later on, his research (He 2013: 256; 2018) was published in English and the dating scheme gained further publicity. As such, many scholars cite He's research and Anglophone scholarship almost exclusively references this dating scheme (e.g., Brunson 2015; Li *et al*. 2014; Li 2018; Tian 2022; Bai 2022; Graeber and Wengrow 2021: 325).



Calibrated by author

Figure 3. Radiocarbon dates from the Taosi site

The purple square highlights the calibrated time span covering 95.4% of the modeled posterior probability.

Such a dating scheme, however, has been disproven by recently published ^{14}C results. Figure 3 and Table 1 present the radiocarbon dates from the Taosi site. Only samples with clear contextual information—those that can be confidently assigned to specific phases—are included here, while four clearly anomalous dates have been excluded from the modeling. With sequential calibration that takes stratigraphic relationships into account, the results suggest that 95% of the modeled dates fall within the range of 2450–1900 BCE. In other words, He's chronological scheme mistakenly shortens the temporal span of Taosi by pushing its starting date to 2300 BCE.

That means, the Early Taosi Phase is largely contemporaneous with the Late Miaodigou II Culture in the Yuncheng Basin, as He Nu himself noted based on ceramic evidence (He 2006: 164) and as other scholars have discussed (e.g., Dai 2019: 55, 57; Han 2006: 194; Wang 2017: 39). Based on the strong similarities in ceramic styles (see Chapter 5 for further discussion) and the radiocarbon data, it is reasonable to infer that the Early Taosi Culture in the Linfen Basin, the Late Miaodigou II Culture in the Yuanqu Basin, and the Late Dawenkou Culture in the western Haidai region were contemporaneous. As noted above, different regions entered the Longshan Era at different times.

A trickier question than determining the starting date of Taosi concerns the boundaries between its Early, Middle, and Late Phases. As the unmodeled dates in Table 3 indicate, the ranges of these three phases overlap substantially, making it difficult to define their boundaries precisely. As it would be impractical to procceed without these divisions, I tentatively propose the following ones: Early Taosi (2450–2200 BCE), Middle Taosi (2200–2000 BCE), and Late

Taosi (2000–1900 BCE). However, it should be noted that these boundaries are arbitrarily defined within a broad range derived from statistical modeling.

Table 1. Radiocarbon dates from the Taosi Site

Lab ID	Unclibrated (BP) [Half-life-5568]		Calibrated but unmodelled (BC) (68.3%)		Modelled (BC) (68.3%)		Material	Context	Phase	Source
			from	to	from	to				
ZK1051	4830	125	3764	3380	—	—	Human bones	M2001	Early	Zhongguo 1985: 654
ZK1296	4230	80	2915	2671	—	—	Lime plaster	H333	Early	Zhongguo 1985: 659
ZK1382	4220	80	2909	2671	2764	2577	Charcoal	H364	Early	Zhongguo 1986: 657
ZK0682	4253	90	3010	2670	2772	2577	Charcoal	H102④	Early II	Zhongguo 1980: 374
ZK1383	4170	115	2891	2584	2742	2492	Charcoal	H371	Early	Zhongguo 1986: 657
ZK1310	4000	140	2848	2301	2658	2301	Human bones	M2103	Early IIB	Zhongguo 1986: 657
ZK0579	3896	90	2475	2206	2473	2210	Charcoal	II T2③B	Early	Zhongguo 1980: 374
ZK1098	3896	70	2470	2238	2470	2238	Charcoal	II T1③B	Early	Zhongguo 1983: 648
ZK1384	3850	105	2466	2147	2457	2205	Charcoal	F324	Early	Zhongguo 1986: 657
ZK1099	3796	70	2396	2066	2341	2143	Charcoal	II T2③B	Early	Zhongguo 1983: 648
ZK1104	3796	70	2396	2066	2342	2143	Charcoal	H1102②	Early	Zhongguo 1983: 649
ZK1312	3750	85	2289	2033	2338	2119	Human bones	M2172	Early IIB	Zhongguo 1986: 657
ZK1236	3740	95	2292	1982	2340	2116	Human bones	M2092	Early III	Zhongguo 1985: 654
ZK1311	3710	95	2277	1958	2291	2101	Human bones	M2168	Early IIB	Zhongguo 1985: 654
ZK1313	3710	85	2276	1972	2287	2107	Human bones	M2180	Early IIB	Zhongguo 1986: 657
ZK1202	3780	70	2337	2047	2104	2018	Human bones	M2068	Middle	Zhongguo 1984: 649
ZK6203	3700	58	2197	1983	2107	2017	Animal bones	VT1Q6	Middle	Zhongguo, Shanxisheng, and Linfenshi 2025: tab. 4-1
ZK1086	3631	70	2131	1896	2115	1994	Charcoal	T422④D	Middle	Zhongguo 1983: 648
ZK1085	3601	70	2121	1829	2117	1992	Charred grains	T423④D	Middle	Zhongguo 1983: 648

ZK1050	3601	70	2121	1828	2117	1992	Charcoal	H420	Middle	Zhongguo 1985: 654
ZK1301	3200	160	1678	1265	—	—	Animal bones	H321	Middle	Zhongguo 1985: 654
ZK0681	3876	80	2464	2210	—	—	Charcoal	H302	Late	Zhongguo 1980: 374
ZK1237	3710	70	2202	1981	2012	1936	Charcoal	M3231	Late II	Zhongguo 1984: 649
ZK1297	3695	80	2200	1961	2012	1933	Charcoal	T312③B	Late	Zhongguo 1988: 659
ZK1103	3671	70	2141	1951	2011	1933	Charcoal	H1101④-⑥	Late	Zhongguo 1983: 649
ZK1298	3670	145	2286	1828	2011	1925	Charcoal	H318	Late II	Zhongguo 1988: 659
ZK1087	3656	70	2136	1944	2011	1932	Charcoal	H428	Late	Zhongguo 1983: 648
ZK1300	3650	75	2137	1933	2011	1931	Charcoal	M3338	Late	Zhongguo 1987: 654
ZK6201	3622	68	6201	1891	2011	1928	Animal bones	I T3④	Late II	Zhongguo, Shanxisheng, and Linfenshi 2025: tab. 4-1
ZK1381	3600	70	2121	1828	2012	1923	Human bones	M3453	Late	Zhongguo 1988: 659
ZK6200	3591	79	2118	1779	2012	1922	Animal bones	I T3③B	Late II	Zhongguo, Shanxisheng, and Linfenshi 2025: tab. 4-1
ZK1088	3540	70	2008	1751	2013	1910	Human bones	M3141	Late	Zhongguo 1983: 648
ZK1101	3456	70	1882	1687	2015	1900	Charcoal	H303⑧	Late II	Zhongguo 1983: 649
ZK1314	3450	75	1881	1641	2015	1876	Human bones	M3296	Late II	Zhongguo 1985: 654
Modelled Boundaries					from_95.4	to_95.4	Note: ZK1051 and ZK0681 fall earlier than the expected temporal window for their assigned phase, ZK1301 falls later, and ZK1296 derives from unsuitable material for radiocarbon dating. Accordingly, all four determinations were removed prior to sequential modeling.			
Early-Middle					2201	1993				
Middle-Late					2108	1938				

Based on the radiocarbon date ranges, we can now situate the Taosi Culture into the Longshan horizon in Table 2.

Table 2. Situating Taosi in the Longshan Horizon

<table>
<tr><th>14C Dates</th><th>Taosi</th><th>South of Zhongtiao Mountains</th><th>Central Plains</th><th>Central Shanxi</th><th>Shandong</th><th>Northern Shaaxi</th><th>Southern Shaanxi</th><th>Middle Yangzi</th><th>Lower Yangzi</th></tr>
<tr><td>2600</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="3"></td><td rowspan="8"></td><td rowspan="2">Late Dawenkou 大汶口 2600–2400</td><td rowspan="2"></td><td rowspan="3"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>2500</td><td rowspan="3">L.MDGII 2500–2400</td><td rowspan="3">ZS & ML remains (Note 3)</td><td rowspan="4">SJH</td></tr>
<tr><td>2450</td><td rowspan="4">Early Taosi</td><td rowspan="3">Late Xinghua 杏花 Culture 2500–1900</td></tr>
<tr><td>2400</td><td>MDG II 2400–2300</td><td rowspan="2">Early SLC 2400–2200</td><td rowspan="3">Keshengzhuang 客省庄 2400–1900</td><td rowspan="2">Late LZ ~2300/2200</td></tr>
<tr><td>2300</td><td rowspan="4">DG 2400–2200</td><td rowspan="5">WW III Cultures 2300–2000/1800 (Note 2)</td><td rowspan="3">Shimao Culture 2300–1800</td><td>QSY</td></tr>
<tr><td>2200</td><td rowspan="3">Middle Taosi</td><td rowspan="4">SLQ 2200–1900</td><td>Middle SLC 2200–2000</td><td rowspan="3">Post-Shijiahe cultures (2200–1800)</td><td rowspan="2">GFL</td></tr>
<tr><td>2100</td><td rowspan="2">Late SLC 2000–1800</td></tr>
<tr><td>2000</td><td>Late Taosi</td><td rowspan="3">Maqiao Culture</td></tr>
<tr><td>1900</td><td rowspan="3">Late Taosi (Note 1)</td><td rowspan="3">Baiyan Culture (Note 4)</td><td rowspan="3">Yueshi Culture</td><td rowspan="3">Zhuakaigou 朱开沟 (Note 5)</td></tr>
<tr><td>1800</td><td>DXF</td><td>XZ & ELT I 1820–1720</td></tr>
<tr><td>1750</td><td></td><td></td></tr>
</table>

Miaodigou 庙底沟 II Culture = MDG II; Wangwan 王湾 III=WW III; Dongguan 东关 Culture=DG; Sanliqiao 三里桥 Culture=SLQ Dongxiafeng 东下冯 Culture=DXF; Xinzhai 新砦 Phase=XZ; Baiyan 白燕 Culture=BY; Miaoliang 庙梁 remains=ML; Zhaishan 寨山 remains=ZS; Shijiahe 石家河 Culture=SJH; Xiaojiawuji 肖家屋脊 Culture=XJWJ; Liangzhu 良渚 Culture=LZ; Qianshanyang 钱山漾=QSY; Guangfulin 广富林 Culture=GFL; Shandong Longshan 山东龙山 Culture = SLC

Notes:
(1) The Taosi site was abandoned around 1900 BCE, but according to the date from the Zhoujiazhuang site, the Taosi Culture lasted until 1750 in the Yuncheng Basin (Zhongguo Guojia, Shanxi Sheng, and Yuncheng Shi 2015).
(2) The end date of Wangwan III culture varies region by region. In Zhengzhou, Ying River, and Rusha River, it ended around 1800 BCE, but in Luo River region, Wangwan III culture ended around 2000 BCE (Zhang 2021b).
(3) Shao (2019) identifies Miaoliang remains and Zhaishan remains as the pre-Longshan remains in northern Shaanxi and they represent the predecessor of the Shimao Culture. Based on stratigraphic evidence, there shouldn't be any gap between the ML-ZS remains and the Shimao Culture, but there are very limited 14C dates from the former, and thus its numerical date range is unknown.
(4) Baiyan Culture is named after the fourth phase of the Baiyan site. Yan Zhibin (1999) first suggested using the Baiyan Culture to label the Central Shanxi material culture of the "Xia" period. Later, Jiang Gang (2009) further articulated that the Baiyan Culture lasted well into the Shang period and ended in Early Western Zhou.
(5) The Shimao site appears to have been deserted around 1800, but it was soon reoccupied by another group, likely people who associated with the Zhukaigou Culture until 1600 BCE (Shaanxi Sheng *et al.* 2020).

2. **Space**

The following section begins with an introduction of the macroregional framework. I adopt a three-fold framework: Highlands, Lowlands, and the Central Plains.

2.1 Highlands and Lowlands

The broad geographical contrast between lowland and highland zones has proven analytically useful in archaeological research across both the Old and New Worlds (e.g., Feinman and Nicholas 2017; Glatz and Casana 2016; Marcus 1995; Walker 2012). In Chinese archaeology, in contrast to the long-standing emphasis on eastern China's lowland plains, Tong Enzheng (1987) introduces the idea of a "crescent-shaped region" encompassing mountainous areas that stretch from northeast China and the Korean peninsula, along the Tibetan Plateau, to southwest China. Jessica Rawson (2017: 376) refers to this zone as an "arc" of wide borderlands between the steppe and central China. It should be noted that political and cultural landscape changes over time and these two formulations are designed to understand the Bronze and Iron Age interregional interaction and state formation, not for the Longshan Era.

To address the cultural configuration of the Longshan Era, Li Min (2018: 116) defines the terms "highland" and "lowland" using the Taihang Mountains as a dividing line to highlight the dynamic cultural and political configuration during the Longshan-Erlitou transition. He defines "the highland Longshan society" as (*ibid*):

> [A] broad framework to address the interconnectedness, porousness, hybridity, and mobility of the Longshan communities in the vast region from the Taihang mountain range

to the western highlands, which were associated with the Laohushan culture in the northern loess highlands, the Xinghuacun culture in middle Shanxi, the Keshengzhuang II culture in the Guanzhong Basin, the Qijia culture in the western highlands, and the Taosi culture in the Jinnan Basin (Zhongguo 2010). Despite rich stylistic variations across the complex terrain of the loess highlands, there are enough shared traits among these regional traditions to characterize them as part of the material culture of highland Longshan society.

Li's concept of Longshan highland society signifies that Luoyang Basin—where the first state-level society, Erlitou, is located—served as a gateway between the highland and lowland societies and the rise of Erlitou brought the highland basins of Jinnan 晋南 (southern Shanxi), Guanzhong 关中 (in southern Shaanxi), and the western part of lowland plains into its political orbit, forming the historical notion of Central Plains. Jaang Li (2023), on the other hand, classified Jinnan and Guanzhong as lowlands, and thus conceptualizes Neolithic and Bronze Age China as *uplands* and *lowlands* to distinguish her geographical conceptualization from Li's Longshan high- and lowlands. In this sense, Jaang's concept of the upland is very similar to Tong's crescent-shaped belt and Rawson's Arc.

What is highlighted in these sets of scholarship is that the cultural high- and lowlands do not always align with the geographical ones, indicating that although cultural interactions are largely bounded by their geographical setting, they can break through such frames, and thus a more flexible understanding of the geographical configuration is required.



Map by author

Figure 4. Map of the Longshan world

Blue dotted line indicates the division between Highlands and Lowlands. Regions discussed in this chapter: I. Jinnan; II. Zhengluo; III. Haidai; IV. Ordos; V. Ganqing; VI. Middle Yangzi; VII. Lower Yangzi.

In this dissertation, I adopt *Highlands* and *Lowlands* not purely as terrain-based concepts but also represent shifting cultural affiliations over time. The Highlands and Lowlands are roughly divided by a diagonal line stretching from the Greater Khingan Mountains in Inner Mongolia, through the Taihang Mountains along the edge of the Loess Plateau, to the Wu Mountains in central China, and then to the eastern margin of the Yungui Plateau. (Figure 4). To the east lie the *Lowlands*: expansive plains and coastal regions with some hilly margins. To the west of this line lie the *Highlands*: a region dominated by mountains, plateaus, steppes, and deserts, interspersed with isolated basins and valleys. The Highlands served as connective zones

between the Lowlands of China and wider Eurasian interaction networks to the west (Rawson 2017; Li 2018; Jaang 2023).

Under this scheme, Jinnan and the Guanzhong Basin are geographically located on the highlands, although their cultural affiliation changed over time. Around 2200 BCE, the Jinnan region, located near the dividing line, shifted from a Lowland cultural association to a Highland one around the Middle Phase (Chapter 4), coinciding with the expanding influence of Highland cultural traditions. The Guanzhong Basin, throughout the Longshan Era is a Highland community, although at the turn to the Erlitou Era, its material culture manifested more and more Lowlands influence.

It is important to emphasize that Highlands and Lowlands, as used in this dissertation, are not purely geographical categories. Rather, they represent social distinctions, grounded in differences in economic practices and religious systems. To distinguish these cultural designations from generic topographical terms, I capitalize "Highlands" and "Lowlands" throughout the text.

2.2 The Central Plains

The concept of "Central Plains" is not a fixed one; rather, it changes overtime along with the dynamic power relations between core and peripheries (following Wallerstein's definition) and the "Central Plains" are historically viewed as the core. The Central Plains under this definition emerged only during the Erlitou Era, where a Luoyang-centered political system came into being (Li 2018). In the following Shang and Zhou periods, political centers moved back and forth

among central Henan, northern Henan, and southern Shaanxi. These regions together formed the Bronze Age Central Plains.

During the Longshan Era, however, there was no single center, but there were multiple political and demographic centers in the Yellow and Yangzi regions. Also, the communities in the Central Plains present very little evidence for elaborated elite culture or clear signs for social stratification (Liu 2004; Zhang 2021: 356-357). As such, the concept of Central Plains does not apply to the Longshan Era. That said, habitually, scholars still use the term for this period to refer to the aforementioned region. We should understand it as a pure geographical term, without any political implication during this time. In the Bronze Age, the Jinnan region—where Taosi is located—was considered part of the broadly defined Central Plains. During the Longshan Era, however, it remained independent from the Central Plains, though frequent cultural contacts connected the two regions.

Where exactly is one to locate Central Plains in the Erlitou Era? In the narrow sense, the Central Plains refer to the regions in the south and north of the Song Mountains (Figure 5). In a broader sense, the Central Plains refers to the region encompassing western Henan, southern Shanxi, southern Shaanxi, and western Shandong (Figure 4).

2.3 Regions and their Archaeological Cultures

Again, this dissertation crosscuts different spatial scales. The smallest scale concerned here is individual archaeological sites, which is often discussed in relation to the changes in its

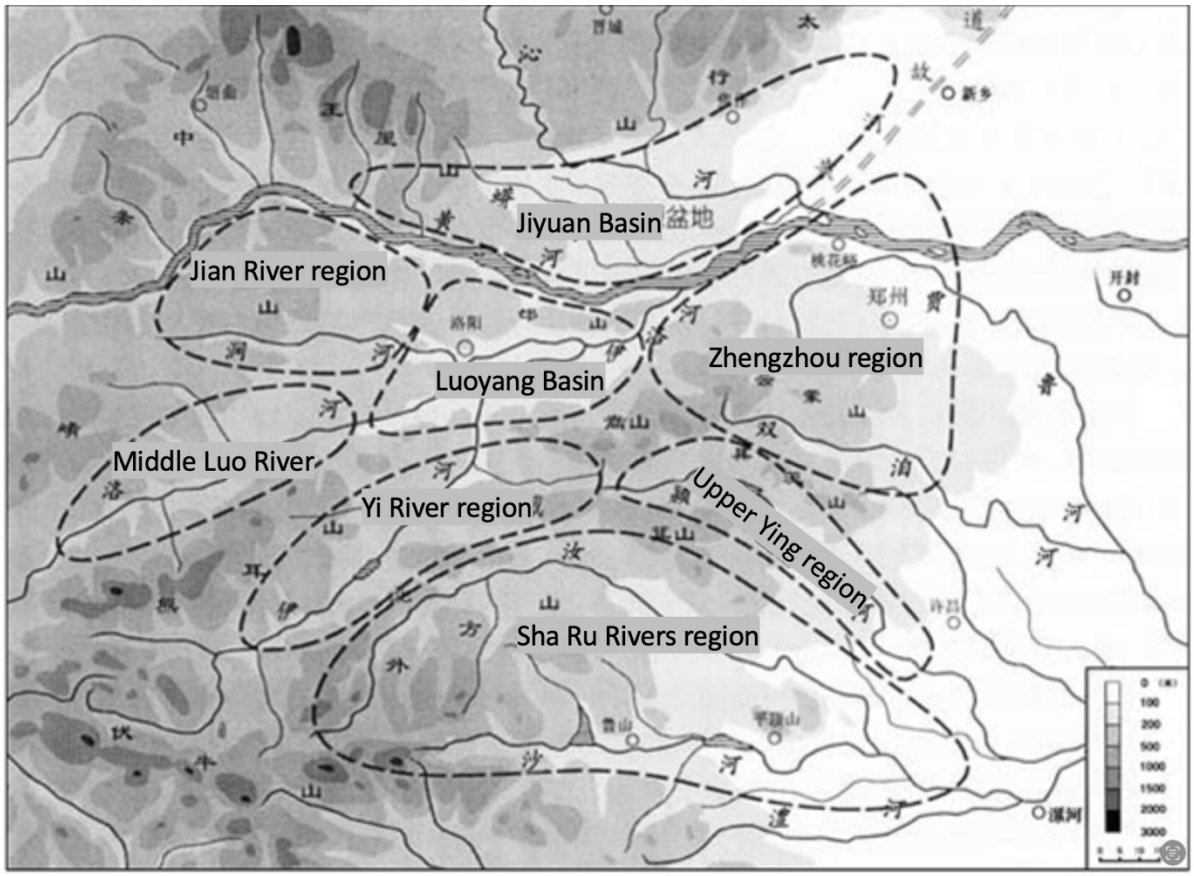
immediate environs. The medium-scales or regional scales may refer to a wide range of scopes. On the more specific end of the range, the following regions are under discussion.

Zhengluo

The Zhengluo 郑洛 region is defined through a combination of natural geographical distribution and administrative divisions. It specifically refers to the portion of Henan 河南 Province stretching from Luoyang 洛阳 in the west to Zhengzhou 郑州 in the east. Geographically, it primarily encompasses the middle reaches of the Yellow River and the upper reaches of the Yiluo, Ying 颍, and Ru 汝 Rivers, covering a broad area that includes the Luoyang Basin, the western Henan hilly region, and the circum-Mt. Song 嵩山 area (Figure 7).

During the Longshan Era, this region was occupied by the Wangwan III Culture 王湾三期文化. Divided by Mt. Song, the Wangwan variation was located on the north of the mountains, while the Meishan 煤山 type in the south. The Meishan variation is also referred to as Wangchenggang 王城岗 variation or Haojiatai 郝家台 variation. To the east of the Zhengluo region in eastern Henan Province was its buffer zone with the Haidai region, where several mixed archaeological cultures were distributed, such as the Hougang II 后岗二期 Culture, Zaolütai 造律台 Culture, and the Wangyoufang 王油坊 variation.

In the subsequent Erlitou Era, along with the rise of the Erlitou polity, the concept of Central Plains as the center of political and cultural stage began to emerge. The Zhengluo region—where Erlitou is located—became the core of the Central Plains. For this reason, the Zhengluo region holds particular importance in the discussion of state formation in Early China.

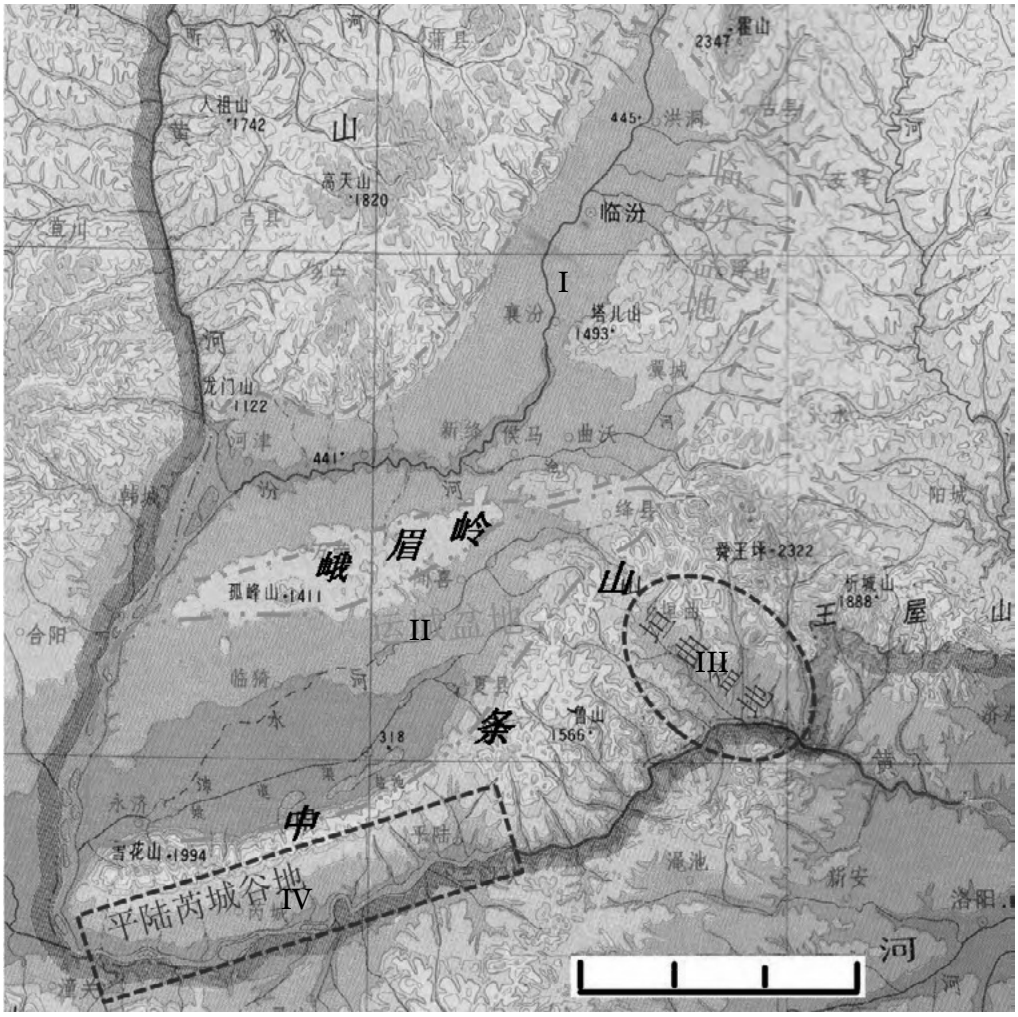


(Zhang 2021: fig. 2-1)

Figure 5. The Zhengluo region and its internal division

Jinnan

The Jinnan 晋南 region (southern Shanxi Province) is divided by Mt. Zhongtiao and Mt. Emeiling 峨眉岭 into four units: the Linfen 临汾 Basin, the Yuncheng 运城 Basin, the Yuanqu 垣曲 Basin, and the Pinglu-Ruicheng 平陆-芮城 Valley. During the Longshan Era, the Taosi Culture was distibuted in the Linfen Bain and the Yuncheng Basin, while the Sanliqiao Culture flourished in the Yuanqu Basin and Pinglu-Ruicheng Valley.



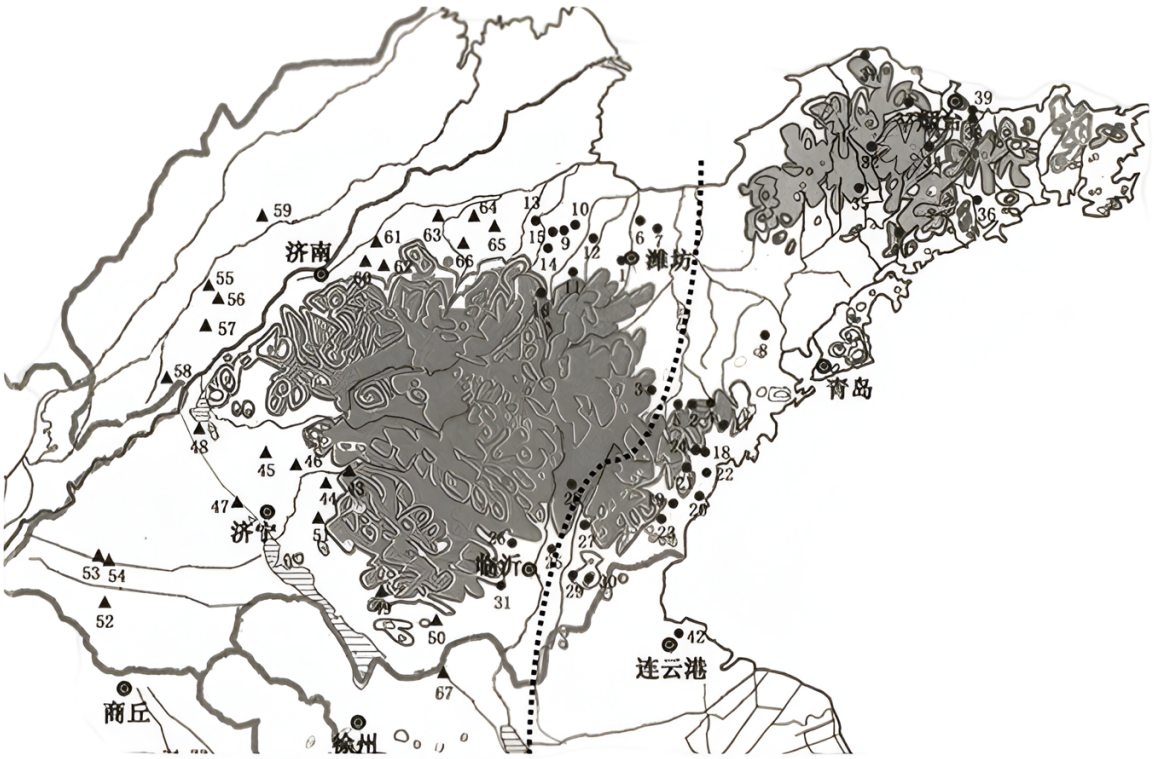
(Wang 2017: fig. 1)

Figure 6. The Jinnan region and its internal divisions

Haidai

As a geographic term adapted from *Yugong* 禹贡, Haidai 海岱 refers to the land between the Bohai Gulf and Mt. Tai (Qingzhou) and the land between Mt. Tai and the Huai River (Xuzhou). In archaeological classification, the Haidai region refers to the lower reaches of the modern Yellow River and Huai River, including the entire Shandong province, northern

Jiangsu, northern Anhui, eastern Henan, southeastern Hebei, and southern Liaoning peninsulas (Figure 7).



(Luan 2006: fig. 1)

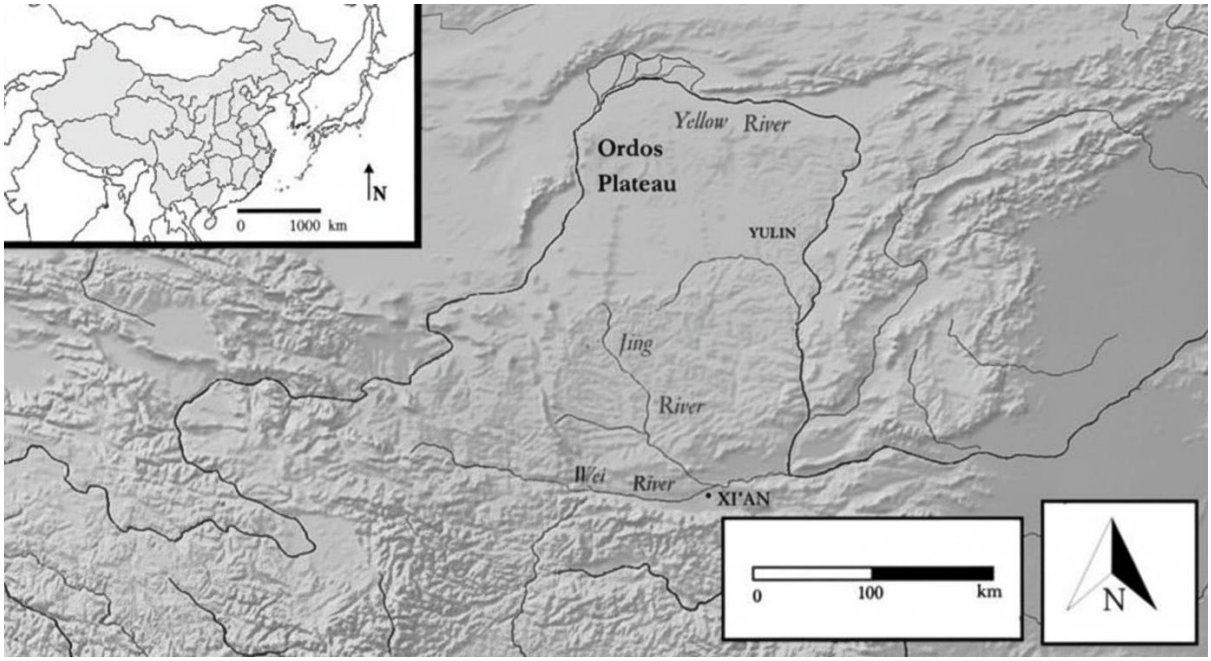
Figure 7. The Haidai region

The dotted line marks the division between eastern and western Haidai.

This region could be further divided into eastern and western Haidai. From north to south, the dividing line aligns with the Zi River 淄河, the Mt. Lu 鲁山 and Mt. Meng 蒙山. During the Longshan Era, both the eastern and western parts were occupied by communities associated with the Shandong Longshan Culture, after which the Longshan Era was named as mentioned above.

Ordos

Located to the north of the Loess Plateau, the Ordos region refers to the area enclosed by the large bend of the Middle Yellow River and north of the Great Wall within the bend (Li 2018: 138), including northern Shaanxi, central and northern Shanxi, and central southern Inner Mongolia (Figure 8). Several other terms—such as Hetao 河套 or the northern area 北方地区 in a narrow sense—are often used interchangeably in archaeological literature, despite they technically refer to slightly different geographic scopes.



(Owlett *et al.* 2018: fig. 1)

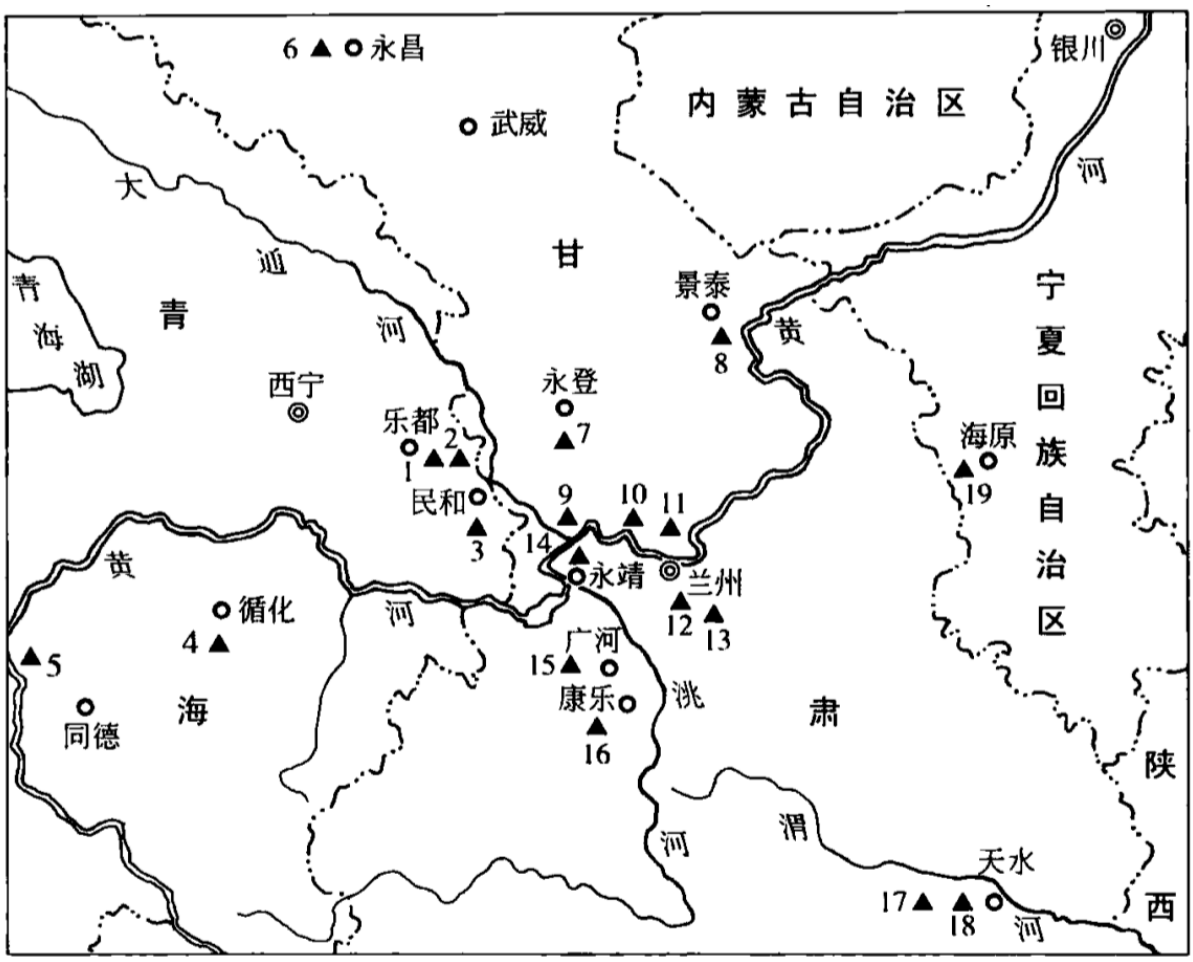
Figure 8. The Ordos region

Due to the cross-regional similarity and regional variations in ceramic traditions on the Highlands resulting from intensive inter-group interactions, the names of archaeological cultures have been debated in the past decade and proposals include Dakou 大口 I or Dakou II

Culture (Gao 1986; Shaanxi Sheng and Yulin Shi 2005: 272-274), the Zhukaigou 朱开沟 Culture (Neimenggu and E'erduosi 2000; G. Tian and Han 2003), the Laohushan 老虎山 Culture (Han 2003), the Xinghua 杏花 Culutre (Zhang 2004), the Yongxingdian 永兴店 Culture (Wei 2000), the Zhaimao 寨峁 Culture (Lü 2000), and the Xinhua 新华 Culture (Sun 2005). In recent years, there is an emerging consensus of naming the material culture the Shiamo 石峁 Culture (Dai 2022; Sun, Shao, and Di 2020;), due to the wealth of the materials excavated from Shimao.

Ganqing

The Ganqing 甘青 region, located in the Upper Yellow River area, encompasses Gansu 甘肃 Province, eastern Qinghai 青海, and southern Ningxia 宁夏 (Figure 9). Li (2018) refers this region as the western highlands, separating it from the Loess highland by the Liupan 六盘山 or Long Mountains 龙山. A commonly mentioned unit in this region is the Hexi 河西 corridor, which is located in the north of Qilian 祁连 Mountains and served as a passage linking China Proper to Central Asia. Equally important, the Gonghe 共和 Basin is located in the upper reaches of the Yellow River in eastern Qinghai Province. Surrounded by mountains on all sides, the Yellow River flows through the basin. To the northeast, it connects with the Haidong section of the Yellow River basin via Longyang Gorge 龙羊峡 and the Guide 贵德 Basin, and it extends southward to Tongde 同德.



(Zhongguo 2010: fig. 6-44)

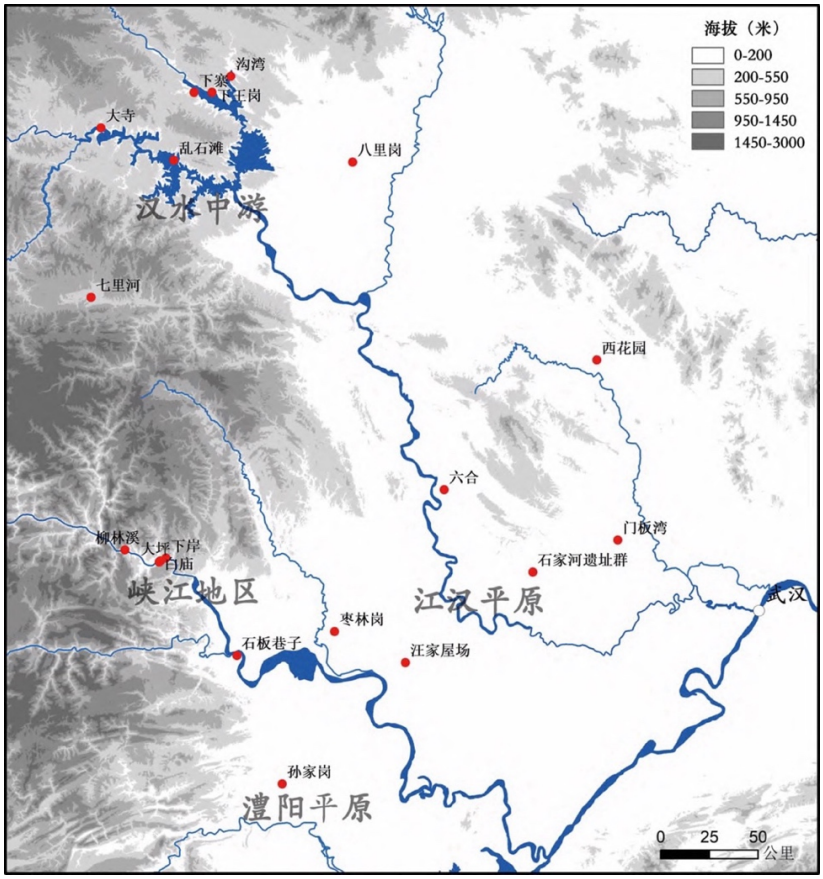
Figure 9. The Ganqing region

During the Longshan Era, three different yet highly interconnected archaeological cultures were distributed in this region. In the Hexi region distributed the Machang 马厂 Culture, which then gradually transitioned into the Siba 四坝 Culture around 2000 BCE (Wang 2012; Note that according to Womack *et al.* 2017, the transition did not happen until 1900 BCE). In the Tongde and Gonghe Basins distributed the Zongri 宗日 Culture, which declined around 2100 BCE (Wang 2012). In southern Ningxia, along the Qinshui 清水 River, distributed the Caiyuan 菜园 type, which then developed into the Qijia 齐家 Culture (2600–1500) (Wang 2012;

Womack *et al.* 2017). During the Qijia period, Qijia Culture became highly expansive, covering entire the entire Ganqing region during its peak, and its distribution region seemed to have gradually moved from east to west from the Early to Late Qijia Phases (Wang 2012).

Middle Yangzi

The Middle Yangzi region (Figure 10) covers various geographical units, including Jianghan 江汉 Plains, Xiajiang 峡江 region, and Liyang 澧阳 Plains. In some research, the Nanyang 南阳 Basin, which is located between the Yellow and Yangzi River, is also considered Middle Yangzi.



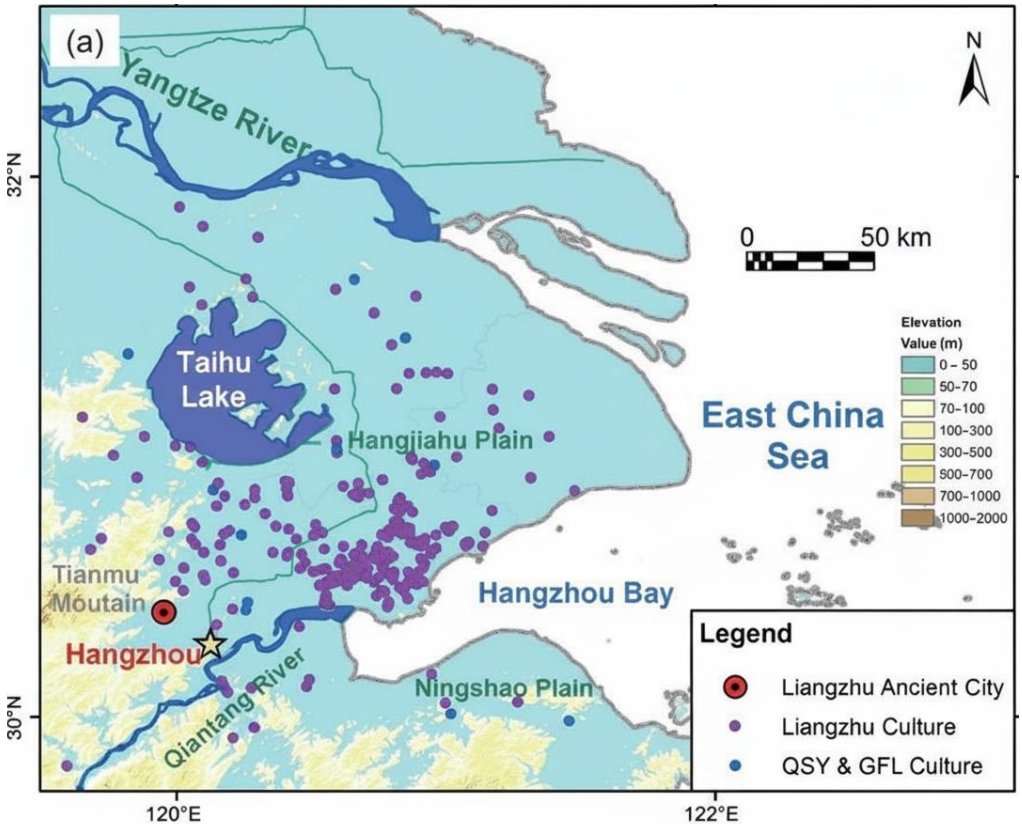
(Zhang 2021: fig. 1)

Figure 10. The Middle Yangzi region

At the beginning of the Longshan Era, the Shijiahe Culture once flourished in the Middle Yangzi region but declined and gave way to a range of post-Shijiahe traditions. Scholars have proposed different schemes to name the various regional traditions (He 2006; Wang 2007). In this dissertation, I adopt Zhang Hai's (2021) scheme, which proposes that in the Jianghan and Liyang Plains, the Shijiahe Culture transitioned into the Xiaojiawuji 肖家屋脊 Culture, while further west, in the Middle Han River and Xiajiang regions, the Luanshitan 乱石滩 Culture was distributed. These post-Shijiahe traditions were largely contemporaneous and lasted between 2200–1800 BCE.

Lower Yangzi

After the decline of the Liangzhu Culture around 2300 BCE, the Lower Yangzi region appears to have been sparsely occupied. However, recent discoveries suggest that while the major Liangzhu settlements were abandoned during this period, the region was not entirely uninhabited. The emergence of sites such as Qiangshanyang 钱山漾 (2600–2200 BCE) (Guo 2020: 79) and Guangfulin 广富林 (2200–2000 BCE) (Zhai 2006: 72) indicates continued, albeit limited, occupation in the post-Liangzhu landscape.



(He *et al.* 2021: fig. 1)

Figure 11. The Yangzi Delta in the Lower Yangzi River

By 2470 BCE, the density of occupation in the Lower Yangzi had begun to decline (Zhang *et al.* 2015), although many sites continued in use until at least 2300 BCE and perhaps as late as 2200 BCE. It is important to note that although 2300 BCE is commonly cited as the end of the Liangzhu Culture (Renfrew and Liu 2018a; Li 2018), recent radiocarbon dates suggest that the Late Liangzhu phase may have persisted until 2200 BCE (Zhejiangsheng and Huzhoushi 2014: 691).

The older dating scheme for Liangzhu—which dates the end of the culture around 2300 BCE—combined with the frequently cited short chronology for Taosi—which incorrectly places its beginning at 2300 BCE—has created the impression that the two cultures never overlapped.

The revised chronology, however, indicates that Early Taosi may have coexisted with Late Liangzhu, suggesting a temporal overlap between the two cultural traditions and their major centers. Direct evidence of interaction between the two sites remains limited, likely due to the long distance between the two regions and the fact that Liangzhu had already begun to decline around 2470 BCE.

Chapter 1 Climate Change in the Longshan Era

1. Introduction

The 4.2 ka BP event is widely recognized as a period of abrupt and severe climate change, marked by widespread cooling and/or drought, as evidenced by a range of paleoclimate proxies—including ice cores, speleothems, lake and marine sediments, and loess deposits. In China, regional records indicate a general trend of temperature decline across much of the continent (Jin and Liu 2002; Zhou *et al.* 2002; Zhong *et al.* 2017; Xu *et al.* 2006; Yao *et al.* 2017), while others emphasize shifts in precipitation patterns, with north-south variation (Tan and Cai *et al.* 2018; Tan and Shen *et al.* 2018; Huang *et al.* 2010; 2011; Wu *et al.* 2017). This climatic disruption has been formally recognized by the International Commission on Quaternary Stratigraphy as the boundary marker of the Meghalayan stage, the most recent stage of the Holocene epoch, based on a geochemical transition in stalagmites from northeastern India (Walker *et al.* 2018).

Globally, the 4.2 ka BP event has been linked to the collapse of major ancient civilizations, such as those in Egypt, the Indus Valley, Mesopotamia, and the Yangzi Valley, and to episodes of large-scale human migration (Weiss *et al.* 1993; Cullen *et al.* 2000; Gasse 2000; DeMenocal 2001; Weiss and Bradley 2001; Thompson *et al.* 2002; Booth *et al.* 2005; Bar-Matthews and Ayalon 2011; Berkelhammer *et al.* 2013; Ruan *et al.* 2016; Railsback 2018; Burke 2021). In China, it has similarly been implicated in the decline of Neolithic cultures, particularly in the

Central Plains (Jin and Liu 2002; Huang *et al.* 2010; 2011; Zhang *et al.* 2010; Liu and Feng 2012; Wu *et al.* 2017).

Interest in how this climate event affected Chinese cultural development was notably sparked by (Hsü 1998), who hypothesized that climate-induced food shortages and population displacements may have contributed to sociopolitical transformations. Synthesizing data from eastern China, Wu and Liu (2004) proposed that around 4.2 ka BP, northern China experienced drought, while the south faced flooding, contributing to the collapse of Neolithic cultures in the Central Plains. They emphasized the role of agricultural stress, whether through prolonged drought or excessive moisture, as a major driver of cultural collapse.

However, more recent analyses—particularly that of Liu and Feng (2012)—have nuanced this interpretation. Reviewing new archaeological and climatic evidence from the mid-to-late Holocene transition, they argued that while northern China experienced significant aridification, the south underwent multi-faceted climatic shifts, including cooling, reduced precipitation, and changes in soil moisture levels. Within a broader framework that accounts for cultural dynamics, socioeconomic factors, and environmental carrying capacity, they concluded that the 4.2 ka BP event likely "directly or indirectly led to the observed collapses of many Chinese Neolithic cultures" (Liu and Feng 2012: 1193).

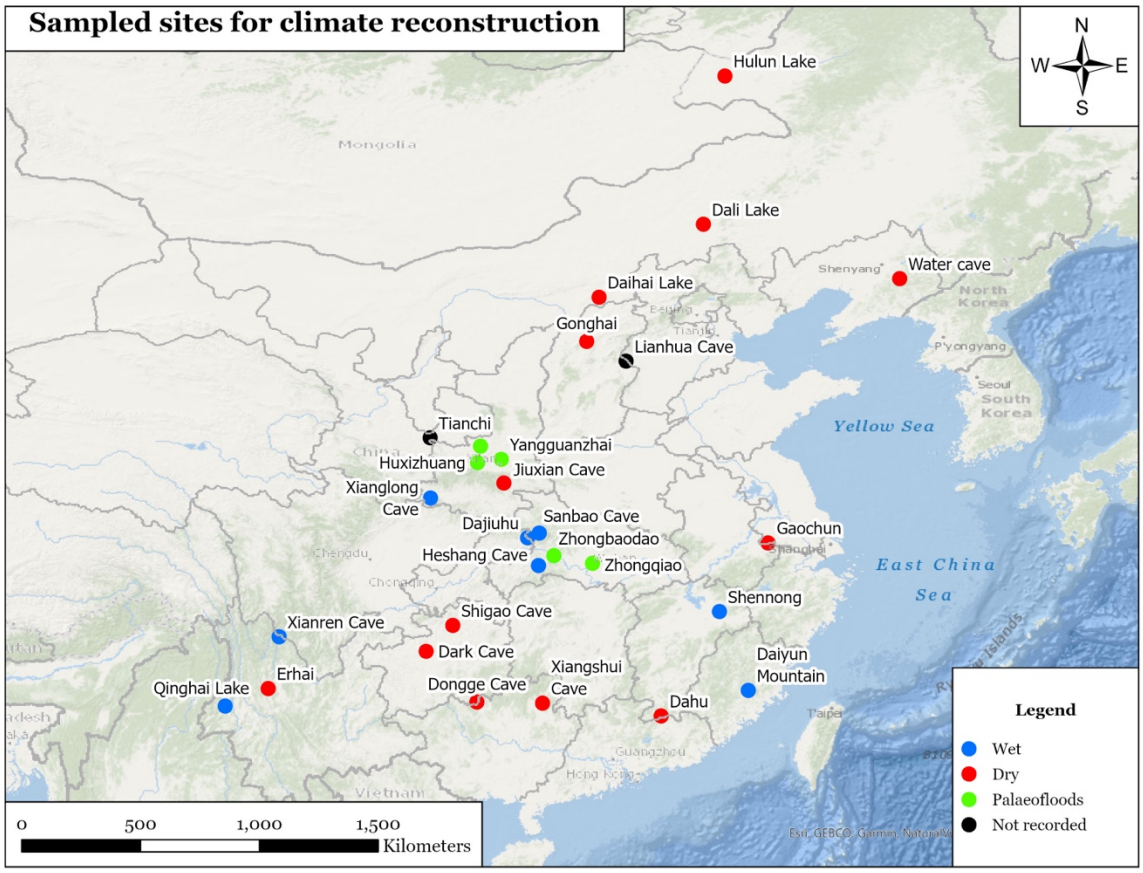
Citing the 4.2 ka BP event as the primary driver of cultural change is a prevalent practice, and so too is the critique of this hypothesis (Su and Kidder 2019; Jaffe *et al.* 2020). Su and Kidder (2019) focus on case studies in Henan and Shandong Provinces, demonstrating that human occupation at sites in these two provinces did not align with macroregional climatic and

paleoenvironmental changes. Jaffe *et al.* (2020) critiques the tendency of archaeologists and climate scientists to operate at different spatial and temporal scales, leading to interpretive mismatches and problematic correlations. This mismatch can result in false correlations—climatic trends may appear to align with archaeological change, but without sufficient resolution or contextual control. Such critiques have been valuable in reshaping how we conceptualize cultural change.

Building on these insights, I review paleoclimatic studies to establish a more accurate foundation for evaluating the climate change hypothesis in relation to the Longshan Transformation. A nuanced understanding of the 4.2 ka BP event is essential for assessing its impact on human-environment interactions during the Longshan Era. However, previous scholarship has often characterized the Longshan period as a uniformly cooling and drying phase, overlooking significant regional variability and assuming a synchronous and uniform impact. This approach neglects the temporal lags and spatial differences evident in various climatic proxies across distinct regions.

Over the past two decades, a growing body of research on Holocene climate change has revealed a more complex and regionally differentiated picture of the 4.2 ka BP event. Although earlier models linked it to widespread aridification and social collapse, current evidence indicates that different regions experienced distinct climate regimes between the late fourth and early third millennia BCE. These findings challenge overly deterministic, climate-centered narratives of the Longshan Transformation.

To understand better the climatic backdrop of this transformation, this chapter reviews paleoenvironmental studies published since 2000, aiming to reconstruct macroregional climate patterns across the broader Longshan cultural sphere. While not exhaustive, the selected sites (Figure 14) are sufficient to demonstrate the diversity of environmental responses to the 4.2 ka BP event and to support a more nuanced analysis of climate-cultural dynamics during this critical transitional period.



Map by author

Figure 12. Sampled sites mentioned in Chapter 1

Red indicates a drier climate during the Longshan Era, while blue indicates a wetter climate. Green indicates the discovery of evidence for paleoflood. Grey indicates where the 4.2k event is not recorded by the materials under analysis.

2. **Proxy data and their limitations**

Before turning to individual case studies, it is important to briefly introduce the types of proxy data employed in the analyses that follow. In the absence of direct climatic records—such as for the Neolithic period—researchers rely on proxy data to reconstruct past climate conditions. These proxies are natural phenomena that respond to climatic changes and thus serve as indirect indicators. They include *historical* records (e.g., fluctuations in wheat harvests), *paleoecological* evidence (such as fossil pollen, faunal remains, and foraminifera in marine sediments), and *geological* data (including sedimentation rates in lakes and valleys, stream terrace formation, and isotopic analyses of oxygen and carbon in marine deposits) (Rosen 2007: 17).

As Rosen (*ibid*) emphasizes, it is essential for students of climate change and cultural change to understand both the strengths and limitations of these various proxy sources. Since proxy data often require interpretive judgment, researchers must critically assess the climatic evidence they cite, especially when using it to support arguments about cultural change. With this caution in mind, the following section presents the key proxy data used in the case studies discussed in this chapter.

2.1 Palaeoecological proxy data

Pollen Analysis

When presenting pollen data, the total count is referred to as pollen sum. These counts can be expressed either as relative percentages of total or as absolute number s of pollen per unit of

sediment. Pollen diagrams illustrate pollen numbers and/or percentage in samples from stratified sediments. They are presented as curves for each pollen category displayed in columns, and they record the progression of vegetation changes through time.

To read a pollen diagram, one should be aware that certain pollen forms indicate wetter or driers conditions, and others point to cooler or warmer environments. Plants that indicate wetter conditions include *Cyperaceae* (sedge), *Typha* (cattail), *Phragmites* (reed), *Alnus* (alder), *Salix* (willow), *Quercus* (oak), and *Ulmus* (elm). Plants that indicate drier conditions include *Artemisia* (sagebrush), *Chenopodiaceae* (goosefoot family, including *Chenopodium* and *Haloxylon*), *Ephedra*, *Poaceae* (grasses), *Pinus* (pine), and *Calligonum*. The major phases of pollen change are divided up into pollen zones. These zones are used in interpreting changes of vegetation that may have been influenced by climate change or human land use.

Another method employed by pollen analysts is comparing the proportion of arboreal and non-arboreal pollen. In northern China, an increase in arboreal pollen is typically interpreted as evidence of wetter climatic conditions, while a rise in non-arboreal pollen—especially from dry-steppe shrubs like *Chenopodiaceae* and *Artemisia*—is taken to signal a shift toward drier climates.

There are several pitfalls in the interpretation of pollen data. When comparing pollen data with archaeological data, archaeologists must also take into consideration that vegetations themselves are a complex system and respond to climate change in a nonlinear and complex manner. Zhao Yan *et al.* (2017) demonstrate that abrupt ecological changes can result from gradual climatic forcing, challenging the assumption that ecosystems respond in proportion to

environmental changes. Rosen (2007: 24) also noted that when the climate improves, it can take several hundred years or more for forests to expand into a new area. This delay depends on factors such as the location of forest refugia, the distance from the pollen core site, and the environmental zones the forest must pass through. As a result, the climatic shift that allowed forest growth may have taken place well before it becomes visible in the pollen record. Given this, it is possible that the climate change indicated by pollen records may lag behind the actual climatic shift by several hundred years. Therefore, it is important to statistically evaluate the correspondence between different categories of proxy data and the timing and trends of the climate changes they reflect.

Littoral ostracods

Littoral ostracods—microscopic crustaceans that thrive in shallow, well-oxygenated waters—offer complementary evidence. A high abundance of littoral ostracod species suggests that sediments were deposited in shallow, nearshore environments, which typically occur during low lake stands. In contrast, a decline in these species, replaced by deeper-water or planktonic ostracods, indicates a rise in lake levels and a shift in depositional conditions toward deeper water (Holmes and Chivas 2010).

2.2 Geological data

Total Organic Carbon

Total Organic Carbon (TOC) is a key parameter used to describe the abundance of organic matter in sediments. TOC concentration reflects the proportion of organic matter that escaped

remineralization during the process of sedimentation. Similar to pollen records, TOC data are typically extracted from lake or peat sediments. To interpret TOC accurately, it is essential to first identify its source. In lake sediments, TOC generally derives from two main sources: autochthonous aquatic plants produced within the lake and allochthonous terrestrial vegetation transported from the surrounding watershed. Aquatic phytoplankton typically exhibit carbon-to-nitrogen (C/N) ratios between 4 and 10, while terrestrial vegetation tends to have C/N ratios of 20 or higher (Meyers 1994). Therefore, by measuring the C/N ratio of sediment samples, researchers can infer the origin of the organic matter.

When the organic matter in the sediments mainly derives from terrestrial plants growing in the lake catchment, because the terrestrial organic matter entering the lake would be transported by rivers and streams from the lake catchment, the decreases in the TOC concentration could be interpreted to indicate decreases in the surface runoff of the lake catchment, and thus decreased precipitation (Xiao *et al.* 2008).

Using Total Organic Carbon in lake sediments to reconstruct paleoclimate presents several challenges, because TOC is shaped by a complex interplay of environmental factors beyond precipitation and temperature. TOC levels are influenced by primary productivity (both aquatic and terrestrial), organic matter preservation, sediment composition, and catchment dynamics (Meyers and Teranes 2001: 241). As a result, changes in TOC do not necessarily correspond directly to changes in climatic conditions and it is hard to pinpoint whether the changes are related to temperature or precipitation variations.

Additionally, it is common for sediment TOC concentrations to vary substantially from place to place within a lake because the multiple factors mentioned above interact in complicated ways (Meyers and Teranes 2001: 241-242). A case study in Pyramid Lake, Nevada, USA, shows that contributions of land-derived material to sediment organic matter become minor beyond a few hundred meters from shore (Tenzer and Meye 1997).

Furthermore, similar to the limitation of pollen records, non-climatic influences—such as anthropogenic land use, vegetation clearance, or tectonic events—can independently alter TOC input and preservation. These changes may mimic or obscure precipitation signals, complicating the interpretation of sediment records. Finally, ecosystem responses to precipitation are often nonlinear and may exhibit threshold effects or delayed reactions. This means that TOC might not capture subtle or short-term fluctuations in rainfall.

Carbon isotope

The $\delta^{13}C$ (ratio of $^{13}C/^{12}C$) record is a valuable proxy to infer past changes in climate, particularly in relation to vegetation dynamics, precipitation, and to a lesser extent, temperature. In terrestrial contexts such as lake sediments, soils, and plant remains, $\delta^{13}C$ is primarily shaped by the types of plants that dominated the landscape. Plants using the C_3 photosynthetic pathway (e.g., trees and temperate grasses) discriminate more strongly against ^{13}C and thus have more negative $\delta^{13}C$ values (typically around –27‰). In contrast, C_4 plants (e.g., tropical grasses and sedges) produce less negative $\delta^{13}C$ values (around –13‰). Therefore, a shift toward less negative $\delta^{13}C$ values in the sedimentary record can suggest a transition to C_4

vegetation, which is often associated with warmer and drier climatic conditions. Conversely, more negative $\delta^{13}C$ values typically signal increased C_3 plant dominance, often reflecting wetter and cooler conditions (Liu *et al.* 2005).

$\delta^{13}C$ is more sensitive to precipitation levels than to temperature changes, especially in ecosystems dominated by C_3 plants. Under drier conditions, plants reduce stomatal conductance to conserve water, which decreases their discrimination against ^{13}C, leading to less negative $\delta^{13}C$ values. As a result, $\delta^{13}C$ can serve as a proxy for aridity or drought, while more negative values often correlate with higher moisture availability. While temperature can influence plant growth and soil carbon processes, $\delta^{13}C$ generally reflects moisture conditions more directly than it does temperature alone (Stein *et al.* 2021).

In speleothems (cave carbonates), $\delta^{13}C$ values provide insight into overlying vegetation density and soil productivity. More negative values often indicate dense vegetation and active soil respiration, associated with wet and biologically productive conditions. Conversely, higher $\delta^{13}C$ values may result from reduced vegetation cover, drought, or prior calcite precipitation, a process enhanced in dry cave environments.

Oxygen isotope

The record of **$\delta^{18}O$** (ratio of $^{18}O/^{16}O$) in cave speleothem may serve as indicators for temperature and precipitation change. Using modern climate data from the Global Network of Precipitation at ten sites across China, Johnson and Ingram (2004) found that $\delta^{18}O$ in precipitation is influenced by different factors depending on the region. In southern China,

δ^{18}Op is primarily driven by precipitation levels, whereas in northern China, temperature is the dominant factor. δ^{18}O is usually a negative value. Lower levels (more negative) of δ^{18}O in general indicate cooler environmental conditions (see, for example, Lauritzen 1995; Winograd *et al.* 1997) and stronger monsoon activities (e.g., Hu *et al.* 2008; Ruan *et al.* 2016). In turn, higher (less negative) value of δ^{18}O may indicate warmer temperature and weaker monsoon activities. This is how δ^{18}O values are interpreted in most of the case studies cited in this chapter.

As discussed below, one of the strengths of using speleothem to reconstruct paleoclimate is its high dating resolution, when using U-Th dating method (Section 3 in this chapter). That being said, speleothem isotope records are more complex to interpret for a number of reasons. Firstly, the extent to which oxygen isotopes in speleothems reflect local temperature depends on the specific conditions of the cave where they form (Bradley 2015: 329-334). Speleothems develop from calcite deposited by dripping water and, in theory, record the mean annual surface temperature, as the cave air and surrounding rock are in thermal equilibrium. However, local cave dynamics can influence the reliability of this signal. A strong correlation between carbon and oxygen isotope values often indicates nonequilibrium or kinetic effects—suggesting the speleothem may not be suitable for reconstructing past temperatures. To address this, researchers typically compare δ^{18}O values in modern groundwater and precipitated calcite. Although interpretation is complex, δ^{18}O generally increases as cave temperatures decrease.

Furthermore, Cai *et al.* (2010) have shown the impact of seasonality on the relationship between δ^{18}O values and climate change: δ^{18}O is mainly influenced by temperature during winter, while in summer, the “amount effect” of precipitation becomes the primary control. In

addition, other influences such as shifts in moisture sources, total vapor flux to the continent, moisture recycling, may also contribute to changes in the $\delta^{18}O$ records (LeGrande and Schmidt 2009; Maher 2008). The intricate factors collectively shape the relationship between $\delta^{18}O$ and climate variation, thus render the interpretation of $\delta^{18}O$ records difficult.

2.3 Terrestrial data

Paleoflood slackwater deposits

Paleoflood slackwater deposits (SWDs) are fine-grained sediment layers left behind in low-energy environments adjacent to river channels—such as caves, alcoves, tributary mouths, or overbank zones—during major flood events in the past. These areas, known as slackwater zones, experience a sharp reduction in flow velocity when floodwaters spill out of the main channel, allowing suspended sediments to settle. As a result, SWDs are composed primarily of silt and clay and often exhibit features like lamination, sharp basal contacts, or the inclusion of organic or coarser material at the base (Baker 1987). SWDs serve as important archives for reconstructing the magnitude, frequency, and timing of paleofloods, particularly in regions where instrumental flood records are lacking or too short. Their elevation above the modern floodplain provides a physical record of the maximum flood stage, making them especially useful for assessing extreme hydrological events (Kochel and Baker 1982; Benito and Thorndycraft 2005).

SWDs are commonly dated using radiocarbon dating, optically stimulated luminescence (OSL), and archaeological remains. Both OSL and radiocarbon methods typically carry age

uncertainties of several hundred years. However, when SWDs are studied in conjunction with archaeological remains (typically, pottery sherds), they can provide more direct evidence of occupation disruptions caused by flood events, as well as subsequent reoccupation after the flooding.

Grain-size

An elevated sand content in lake sediments generally indicates deposition near the shoreline in high-energy depositional environments. During periods of low lake levels, wave activity and nearshore currents are capable of carrying and depositing coarser, sand-sized materials into the lake. By contrast, when lake levels are higher and sedimentation occurs farther from the active shore, finer particles tend to dominate, leading to a decrease in sand content. Therefore, variations in the sand fraction over time can effectively reflect transgressive (rising) or regressive (falling) phases of lake development (Liu *et al.* 2016).

3. **Dating methods and their limitations**

In this section, I introduce the strength and weakness of two dating methods that are commonly used in paleoenvironment studies: radiocarbon dating and Uranium-Thorium (U-Th) dating. In this chapter, radiocarbon dating is commonly used to date the lake and peat sediment samples, as well as loess profiles. U-Th dating is primarily used for dating speleothems. Through this introduction, I aim to highlight how errors and misunderstandings regarding the dates reported in paleoenvironmental publications can arise.

Radiocarbon dating

Both conventional radiocarbon dating and AMS dating are commonly used in dating sediment samples. There are a number of challenges that we should be aware of when reading the radiocarbon dates in paleoenvironmental studies. First, when dating lake sediments in areas underlain by carbonate rocks or affected by recent volcanic activity, eroded materials from these sources often contain "old carbon." This ancient carbon enters the lake system, altering its carbonate chemistry. As a result, it can influence underwater photosynthesis in aquatic plants and the precipitation of carbonates by freshwater organisms like mollusks. This process leads to a "hard water effect" in radiocarbon dating, which can cause the ages of mollusk shells and aquatic plant remains to appear up to 1,200 years older than they actually are (Lowe and Walker 1997:245-246).

Second, the chronologies of the sediment core are based on age-depth models. They are statistical reconstructions that estimate the age (in years) of different depths in a sedimentary or stratigraphic sequence, such as lake cores, peat deposits, ice cores, or cave speleothems. Such reconstructions are more reliable when the samples are speleothems, because the dating samples are abundant, but when it comes to radiocarbon dating, the whole chronology (spanning from thousands to ten thousand years) is usually based on less than 10 radiocarbon date samples when using conventional method and no more than 20 samples when using AMS dating methods, because dateable organic materials in the sediment cores are usually not abundant. This means that in some studies, the key period under investigation—the second half

of the third millennium BCE onward—may not be dated with meaningful resolution. In such cases, no radiocarbon samples are taken from the corresponding sediment depth, and the dates for that section rely solely on a loosely constrained age-depth model.[3]

Uranium–Thorium dating

In this chapter, all case studies that use speleothems as samples employ Uranium–Thorium (U-Th) dating, also known as uranium-series dating, to establish their age-depth models. One of the key strengths of U-Th dating is its high precision and accuracy. Under ideal conditions, age uncertainties can be as low as ±1–2‰ (0.1–1%), making it especially valuable for reconstructing millennial- to even decadal-scale climate events. Unlike radiocarbon dating, which often targets associated organic material, U-Th dating directly dates the carbonate material used for the isotope measurements, providing more reliable and internally consistent age-depth models. Additionally, many speleothems grow continuously in layered structures, allowing researchers to sequence multiple dates along the growth axis and the modelled dates are usually much more precise. This enables the construction of high-resolution paleoclimate chronologies based on $\delta^{18}O$ records.

In addition to the two methods discussed, other dating techniques—such as OSL and archaeological dating—are also employed in the case studies cited in this chapter. Due to

[3] Similar dating difficulties also affect the validity of climate hypotheses in explaining the collapse of Late Bronze Age Eastern Mediterranean societies; For a critique on the dating methods used there, see Knapp and Manning 2016: 102-107.

differences in the availability of datable materials and the varying precision of these methods, using multiple dating techniques—much like using diverse proxy data—can potentially introduce inconsistencies in identifying the onset and duration of climate anomalies. Therefore, when a time gap in the onset of climate change is observed, it is essential to consider whether it results from the use of different dating methods.

4. **A review of selected climate studies**

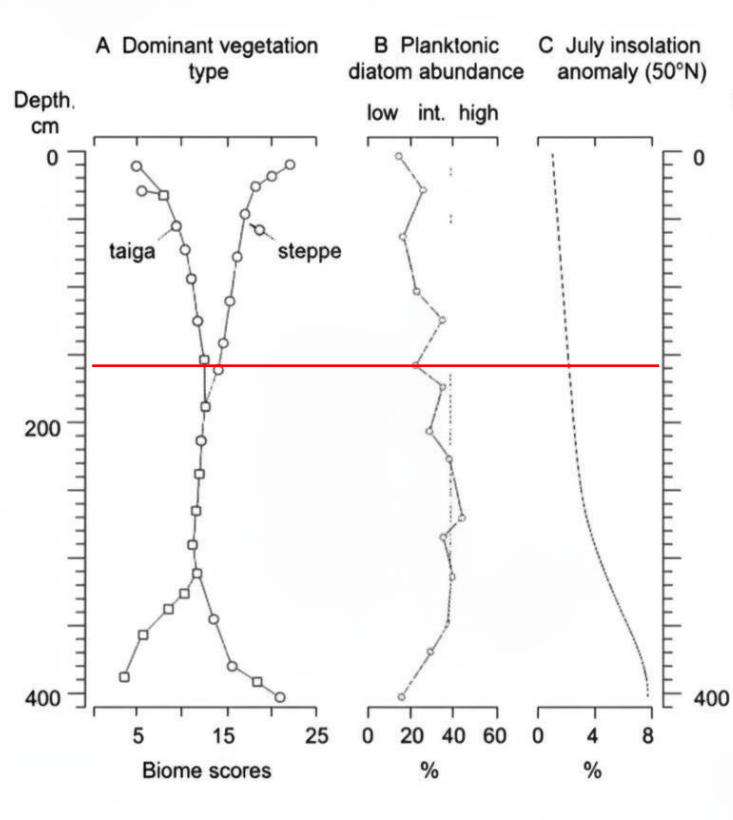
4.1 Northern Macroregion

In this chapter, "northern macroregion" refers to the area north of the Qinling Mountains 秦岭 and Huai River 淮河 as well as the area north of the Tibetan Plateau. One of the sites in northwest Mongolia is also included below, as it is also under heavy influence of the winter monsoon like many other sites among the Longshan Highland communities. As the following regional studies demonstrate, the 4.2ka BP event corresponded to a drying event in this macroregion, although frequent flooding events also occurred along the tributaries of the Yellow River.

Hoton-Nur Lake

Hoton-Nur Lake is a freshwater body in the northern Mongolian Altai. The region experiences cold winters and cool summers, with precipitation primarily occurring during the warmer months due to occasional incursions of humid air from the Pacific (Tarasov *et al.* 2000). Sediment samples for pollen and diatom analyses were collected in 5–10 cm increments. The chronology of these samples was established using six conventionally dated radiocarbon dates.

According to the researchers, pollen analysis revealed that around 4300 BP, steppe biome scores began to surpass those of the taiga (Figure 13), suggesting the drying trend began to affect the vegetational environment around the second half of the third millennium BCE (Tarasov, Dorofeyuk, and Tseva 2000: fig. 5).



(Tarasov, Dorofeyuk, and Tseva 2000: fig. 5)

Figure 13. Affinity scores of dominant biomes

Note: The red bar (added by the author) indicates the possible beginning date of the drying event.

However, due to the low resolution of radiocarbon dating, the exact timing of this climatic shift remains uncertain. The nearest calibrated radiocarbon date below the section showing clear vegetation changes is 4375±475 cal. yr BP. As a result, the onset of the drying event is

inferred from this date, meaning that the change of vegetation may begin at any point between 4850 and 3900 BP.

Hulun Lake 呼伦湖

Hulun Lake, situated in northeastern Inner Mongolia, lies at the northern margin of the East Asian summer monsoon (EASM) zone, making it a climate-sensitive area. Researchers extracted a sediment core from the lake's central area, analyzing it at one-centimeter intervals to reconstruct Holocene hydrological, vegetation, and climate changes. Radiocarbon dating of five organic matter samples, including a correction for the uppermost layer's carbon reservoir effect, confirmed a reliable depth-age relationship (Xiao *et al.* 2018).

The researchers analyzed sand fraction content and littoral ostracod abundance of the samples, and pollen assemblage. A rise in sand fraction between 4430 and 3860 cal. yr BP suggests a period of lower water levels. Ostracod assemblages contained certain littoral ostracodes, such as *Pseudocandona albicans* and *Candoniella subellipsoidea*, typically thrive in small, shallow water bodies with varying temperature and salinity levels. Their increased presence between 4200 and 3420 cal. yr BP suggests a period of lower lake levels. Analysis of pollen assemblages in the core sediments further supports this observation, with an increase in the percentage of Chenopodiaceae pollen between 4300 and 3830 cal. yr BP observed, suggesting drier conditions in the region during that period. Drawing these lines of evidence together, Principle Component Analysis (PCA) suggests a distinct dry event in the Hulun Lake

region, beginning around 4210 cal. yr BP and ending around 3840 cal. yr BP, lasting approximately 370 years.

Dali Lake 达里湖

Dali Lake, an enclosed inland basin, is situated approximately 90 km west of Hexigten Banner 克什克腾旗 in Inner Mongolia. It lies within the transitional zone between semi-humid and semi-arid climates in China's middle temperate zone. Similar to Hulun Lake, its climate is shaped by the interplay of the East Asian monsoon and westerly winds.

One sediment core was extracted from the lake's depocenter. Radiocarbon dating of 18 organic matter samples from the sediment core was conducted using AMS. The age-depth model produced a surface intercept age of 611 years, likely due to hard-water effect. To correct for this, researchers subtracted the surface intercept age from the calibrated model when converting depth to age (Xiao *et al.* 2008).

By analyzing TOC, Xiao *et al.* (2008) argue that the sediment core indicates that lake-level variations in Dali Lake followed three primary phases during the Holocene: a gradual rise and sustained high levels during the early Holocene (11,500–7,600 cal yr BP), fluctuating but relatively high water levels in the middle Holocene (7,600–3,450 cal yr BP), and a general decline accompanied by significant fluctuations in the late Holocene (after 3,450 cal yr BP). Between 4,450 and 3,750 cal yr BP, a noticeable decline in lake levels occurred, situating the Longshan Era in a relatively drier phase.

Daihai Lake 岱海湖

Daihai Lake, a hydrologically closed lake, lies 10 km east of Liangcheng County 凉城县, Ulan Chab 乌兰察布市, Inner Mongolia. Like the two cases above, Daihai Lake is also located at the northern margin of the East Asian summer monsoon that represents a climatically sensitive region. Xiao *et al.* (2019) extracted one sediment core from the central region of Daihai Lake, and eight bulk samples from organic-rich layers were dated using AMS. To ensure accuracy, the researchers accounted for the carbon reservoir effect when reconstructing the age-depth model, which demonstrated a strong correlation over the past 12,000 years.[4] The core was analyzed at 2–4 cm intervals for multiple proxies, including grain-size distribution, carbon concentration, and pollen assemblage.

The results indicate a period of reduced silt fraction content between 4,250 and 3,790 cal yr BP. Given the established relationship between grain size and lake level, this reduction suggests lower lake levels during this time. Additionally, a period of below-average values in TOC concentration was observed between 4,100 and 3,760 cal yr BP. Since the organic matter in Daihai Lake sediments mainly originates from terrestrial plants in the lake catchment, as indicated by C/N ratios, decreased TOC levels suggest a decline in surface runoff. This implies

[4] The carbon reservoir effect refers to the phenomenon where certain carbon reservoirs—like oceans, lakes, or groundwater—contain "old" carbon that can distort the radiocarbon (^{14}C) dating of samples derived from them. This leads to radiocarbon ages that appear older than the sample's true calendar age. For more detailed discussion on the carbon effect in lacustrine systems, see Yu, Shen, and Colman 2007.

that reduced river and stream input transported less organic matter into the lake, indicating weakened catchment hydrology (Xiao *et al.* 2019).

Pollen analysis also revealed a lower-than-average proportion of tree pollen between 4,060 and 3,690 cal yr BP. A decline in tree pollen percentages suggests reduced forest coverage in the lake region, which is interpreted as evidence of decreased precipitation. By integrating these proxy records through PCA, researchers inferred that the climate of the Daihai Lake region became drier between 4,060 and 3,690 cal yr BP (Xiao *et al.* 2019).

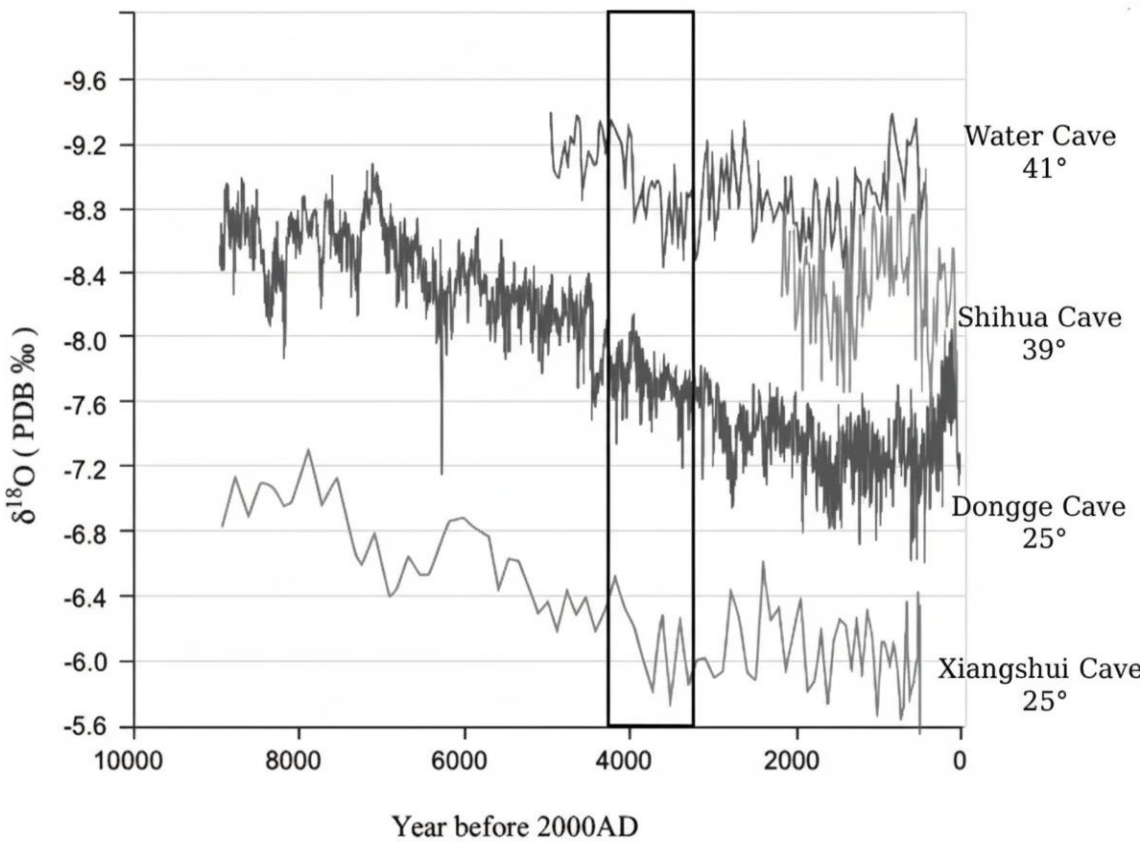
Gonghai 公海

Gonghai Lake in Ningwu County 宁武县 (Shanxi Province), a hydrologically-closed alpine lake, is located in the northern part of the Lüliang Mountains 吕梁山 on the northeastern margin of the Chinese Loess Plateau, a typical EASM dominated region. Chen *et al.* (2015) extracted and analyzed one sediment core from the central part of Gonghai Lake. The age model was developed using a combination of $^{210}Pb/^{137}Cs$ dating for the top 0.35 meters and 25 AMS-dated terrestrial plant macrofossils.

Sub-sampled at one-centimeter intervals, the core was examined for pollen, magnetic susceptibility, and calcium carbonate content. Using multiple models, Chen *et al.* (2015) identifies a two-phase reduction in precipitation, beginning at 5300 cal. yr BP and accelerating around 3300 cal. yr BP. The latter decline was more pronounced and persisted until the end of the Little Ice Age in the seventeenth century. This observation situates the Longshan Era in a relatively drier phase of the Holocene.

Water Cave 水洞

The Water Cave is located in Benxi, Liaoning Province. The region has a monsoon-influenced humid continental climate, which is characterized by humid and warm EASM during the summer months and the Siberian High during winter months. M. Tan and Cai (2005) obtained stalagmite oxygen isotope records and the results suggest that $\delta^{18}O$ ratio became higher (less negative) around 4000 BP (Figure 16), which could indicate a weakened monsoon and a drier climate.



(Tan and Cai 2005: fig. 1)

Figure 14. Comparison of different stalagmite oxygen isotope records.

Note: Black square highlights the changes around the end of Longshan Era.

Lianhua Cave 莲花洞

Lianhua Cave is located on the Chinese Loess Plateau, central Shanxi. The cave is in an arid-semiarid zone in the northern margins of the EASM region, with distinctive wet summers and dry winters. Three stalagmites in the cave were sampled for oxygen and carbon stable isotope analysis and dated by Uranium-Series dating method. The research team suggest that the 4.2k event "is not traceable …… in …. Lianhua Cave," suggesting a weak influence of the 4.2k event in this region (Dong *et al.* 2015: 132).

Tianchi Lake 天池

The Tianchi Lake in Zhuanglang 庄浪 County (Gansu Province) is located in the Liupan Mountains 六盘山 on the southwestern Loess Plateau, near the present East Asian monsoon margin. Nineteen samples of plant macrofossils were collected, and radiocarbon dated using AMS. The nineteen AMS dates are in good alignment with their depth (Zhao *et al.* 2010).

The analysis on fossil pollen assemblages shows that the pollen assemblages were dominated by Betula, Quercus, Picea, Pinus and with some Ulmus between 6200–2900 cal yr BP. Artemisia is the major herb taxon. From 2900 cal yr BP, both deciduous Betula and conifer trees decrease abruptly and herbs became important in the vegetation. By 1100 cal yr BP, Betula no longer dominated the vegetation, though was still present in the forest. In other words, the vegetation in this region changed from a closed canopy forest, dominated by both deciduous and coniferous trees, to an open landscape, dominated by shrubs, over the last 6200 years, reflecting a generally drying climate (Zhao *et al.* 2010), although there is no clear change that reflects the

4.2ka BP event in the pollen records, reflecting the complex response mechanism of vegetation to climate change.

Qingdao 青岛 profile

The studied profile is located in Qingdao (35°35'N, 119°30'E), Shandong, which is in the south of the Shandong Peninsula, adjacent to the Yellow Sea. The chronology is based on five radiocarbon dates. Pollen analysis reveals that between 4550 and 3900 cal BP, the concentration of pollen is low. Arboreal pollen decreased to 11.4%, and the Quercus percentage is only 1.9% (Chen and Wang 2012). This indicates that the Longshan Era experienced a cooling event.

Multiple Sites along the Jing River and Qishui River

The Jing River 泾河 is a major tributary of the Yellow River, flowing northwest to southeast before merging with the Wei River 渭河 in the Guanzhong Basin 关中盆地. The middle and upper reaches of the main channel, along with most of its tributaries, are deeply incised into the Loess Plateau and bedrock mountains, forming narrow and winding valleys with intense erosion. The lower reaches flow through the Guanzhong Basin, passing through loess tablelands and plains. The middle and upper reaches of the Jing River lie in a semi-arid region influenced by the monsoonal climate, where precipitation and hydrological patterns exhibit significant seasonal fluctuations—about 70% of the annual rainfall occurs between June and September (Huang *et al.* 2010). These short-duration, high-intensity rainstorms often trigger large-scale flood events, making the basin known for its severe flooding and high sediment

transport. Overbank floods frequently leave behind sediment deposits in inundated areas along their course. Among these, palaeoflood slack water deposits (SWD) serve as valuable indicators for reconstructing past hydrological events (Huang *et al.* 2010). Investigations of various profiles near archaeological sites have revealed multiple palaeoflood events dating to the Longshan Era (Huang *et al.* 2010; Gu *et al.* 2012; Huang *et al.* 2011), which are detailed below.

Yangguanzhai 杨官寨

The sampled profile is located at the forefront of the first terrace on the northern bank of the lower reaches of the Jing River, near Yangguanzhai village. The stratigraphy is well-preserved and clearly layered. The lower part consists of river terrace deposits with a distinct two-part structure while the upper part is covered by Holocene aeolian loess-paleosol layers, exhibiting distinct pedological and sedimentological characteristics. Based on field sedimentological observations, two sets of typical palaeoflood SWD were identified within the profile. According to OSL dating and magnetic susceptibility, the first set of SWD indicated five palaeoflooding events between 4.2-4.0 kya BP (Gu *et al.* 2012).

Chengjiachuan 程家川

The Chengjiachuan site (2300–2000 BCE) is located in middle reaches of the Jing River. On the sampled profile near the Chengjiachuan site, a set of five palaeoflood SWD beds occurred in the depth between 410–295 cm. These flood deposits directly overlay the primary cultural layer of the late Neolithic settlement. Additionally, slopewash deposits containing anthropogenic materials such as pottery sherds, charcoal, and burnt earth were identified

between the SWD layers. Notably, pottery fragments in the slopewash layer between SWD1 and SWD2 remain sharp-edged, indicating that they were originally deposited in the period between two flooding events rather than being reworked from older layers. The dating of these palaeoflood events is therefore closely linked to the settlement's occupation period. The pottery fragments retrieved from the slopewash layers have OSL ages that align with the main cultural layer, collectively dating the flood events to approximately 4100–4000 BP (Huang *et al.* 2010). This timeline corresponds with palaeoflood deposits found at the Yangguanzhai site in the lower reaches of the Jing River.

These findings suggest that major overbank floods on the Jing River occurred while the Chengjiachuan site was still inhabited. Peak discharge estimates for these palaeofloods, calculated using the slope-area method with a Manning's n value of 0.045, range between 19,500 and 22,000 m^3/s, making them 2.4 to 2.7 times larger than the highest recorded flood at the Jingcun hydrological station (8150 m^3/s). Researchers believe these represent the most extreme floods to have occurred on the Jing River during the Holocene (Huang *et al.* 2010).

Xuxizhuang 浒西庄

Similar to findings along the Jing River, evidence of paleofloods dating to 4300–4000 BP has also been documented along the Qishui 漆水 River, a tributary of the Wei River in the western Guanzhong Basin. Multiple layers of flood slackwater deposits were identified within Holocene loess-soil sequences on the riverbanks. The chronology of these floods was determined using OSL dating, supplemented by archaeological identification of anthropogenic materials

found in the sequences. The results indicate that successive flood events occurred between 4300 and 4000 BP, leading to repeated inundation of riverbank settlements.

Another period of extreme flooding took place between 3200 and 3000 BP, corresponding to the transition from the mid-Holocene Climatic Optimum to drier late Holocene conditions (Huang *et al.* 2011). While previous studies associated the 4200 BP event and the climatic downturn around 3100 BP primarily with droughts, this research provides concrete evidence that both severe droughts and extreme floods were integral aspects of climate variability during abrupt climatic shifts in semi-arid to sub-humid regions globally.

Synthesizing the dry events and palaeoflood events

In addition to the palaeoflood events identified along Jing River and Qishui River, comparable extreme flood events from the same period have also been documented in the Beiluo River 北洛河 to the east (Yao *et al.* 2008). This suggests that catastrophic flooding was widespread in the middle reaches of the Yellow River between 4200–4000 BP. These floods coincide with evidence of a major dry event recorded in the northern macroregion, as discussed above. Studies on the relationship between modern floods and monsoonal climate patterns suggest that such extraordinary flood events were linked to infrequent but severe rainstorms driven by anomalous atmospheric circulation patterns (Knox 2000; Huang *et al.* 2007). This also explains the pattern we observed based on the case studies listed above. In semi-arid and arid monsoonal regions, climate fluctuations are often marked by high variability, with alternating severe droughts caused by reduced rainfall and extreme floods triggered by intense

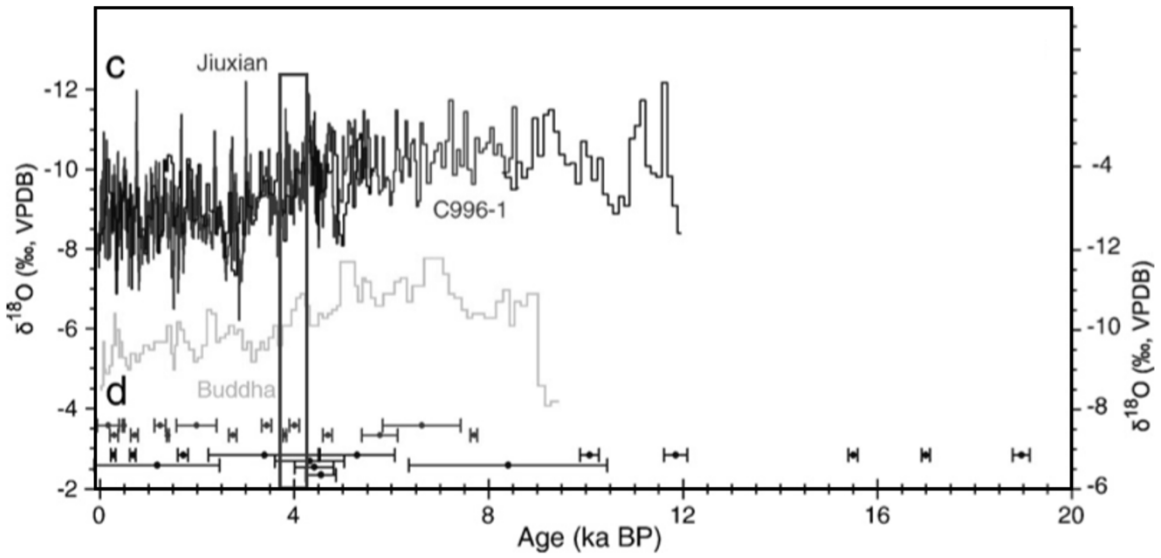
rainstorms. Periods of extreme climate conditions included both severe droughts due to insufficient rainfall and extreme floods triggered by intense rainstorms.

4.2 Southern Macroregion

In this chapter, the "Southern Macroregion" refers to the region south of the Qinling Mountains and Huai River and east of the Yungui Plateau. As demonstrated by the following regional studies, this area experienced wetter conditions during the 4.2 ka event.

Jiuxian Cave 九仙洞

The Jiuxian Cave, Zhashui County 柞水县, Shangluo City 商洛市 (Shaaxi) is situated on the southern slopes of the Qinling Mountains. The region's climate is largely shaped by the East Asian Monsoon, while the Qinling Mountains, spanning southern Shaanxi and extending from western Henan to eastern Gansu, serve as a significant climatic divide. These mountains act as a natural barrier, preventing warm, moist air from moving northward in summer and blocking cold, dry air from the north in winter (Cai *et al.* 2010).



(Cai *et al.* 2010: fig. 4)

Figure 15. δ18O records of the Jiuxian Cave stalagmites

Note: Black square (added by author) highlights the changes around 4000 BP.

Researchers collected two calcite stalagmites from the cave's deeper sections and dated them with 23 and 15 ^{230}Th dates respectively. The $\delta^{18}O$ analysis reveals higher values with centennial-scale fluctuations between 4.5 and 2.5 ka BP (Figure 15), suggesting that summer monsoon rainfall in central China started declining during this period, marked by substantial fluctuations (Cai *et al.* 2010).

When zooming into the plot around 4000 BP, one of the stalagmites indicated an overall increasing value of $\delta^{18}O$ ratio and thus declining rainfall, while the other stalagmite record indicated highly fluctuated conditions, with increasing $\delta^{18}O$ for the first half of the Longshan Era and decreasing values for the second half, thus indicated a change from declining rainfall to increasing rainfall with c. 4000 BP as the time boundary.

Xianglong Cave 祥龙洞

Xianlong Cave is situated in the upper Hanjiang River region on the southern slope of the Qinling Mountains. Researchers collected three stalagmites from the cave, with ^{230}Th dating confirming that their chronological sequence remains intact without any observed hiatus. The stalagmites grew during the periods 1972–4200 yr BP, 653–4912 yr BP, and 2984–6651 yr BP, respectively (Tan, Cai, *et al.* 2018).

Analysis of the $\delta^{18}O$ record indicates fluctuations in monsoon precipitation over time. Increased rainfall occurred during 6500–6100, 4850–4650, 4390–3800, 3590–2960, 2680–2450, 2050–1670, and 1110–790 BP, while reduced precipitation was noted during 5800–4900, 4640–4400, 2950–2680, 1670–1120, and 790–650 BP (Tan, Cai, *et al.* 2018). Of particular relevance to the Longshan Transformation, the $\delta^{18}O$ data suggest increased rainfall in central China between 4390 and 3800 yr BP, contrasting with concurrent drought conditions in northern China.

Gaochun 高淳 profile

The western Taihu Lake 太湖 basin experiences a subtropical humid monsoon climate. The Gaochun profile is located at the edge of the Great Danyang Lake 丹阳湖, positioned where the Mao Mountain 茅山 and Tianmu Mountain 天目山 meet on the western Taihu plain. Samples were taken from the Gaochun profile to reconstruct pollen records. Chronological data were established using 11 AMS dates, though two results were inconsistent with their depth. After

accounting for these anomalies, the age-depth model indicated that the profile developed over the past 13,200 calibrated years BP (Yao *et al.* 2017).

High-resolution studies using pollen and geochemical indicators have confirmed multiple climate fluctuations during the transition from the middle to late Holocene, as well as during the late Holocene. Between 4400 and 4000 cal. yr BP, rapid fluctuations in Quercus, evergreen-Quercus, Ulmus, and Artemisia pollen suggests that the 4.2k event is manifested here as a sudden cooling and drying event during this period. In other words, cool and humid conditions prevailed in the late Holocene and following the 4.2 ka event, both temperature and humidity showed a downward trajectory (Yao *et al.* 2017).

Shennong Cave 神农洞

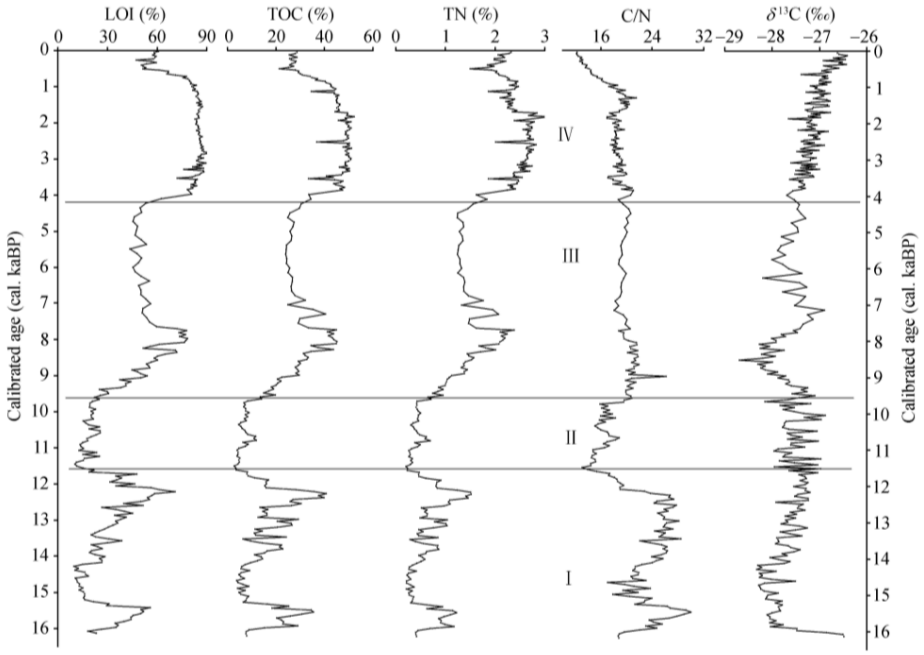
Shennong Cave is situated in northeastern Jiangxi Province, within the mid-subtropical zone heavily influenced by the EASM. A single stalagmite sample from the site was analyzed using ^{230}Th dating. The δ^{18}O and δ^{13}C records suggest that from 5.3 to 4.5 ka BP, the region experienced generally wet conditions, which shifted to drier conditions between 4.5 and 3.57 ka BP, except for a brief wetter phase from 4.2 to 3.9 ka BP. This data implies that during the 4.2 ka BP event, the area saw predominantly humid conditions (Zhang *et al.* 2018).

Dajiuhu peat 大九湖

The Shennongjia 神农架 Mountains are situated in northwestern Hubei Province. Controlled by the monsoonal climate, both temperature and precipitation in this area exhibit remarkable seasonal variability. The Dajiuhu Basin is located at the west of the Shennongjia

Mountains, with 1760–1700 meters in elevation. Ma *et al.* (2008) dug a pit to expose a profile and samples were taken from three sections. Chronological data were established using ten AMS dates, with the calibrated radiocarbon dates displaying a consistent sequence.

TOC percentage showed a marked increase between 4200 and 3800 BP (Figure 18), suggesting a climatic shift from warm and wet into cooler and drier conditions during this period. However, the $\delta^{13}C$ record started to decrease around 4.2ka BP then bounced back after 4.0ka BP, indicating a short-term wet event at the beginning of the Longshan Era. Similar event is not reflected by TOC or TN records. Rather, TOC and TN indicated a trend towards a cool and dry climate (Ma *et al.* 2008).

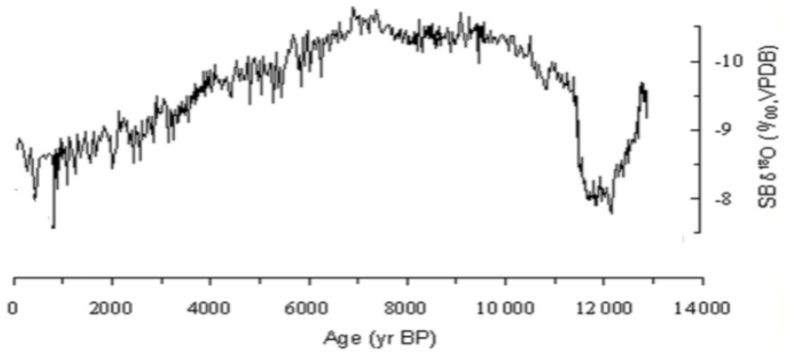


(Ma *et al.* 2008: fig. 4)

Figure 16. Curves of TOC, TN, and δ13C of the Dajiuhu peat profile

Sanbao Cave 三宝洞

Sanbao Cave is situated at an elevation of 1900 meters on the northern slope of the Shennongjia Mountains, within the modern subtropical front. Six stalagmites were sampled from the cave for analysis. The chronology was constructed using 65 ^{230}Th ages.[5] The findings reveal a gradual rise in $\delta^{18}O$ values from 6.5 to 0.2 kyr BP, which could indicate an overall reduction in precipitation during this period (Dong *et al.* 2010). Against this general trend, around 4400 BP, the $\delta^{18}O$ values saw a change towards heavier value, then a quick drop towards more negative values, which is followed by a bounce-back (Figure 17). This would indicate a drastic dryer-wetter-dryer change within five centuries with the time around 4000 BP being the period with higher moisture.



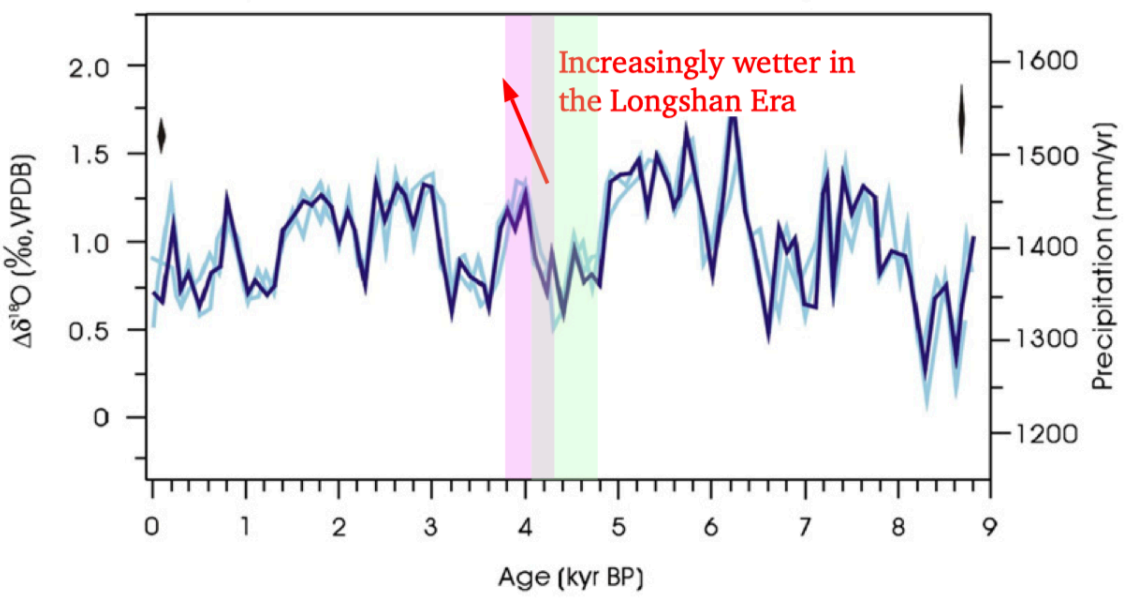
(Dong *et al.* 2010)

Figure 17. Composite $\delta^{18}O$ records from Sanbao Cave

[5] Note that previous research on the Sanbao Cave stalagmite (SB10) indicated very sudden rise and drop of $\delta^{18}O$ values starting 4.3 k BP (Shao et al. 2006). I would suggest that the suddenness is caused by the sparsity of ^{230}Th ages between 7.5-2.1 k BP: only 5 dates are available in the duration of more than five millennia. In the more recent, well-dated research discussed in the text, $\delta^{18}O$ values of the same stalagmite does not show the same suddenness and amplitude of change.

Heshang Cave 和尚洞

Heshang Cave, Changyang County 长阳县 (Hubei) is situated in the Qingjiang 清江 Valley of the middle reaches of the Yangzi River. The climate in this region is heavily influenced by the monsoon system. The age of stalagmite has been determined using both U-Th dating and layer counting. The $\delta^{18}O$ analysis indicates a sharp increase in rainfall between 4200 and 3800 BP, followed by a slight decline (Hu *et al.* 2008).



(Hu *et al.* 2008: fig. 7)

Figure 18. Reconstructed precipitation based on δ 18O values

Note: The values between 4200–3800 BP is highlighted in the pink square (added by author).

Xiangshui Cave 响水岩

Xiangshui Cave, situated in Guanyang County 灌阳县 (Guilin), provided a stalagmite sample for carbon and oxygen stable isotope analysis. The sample was dated using U-Th dating. The findings indicate that between 6000 and 3800 BP, the stalagmite's $\delta^{18}O$ and $\delta^{13}C$ values

were generally lighter, suggesting a stronger EASM and abundant rainfall. Overall, the period from 6000 to 3800 BP experienced a gradually weakening EASM under warm and humid conditions, followed by a cooler phase from 3800 to 373 BP when the EASM weakened further (Zhang *et al.* 2004). During the Longshan Era, $\delta^{18}O$ values rose (became less negative) sharply, indicating decreased precipitation during the Longshan Era (Figure 14).

Dahu Swamp 大湖

Dahu Swamp, situated in a small, enclosed basin within the eastern Nanling 南岭 Mountains, lies approximately 2 km southwest of Dingnan County 定南县 in Jiangxi Province. The site is on the border of Guangdong and Jiangxi Provinces. This region, positioned between the Yangzi and Zhujiang 珠江 River watersheds, marks the southern boundary of the mid-subtropical zone and is significantly influenced by both the East Asian monsoon and broader climatic shifts.

To analyze environmental changes, two different research teams extracted and radiocarbon-dated sediment cores from the swamp (Zhou *et al.* 2004; Zhong *et al.* 2010). They examined multiple indicators, including $\delta^{13}C$, bulk dry density (DD), total organic TOC, total nitrogen (TN), lacustrine organic matter (OM), grain size distribution, and mass magnetic susceptibility.

By integrating these proxy data, Zhong *et al.* (2010) identified alternating wet and dry phases. The period between approximately 6000 to 3000 BCE was a prolonged dry phase. When zooming into the Longshan Era, $\delta^{13}C$ became less negative and OM and DD increased around 4000 BP, indicating that the climate during the Longshan Era was increasingly drier. The TOC%

of the swamp samples showed a sudden drop around 4000 BP. The researchers observe that low TOC% corresponded with sand grains (indicating wetter conditions with stream deposition) and silt (indicating lacustrine conditions), whereas high TOC% corresponded with drier marshy (peat-forming) conditions. These interpretations are supported by overall pollen analyses. As such, the sudden reduction of TOC% should be understood as a very short wet phase during the prolonged dry period. This research situated the Longshan Era in a drier period.

Daping Swamp 大坪

The Nanling Mountains serve as a key geographical boundary between the middle and southern subtropical regions, dividing the watersheds of the Yangzi and Zhujiang river systems. The western section of these mountains lies within the transition zone between the EASM and the Indian Summer Monsoon (ISM) systems, making the area's paleoclimate patterns particularly complex. Zhong *et al.* (Zhong *et al.* 2015a; 2015b) highlighted that the timing of the Holocene optimum's onset and conclusion in this region differs from areas influenced solely by the EASM or ISM.

Zhong *et al.* (2017) retrieved a sediment core from the Daping Swamp in the Nanling Mountains, with its chronology established using eight radiocarbon-dated bulk samples. The isotope data from Daping Swamp indicate that the Holocene optimum spanned from approximately 8000 to 6000 cal BP. The termination occurred significantly earlier compared to other research, which suggest the termination date to be around 4000 BP (Shi *et al.* 1992). This

discrepancy may be attributed to variations in Holocene sea surface temperature (SST) in the western tropical Pacific and shifts in the primary EASM moisture source (Zhong *et al.*, 2015a).

Between 5000 and 4000 cal BP, elevated $\delta^{15}N$ and lower TOC/TN values suggest a period of deep water, increased aquatic organic matter input, and terrestrial organic matter deposition with lower $\delta^{13}C$ values, all indicative of warm and wet conditions. However, from 4000 to 2500 cal BP, rising TOC/TN ratios and higher δ13C values point to a greater influx of terrestrial organic matter with higher $\delta^{13}C$ values, signaling a transition to cooler and drier conditions. This suggests that during the latter half of the Longshan Era (around 4000 BCE), a climatic shift from warm and wet to cold and dry took place. However, given the resolution limitations of the radiocarbon dates, the precise timing of this transition within the Longshan period remains uncertain.

Daiyun peat 戴云

The Daiyun Mountain 戴云山 located in central Fujian Province, falls within the southern subtropical climate zone. Researchers analyzed two sediment sections from which pollen samples were collected and dated using AMS, although a slight age-depth reversal was observed at a depth of 32-31 cm. Between 7000 and 2450 cal. yr BP, the pollen record was dominated by evergreen Quercus, which had the highest concentration throughout the sequence. Castanopsis and Castanea also contributed significantly, indicating a warm and humid climate that facilitated the widespread growth of warm-temperate evergreen broadleaf forests in the region (L. Zhao *et al.* 2017). These findings situate the Longshan Era in a wet phase.

Archaeological sites in the Yangzi River region

Zhongqiao 钟桥 site

The Zhongqiao site is located on the first terrace of the north bank of the Changhu Lake. It extends NE-SW along the border zone of the loess terrace and downhill between the northwestern edge of Jianghan Plain and the Jingshan 荆山 Mountains. The site is only 30 km away from the Yangzi River, flood deposits form readily under the dual impact of backwaters and summer peaks of the Yangzi River. A total of 225 samples were taken from the cultural layers on the excavation unit profiles. The samples were dated by AMS. The researchers identified three paleoflood events dating to 4800–4597, 4479-4367, and 4168-3850 cal. yr BP respectively (Wu *et al.* 2017).

The three flooding events correspond to the Qujialing period, Early to Middle Shijiahe period, and Late Shijiahe to Xiaojiawuji periods. While the transition from Qujialing to Shijiahe culture was companied by cultural continuity with sustained population growth, and the Early to Middle Shijiahe phases the peak of the settlement density and cultural prosperity in Middle Yangzi, the Late Shijiahe and Xiaojiawuji periods are very sparsely populated (C. Zhang 2013). The end of the Xiaojiawuji period brought a cultural breakage in the Middle Yangzi Region and a sudden drop in the number of settlements (C. Zhang 2017). In other words, similar flooding events are accompanied by distinct cultural trajectories, suggesting that major floods alone were not the sole drivers of the broader cultural transformations marking the end of the Longshan Era.

Zhongbaodao site 中堡岛

The Zhongbaodao site is located on the southern bank of the Xiling Gorge 西陵峡 section of the Yangzi River, between Sandouping 三斗坪 in Yichang 宜昌 County (now under the jurisdiction of Yiling District, Yichang City) and Maoping 茅坪 in Zigui 秭归, at the site of the Three Gorges Dam (Yang *et al.* 2002). The site has been occupied since the Daxi 大溪 cultural period, and on top of the layer of the subsequent Qujialing cultural period laid a thick layer of river sands, suggesting a significant palaeoflood event after the Qujialing period (Yichang 1996). During a later savage excavation, Shijiahe cultural remains (or Jishi 季石 type or Baimiao 白庙 type), though less abundant, were discovered at the site, on top of which laid another layer of river sand, indicating another palaeoflood event following the Shijiahe period. Although the researchers did not provide OSL dating for this layer, based on the stratigraphy of the cultural layers, it is likely that this second flood event was concurrent to the Longshan-Era floods identified in the eastern part of Jianghan Plain (Yang *et al.* 2002). Collectively, they suggest frequent flooding events in the Middle Yangzi during the Longshan Era.

4.3 Southwestern Macroregion

Here, "Southwestern Macroregion" mainly refers to the Yungui Plateau 云贵高原. As the following regional studies demonstrate, despite some outliers, there was a general drying trend in this macroregion during the Longshan Era.

Xianren Cave 仙人洞

Xianren Cave is located in the Ninglang 宁蒗 County, Yunnan Province. The study area is under the low-latitude plateau monsoon climate. During the winter and spring, it is mainly influenced by westerly circulation, exhibiting strong continental monsoon characteristics with dry conditions and minimal precipitation. In summer, warm and humid airflows from the southwestern Pacific or southeastern Indian Ocean dominate the region.

The stalagmite sampled, located 20 meters from the cave entrance, was dated using three TIMS-U dates (Zhang *et al.* 2006), although the number of dates (3 dates spanning 4500–2000 BP) and the wide error (from ±200 to ±300) rendered the dating resolution very low. Isotopic analysis of carbon and oxygen reveals that between 4500–4000 BP, the climate was relatively warm and dry, likely due to a reduction in the Indian Ocean monsoon. Between 4000–3400 BP, the climate shifted to relatively cold and dry, with a short period of wet climate around 4000 BP (Zhang *et al.* 2006).

Dark Cave 黑洞

The Dark Cave is located about 35 km northeast of Qianxi County 黔西县, Guizhou Province. The region experiences a typical monsoon climate, with warm, wet summers when the intertropical convergence zone (ITCZ) lingers over south-central China, and cold, dry winters when the Siberian High dominates Asia, causing the ITCZ to shift southward. Two stalagmites were sampled and dated using 28 ^{230}Th dates, all of which are consistent with the stratigraphic order.

The Dark Cave stalagmite $\delta^{18}O$ record shows a gradual decline from -9.5‰ at 6.1 kyr BP to -6.9‰ at 0.49 kyr BP, reflecting a long-term decrease in EASM intensity since the mid-Holocene. Four distinct periods of weak monsoon, each lasting more than 100 years and marked by high $\delta^{18}O$ values with amplitudes ranging from 0.5-1.5‰, were identified (Jiang *et al.* 2013). These periods occurred around abrupt transitions in $\delta^{18}O$ values at 4.2, 2.8, 1.6, and 0.5 kyr BP in both stalagmite records (Jiang *et al.* 2013). This suggests that the climate during the Longshan Era may have been drier than during earlier periods.

Shigao Cave 石膏洞

Shigao Cave is located in the Shuanghedong 双河洞 National Geological Park in Suiyang 绥阳, Guizhou Province. The regional climate is similar to that of Dark Cave. Two stalagmites were collected from the cave, and their chronology is established through 12 ^{230}Th dates. The $\delta^{18}O$ values indicate a gradual decline in precipitation from 6.6 to 1.6 kya BP. Notably, at around 4.0 kya BP, a sudden 1‰ increase in $\delta^{18}O$ values took place over a 700–year period, which coincides with the slowest growth rate of the stalagmites (Jiang *et al.* 2012). This shift suggests a rapid decrease in monsoonal precipitation during this time, placing the Longshan Era within a period of significant drying.

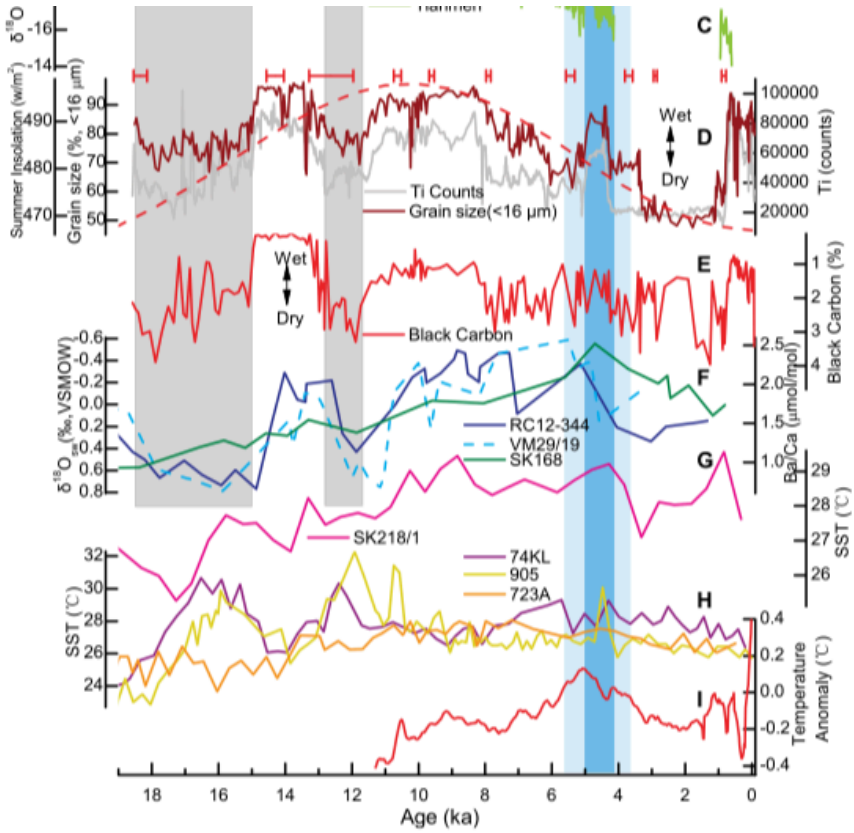
Erhai Lake 洱海

Erhai Lake is situated on the northwestern Yunnan Plateau, where the climate is a low-latitude plateau subtropical monsoon type, marked by distinct wet and dry seasons. The climate is influenced by the alternating effects of the westerly southern branch jet stream and the

southwest monsoon from the Bay of Bengal, as well as the plateau climate system of the Tibetan Plateau. A sediment core was extracted from the lake's central area, and high-resolution multi-proxy analyses, including AMS dating, pollen-spore, grain size, algae, and carbon fragments, were conducted. These analyses revealed eleven phases of climatic and environmental changes over the past 10,000 years. Four significant global cold events were recorded, occurring at 9.9 ka BP, 8.5 ka BP, 7.1 ka BP, and 5.1 ka BP. After 5100 BP, temperatures slightly increased, but the climate remained cold and dry (Zhou *et al.* 2003), although no direct evidence of the 4.2k event was found in the pollen assemblages.

Qinghai Lake 青海

Qinghai Lake is a small maar lake located near Tengchong 腾冲 in southwestern Yunnan. The hydroclimate in the eastern Indian Summer Monsoon region has been influenced by both boreal summer insolation and sea surface temperature. A sediment core was collected from the central area of the lake and dated by 10 AMS dates. Zhang *et al.* (2017) used small grain-size (SGS) distribution as the main proxy for lake-level changes, with increased SGS corresponding to increased lake levels. Titanium, a conservative element, mainly comes from catchment runoff and thus monsoon rainfall; therefore, higher titanium concentration would correspond to higher lake-level. The results revealed millennial-scale hydroclimate fluctuations, including a wet period between 5 and 4 ka and a dry phase from 4 to 1 ka (Figure 19) (Zhao *et al.* 2017). This finding places the Longshan Era at the tail end of the pronounced wet phase.



(Zhang *et al.* 2017: fig. 2)

Figure 19. SGS and Ti counts from the Qinghai Lake sediment core

Note: Blue shaded band indicates the pronounced wet event during the mid-Holocene.

Dongge Cave 董哥洞

Dongge Cave, located in Libo County 荔波县, Qiannan 黔南, Guizhou Province, provided stalagmite samples for analysis. The region experiences two distinct seasons: a cool, dry winter influenced by the Siberian high, which causes a strong anticyclone on the Tibetan Plateau, and a warm, wet summer when the intertropical convergence zone shifts north, bringing maximum monsoonal rainfall. Researchers identified an event occurring between 4.4 and 3.9 ky BP, marked by a general decrease in monsoonal intensity (Figure 14). This event, both long-lasting

and significant, showed an abrupt transition with a change of 0.8 to 1.0‰ and two brief reversions (Wang *et al.* 2005). This indicates that during the Longshan Era, the region underwent a drying phase, interspersed with two short periods of increased rainfall.

4.4 The Tibetan Plateau

Hongshui River section

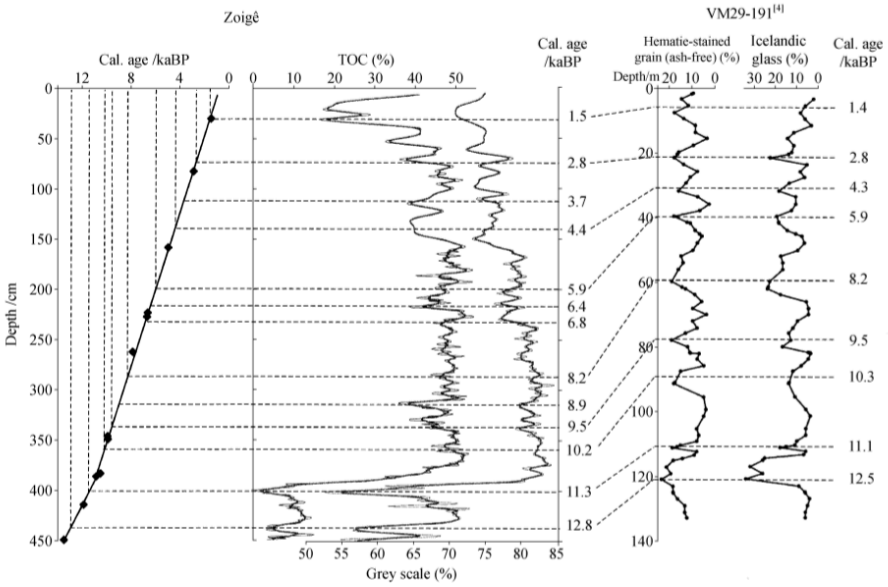
The study area lies at the junction of the Tengger Desert and the Wuwei alluvial–fluvial fan of the Qilian Mountains on the northeastern Tibetan Plateau. It is bordered by the Tengger Desert to the north, the Loess Plateau to the southeast, and high mountain and plateau regions to the southwest. This region, positioned in the southeastern part of the Eurasian continent—and contrasting with the vast Pacific Ocean—experiences significant topographical variations, which plays a key role in the thermodynamic processes that drive the monsoon system. Climatically, the area is influenced by multiple systems: the arid to hyperarid regions of northwest China, the semi-arid conditions to the southeast, and the cold high-altitude plateaus to the southwest. The Westerly Jet meanders through the region, while the East Asian Monsoon brings seasonal rainfall between July and September. In contrast, winter is dominated by the Siberian–Mongolian High, bringing cold, dry air and subzero temperatures. Due to its climatic sensitivity, the region serves as a valuable site for studying both regional and global climate variations (Zhang *et al.* 2000).

Sediment samples were collected at 10 cm intervals from a section along the Hongshui River, with the chronology established using eight conventional radiocarbon dates (Zhang *et al.*,

2000). Analysis of TOC, $\delta^{18}O$ values, and pollen data indicates that between 4300 and 3740 BP, the region experienced a prolonged and intense cooling phase, characterized by cold and humid conditions (Zhang *et al.* 2000).

Zoigê-Hongyuan Plateau

The area is characterized by a cold and wet climate, with long winters and no summers, as well as a long frost period. This area is a transition zone between semi-humid sub-mountain and semi-humid temperate climates, and its northeast margin is significantly influenced by the southwest monsoon. The peat swamp sampling site is in Hongyuan County, Sichuan. One sediment core was taken here and the chronology was established with AMS dating. The results show that between 4400–3700 BP, TOC% significantly rose and dropped (Figure 20), indicating the climate might have been relatively drier than previous during this duration.



(Zhou *et al.* 2002: fig. 2).

Figure 20. TOC profile from the Zoige Plateau

5.**Discussion**

5.1 Regional Variation of Climate Change

While the late Holocene witnessed a long-term cooling and drying trend, when zooming narrowly into the Longshan Era (2400–1800 BCE) a varied pattern of climate change across different parts of the Longshan world emerges. Table 4 summarizes the macroregion and the climate change trends observed in that macroregion. The number in the table indicates the number of sites showing the corresponding trends. Despite some exceptions, such as the Gaochun profile in southern Zhejiang and Dahu peat in southern Fujian, chi-squared test reveals a statistically significant correlation between climate trend and region, with a p-value of 0.0057. The map at the beginning of this chapter also visualize similar trends (Figure 12). The general macroregional pattern can be summarized, therefore, as follows. During the Longshan Era, northern China, the Tibetan Plateau, and the Yungui Plateau became drier, while southern China became wetter and the Middle Yangzi and Middle Yellow river valleys experienced frequent floods.

Table 3. Summary of Regions and Associated Climate Change Trends. The number in the table indicates the number of sites experience the corresponding climate change.

Region	Drier	Wetter	No clear change	Mixed
Northern Macroregion	8	1	0	0
Southern Macroregion	1	6	0	1
Southwestern Macroregion	5	1	0	1
Tibetan Plateau	1	0	1	0

Paleoclimatologists suggest that these differences were driven by a southward displacement of the mid-latitude westerlies and a weakening of the East Asian summer monsoon caused by complex mechanisms (Liu and Zhu 2024), such as changes in solar output (e.g., Bond *et al.* 2001 and Wang *et al.* 2005) and the weakened Atlantic Meridional Overturning Circulation (Zhang *et al.* 2018: 1318). As a result, areas in the Northern Macroregion that previously received monsoonal precipitation experienced intensified aridity, whereas southern and southeastern regions—closer to the monsoon front and influenced by increased water vapor transport from the South China Sea—saw relatively enhanced humidity (e.g., Zhang 2018 1318). These circulation shifts likely produced the contrasting hydroclimatic conditions that framed the divergent developmental trajectories of regional societies.

The regional variation in climate change has important implications for understanding the Longshan Transformation. Rather than broadly linking the entire 4.2k event to the Longshan Transformation as a whole—as many previous studies have done—it is crucial to consider the regional specificity of climate shifts. It has been suggested that the cooling and drying event drove southwards migration within the steppes and in northern China (e.g., Liu and Feng 2012), and in recent years, researchers also suggest that such events have contributed to the spread of sheep husbandry in northern China. While such correlation may oversimplify the complexity between climatic and cultural changes, the rise of Highland communities—characterized by similar forms in their pottery assemblages (which may have resulted from frequent interactions among different communities) and increasing reliance on sheep and cattle herding in their economic configuration—should be situated within the context of such climatological changes.

In the meantime, in the south, the relatively sudden increase in rainfall, may have had catastrophic results. As the Shennong cave records have shown, the wet interval around 4.2 ka BP is situated within a long-term drying phase (above). Such a situation may have weakened the ability of the ancient populations of southern China to respond to flooding and heavier rainfall. While the collapse of Liangzhu, which predates the Longshan Transformation (discussed below), is beyond the scope of this dissertation, flooding events have been frequently cited as the cause for such cultural changes and research also suggests that long-term drying before the 4.2 ka BP made the situation worse (e.g., Zhang *et al.* 2021).

The case studies presented here do not support a simplistic view that Longshan societies collapsed due to drought while southern cultures like Liangzhu and Shijiahe declined because of flooding. Rather than endorsing such broad, deterministic explanations, this analysis emphasizes that aridification does not uniformly lead to societal decline, fragmentation, or collapse. In some cases, such as the rise of Longshan Highland communities, environmental shifts may have even facilitated sociopolitical development, while southern regions appear to have been more adversely affected by inundation. This complexity arises not only from regional differences in climate trends, but also from the diverse ways in which human societies respond to environmental change. Future research should consider the multiple layers of complexity arising from both climate change and human agency.

5.2 Macroregional time lag in climate change and its implication

Based on dated stalagmite records, it is noticeable that the trend of increasing ^{18}O values (which we can, at the risk of oversimplification, understand as an index for weaker East Asian monsoon activities) took place first in low-latitude regions then in mid-latitude regions. This is observed around 7.0 ka BP according to the Dongge Cave records on the Yungui Plateau, around 5.3 ka BP according to the Heshang Cave in the Yangzi River region, around 4.7 ka BP according to Sanbao Cave in the Shennongjia Mountains, around 4.5 BP according to the Shennong Cave in Jiangxi,[6] and around 4.5 BP according to the Jiuxian Cave in the south slope of the Qinling Mountains, and 4.2 BP according to the Water Cave in northeastern China. Although the only stalagmite from the Northern Macroregion does fit in this pattern, stalagmite data in northern China is essentially insufficient to determine how well this pattern applies to the situation in northern China.

That said, should the "south-early and north-late" pattern stand, this time difference in climate change poses a very interesting question as the transformation of archaeological cultures also happened in southern China before that in northern China. Is this time lag relevant to the different timing of climate change in southern and northern China? Although with current data, it is hard to make a conclusive statement, I would like to present a potential correlation here.

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[6] Zhang and colleagues' (2018) research shows that the climate in the area of Shennong Cave changed to a rather dry condition between 4.5 and 3.57 ka BP, interrupted by one wet interval between 4.2 and 3.9 ka BP. Therefore, while the Longshan Era climate was characterized by a short event of wetter condition, the long-term trend has shifted around 4.5 BP.

The fragmentation and transformation of archaeological culture along the Yangzi River predates the Longshan Transformation. As briefly mentioned in the previous chapter, the end of the Liangzhu Culture in Lower Yangzi is traditionally dated to the second half of the third millennium BCE (Renfrew and Liu 2018b; Zhang *et al.* 2015). While at very specific sites, it may have lasted until 2200 BCE (Zhejiangsheng and Huzhoushi 2014: 601), the materials have become very sparse by then. Moving to Middle Yangzi, by 2300 BCE, the Qujialing-Shijiahe Cultures had disintegrated and transitioned into the Late Shijiahe Phase, with significant drop in settlement number and density and clear decline in the quality of pottery production (for changes in material culture, see Zhang 2013; for radiocarbon dates, see Liu and Yi 2914).

Putting the chronology and settlement pattern change of Liangzhu and Shijiahe Cultures together, we can roughly situate the transformation of the communities along the Middle and Lower Yangzi between 2300–2100 BCE, predating the Longshan Transformation around 2000–1800 BCE in northern China. Assuming the changing climate may plant the seeds for social change (the change could happen along different directions, social consolidation or disintegration and cultural diversification or unification, etc.) the difference in the pace of climate change may be partially responsible for the time lag in social transformation observed in southern and northern China respectively.

It should also be clarified that previous research has pointed out that speleothem records indicate relatively consistent climate trend during the Longshan Era, although proxy data other than speleothem suggest the Holocene Optimum ended somewhat later, and such time lag is like caused by different responding mechanisms of different proxy data to climate change (K. Su and

Kidder 2019: 112). The time lapse referred to in this section is consistently reflected by speleothem records, which are dated using U-Th method. Therefore, we can rule out the possibility that these temporal differences are simply the result of using different types of proxy data or using different dating methods.

6. **Conclusion**

This chapter has examined the regional and temporal variability of climate change before and during the Longshan Era and explores its potential relationship with the Longshan Transformation. While a general drying trend prevailed across various macroregions following the Holocene Optimum, the 4.2 ka BP event introduced more complex regional patterns. Between 4200 and 3800 BP, the northern macroregion experienced intensified aridity, while the southern macroregion witnessed increased humidity. Furthermore, along both the Yellow and Yangzi Rivers and their tributaries, flooding events were frequent. Along the Yellow River and its tributaries, floods were likely caused by sudden rainfall following prolonged droughts. In the Yangzi River basin, floods appear to have resulted primarily from heavy rainfall. Some records also indicate decadal-scale climatic reversals, suggesting short-term variability superimposed on long-term trends.

These environmental instabilities correspond with divergent cultural trajectories between the Yellow and Yangzi River regions between 2400 and 2300 BCE: while the Liangzhu and Shijiahe cultures in the middle and lower Yangzi began to decline, the Lowlands and Highlands Longshan communities in the Yellow River basin reached new heights of complexity.

Additionally, asynchronous onsets of climate change may be associated with the different timing of societal changes in northern and southern China. Speleothem records suggest that the 4.2 ka BP event began earlier in the south than in the north—a pattern that aligns with the earlier collapse of the middle and lower Yangzi societies around 2300 BCE and the later decline of Yellow River societies around 1800 BCE. These divergent responses may also result from distinct adaptive strategies employed by different communities. Comparative analysis between the Liangzhu and various Longshan societies may help elucidate the ways in which social organization, economic practices, and political structures influenced resilience or vulnerability to environmental stress. While such discussion is beyond the scope of this dissertation, it might be worth exploring in future research.

It is also worth noting that, while past research has often been criticized for conflating synchronic correlations with causation, the challenge in this case is more fundamental: we cannot yet determine with confidence whether climate change and socio-cultural transformations during this period were even synchronous (for a similar argument focused on the Lower Yellow River, see K. Su and Kidder 2019). This uncertainty stems in part from the difficulty of precisely dating climatic shifts, as discussed earlier in this chapter, and in part from the regional variability of the 4.2 ka BP event, which precludes the establishment of a single, uniform date for its occurrence.

The 4.2 ka BP event should not be understood as a homogeneous phenomenon, nor should its impacts on human societies be assumed to follow a uniform pattern. Nevertheless, social disturbances are often associated with climate change without specifying the mechanisms by

which the latter may have produced the former. A common—yet rarely examined—assumption is that climate change led to agricultural failure, which in turn caused food crises and social disruption. But is this truly the case in the Longshan Era? Is there archaeological evidence suggesting food insecurity during this period? The next chapter will examine this often implicit assumption embedded in climate-driven models of social collapse.

Chapter 2. Food (In)security

1. Introduction

As Chapter 1 has reviewed evidence for climate change, this chapter will examine a related but often implicit assumption in climate-based hypotheses: that climate change led to agricultural failure, which subsequently triggered social disruption, population decline, and large-scale migration—developments that ultimately manifested as "collapse" in the archaeological record. To evaluate this largely untested assumption, I attempt to address the question of whether there are signs of food insecurity in the archaeobotanical, zooarchaeological, and osteological records. The chapter takes a broad regional approach, assessing evidence for food insecurity across the Longshan world by analyzing proxy data from Haidai, Zhengluo, Yulin, and Jinnan. The survey, however, produces an inconclusive result: there is no strong evidence showing food insecurity, although this absence of evidence should not be taken as definitive proof of the absence of dietary stress.

2. Osteological records

2.1 Indicators and expectations

Osteological and bioarchaeological research provides the most direct evidence of food insecurity, as malnutrition and physiological stress often leave identifiable traces on human skeletons. Biological anthropologists employ a range of skeletal and dental stress indicators that can be empirically measured. One of the most commonly observed indicators is linear enamel hypoplasia (LEH), which manifests as linear or pitted defects on tooth enamel (Larsen 2015:

46). These defects occur when systemic stress or nutritional deficiencies interrupt normal enamel formation during childhood (*ibid*). Because teeth do not remodel after they form, these disruptions provide a durable record of early-life stress. A study based on a medieval Gaelic population from Ballyhanna shows that compared to porotic hyperostosis and healed periosteal lesions, and stunting and micronutrient deficiency, LEH appears to be most closely related to the decrease of survivorship (Wyatt *et al.* 2023). Thus, in the analysis below, I will devote particular attention to this indicator, while using other indicators as supplementary indexes. If food security was deteriorating, I would expect an increase in LEH prevalence during the Longshan Era (for similar research and further references, see Bereczki *et al.* 2018).

Another important set of indicators includes cribra orbitalia and porotic hyperostosis. These conditions present themselves as porous lesions in the orbital roofs and cranial vault, respectively, and are typically associated with anemia, often due to iron deficiency (Stuart-Macadam 1985). Such anemia may result from inadequate dietary intake, chronic infections, or gastrointestinal parasites. Their presence can suggest systemic stress and immune challenges that accompanied poor nutritional status.

Deficiencies in specific micronutrients also produce distinctive skeletal changes. Vitamin C deficiency, or scurvy, may cause porosity and abnormal bone growth, especially around the face and skull, due to subperiosteal hemorrhaging (Brickley and Ives 2006; Ortner and Ericksen 1997). Vitamin D deficiency can lead to rickets in children, characterized by bowed limbs and flared metaphyses, or osteomalacia in adults, marked by bone softening, pain, and increased

risk of fractures (Mays *et al.* 2006). These conditions reflect inadequate access to sunlight or essential dietary sources.

Despite the diagnostic potential of osteological analysis, no systematic studies of Longshan-Era human remains have yet applied these bioarchaeological indicators on a transregional scale. Consequently, it is currently not possible to quantify the frequency or regional variation in these signs of physiological stress across the Longshan world with sufficient sample size. The discussion that follows instead outlines the skeletal clues through which future research might pursue a more systematic investigation of food insecurity and stress in Longshan populations.

2.2 Discoveries

Table 5 presents a summary of stress indicators identified in the Zhengluo, Haidai, and Ordos regions. Although the sample sizes are limited and many remains are fragmentary—introducing the potential for error—some clear patterns still emerge.

Table 4. The discovery of indicators for dietary stress. The number in [] indicates sample size.

Site	Porosity of cranial vault	Moderate/severe porotic hyperostosis	Cribra orbitalia	Sphenoid porosity	Linear enamel hypoplasia	Reference
Zhengluo						
Guanjia (Middle Yangshao)	0.33 [21]	0.14 [21]	0.1 [20]	0 [4]	0.76 [17]	Pechenkina *et al.* 2007
Xipo (Middle Yangshao) [adult]	0.30 [17]	0.12 [17]	0.06 [16]	0 [11]	0.33 [12]	
Meishan (Late Longshan)	0.83 [6]	0.5 [a/6]	0.5 [6]	—— ——	0.6 [5]	Sun *et al.* 2020

Mengzhuang (Late Longshan)	0.14 [7]	0.14 [7]	0.4 [5]	——	1 [4]	
Haojiatai (Late Longshan)	——	——	0.23 [13]	——	0.89 [9]	
Pingliangtai (Late Longshan)	——	——	0.14 [14]	——	0.8 [10]	
Xiazhai (Late Longshan)	——	——	0.05 [20]	——	0.92 [25]	
Haidai						
Liangwangcheng 梁王城 (Dawenkou Culture)	——	——	0.006 [146]	——	——	Zhu *et al.* 2013
Fujia 傅家 (Dawenkou Culture)	——	——	0.194 [129]	——	0.27 [107]	Zhang 2016
Jiaojia (Late Dawenkou)	0.0575 [86]	——	——	0.0227 [86]	0.51 [86]	Zhang 2017
Dinggong 丁公	——	——	——	——	0.1631 [31]	Zhang 2016
Yuchisi 尉迟寺 (Dawenkou)	——	——	0.375 [8]	——	0.286 [21]	Zhongguo 2001
Yuchisi (Longshan)	——	——	1 [1]	——	0.5 [6]	Zhongguo 2001
Ordos						
Houyangwan (Shimao Culture)	0.17 [6]	——	——	——	——	Chen *et al.* 2017
Muzhuzhuliang (Shimao Culture)	0.14 [7]	——	——	——	——	Chen *et al.* 2015

Bioarchaeological data from multiple Longshan sites reveal significant regional variation in the prevalence of linear enamel hypoplasia (LEH), a key indicator of early childhood stress. The Jinnan region exhibits almost no evidence of LEH. At the Xiajin cemetery, which dates to the

Early Taosi phase, only one out of 283 individuals (Tomb M258) shows signs of enamel hypoplasia, resulting in an effectively 0% prevalence. Similarly, low LEH rates are found at Taosi and Qingliangsi cemeteries, which are also associated with earlier phases.

In contrast, in the Zhengluo region, LEH rates are exceptionally high: 88.89% at Haojiatai, 80.00% at Pingliangtai, and 92.00% at Xiazhai (Sun *et al.* 2020). These sites, dated between approximately 2448 and 1662 BCE, suggest that local populations experienced physiological stress during early childhood. Particularly high LEH rates on the I2, C, and P1 teeth point to disruptions in enamel formation between the ages of 2 and 4—likely due to malnutrition, micronutrient deficiencies, or disease.

In the Haidai region, LEH, moderate to severe porotic hyperostosis, and cribra orbitalia have been observed at several Dawenkou-period sites (Liangwangcheng, Fujia, Jiaojia, and Yuchisi), while data from Longshan-period burials remain sparse. This is partially because of the limited skeletal recovery in the Longshan period, resulting from the transition from communal cemeteries to household-based burial practices at this time (Sun 2020). Nevertheless, the Dinggong 丁公 site, one of the central Longshan sites in the region, does yield LEH cases (16.31%), though at significantly lower frequencies than Zhengluo (statistical comparison below).

Finally, in the Yulin region, bioarchaeological data remain limited due to the absence of large communal cemeteries. Only two sites yield evidence of LEH, with a modest prevalence of 15.38%, more comparable to Dinggong than to the Zhengluo group.

To understand the variations stated above, one should consider regional and temporal differences. This stark contrast between the Jinnan and Zhengluo regions may reflect genuine regional differences in childhood stress and nutrition, although alternatively, the temporal discrepancy—the samples from Xiajin, Taosi, and Qingliangsi being earlier than the Middle and Late Taosi-dated sites in Zhengluo—may imply an increasing trend of nutritional stress over time during the Longshan period. The samples from Haidai and Zhengluo are essentially contemporaneous, and the differences between these two groups should be understood as regional variations.

Analysis on stable isotope, plant, and animal remains adds dietary context to these stress indicators. Populations at Haojiatai, Pingliangtai, and Xiazhai relied heavily on millet with minimal meat consumption (Zhou 2017)—diets that correlate closely with their high LEH rates. Within the same region, individuals at Meishan consumed more rice and meat (*ibid*) and had a lower LEH prevalence. While we don't have the stable isotopic results from Dinggong, the results of faunal and floral remains suggest people at Dinggong practiced a mixed subsistence economy including rice agriculture, fishing, hunting, and gathering (Rao 2014; Wu *et al.* 2018). Similarly, people in Jinnan had dry farming with rice as supplement (Zhao and He 2006). Pigs contributed as a major source of meat, while sheep, which may have been exploited for wool production, also served as a meat source (Brunson 2015). These dietary differences may partly explain the regional disparities in stress markers.

2.3 Statistical Comparison of Physical Stress across Time and Regions

Several indicators reported are related to anemia and thus they are grouped together for statistical comparison, which reveals significant variation in physiological stress indicators across temporal and regional contexts in the Longshan world. Comparisons between the Middle Yangshao and Late Longshan sites in the Zhengluo region show a statistically significant increase in LEH prevalence in the latter (Chi-square = 7.05; p = 0.0079), suggesting elevated early-life physiological stress during the Late Longshan period. Relative risk (RR) and odds ratio (OR) analyses further support this trend: individuals from the Late Longshan period were 1.5 times more likely to exhibit LEH (RR = 1.49), with over 4.7 times the odds of LEH occurrence (OR = 4.73) compared to Middle Yangshao populations.

In contrast, anemia prevalence does not differ significantly between Middle and Late Yangshao (Chi-square = 0.62; p = 0.432), and Late Longshan individuals actually show a lower risk of anemia. The relative risk for anemia in Late Longshan is 0.70, and the odds ratio is 0.62—suggesting a moderate, but statistically non-significant, decrease. The conflicting patterns observed in LEH and anemia-related lesions lead to an inconclusive assessment of whether Late Longshan sites exhibit stronger evidence of dietary stress.

Data from the Haidai region indicate a significant decline in LEH prevalence from the Dawenkou to Longshan periods (Chi-square = 4.49; p = 0.034). Longshan individuals had less than half the risk (RR = 0.43) and about one-third the odds (OR = 0.32) of developing LEH

compared to Dawenkou populations. This points to a substantial improvement in early-life health and reduced physiological stress in Haidai during the Longshan period.

In the Jinnan region, diachronic comparison is limited due to the absence of earlier Miaodigou-period skeletal data. However, comparison between Jinnan Longshan and Haidai Dawenkou populations shows a highly significant decrease in LEH prevalence (Chi-square = 188.91; $p < 0.0001$), further indicating improved childhood health during the Longshan period. Anemia prevalence also differs significantly (Chi-square = 10.06; $p = 0.0015$), although here Dawenkou populations show a lower relative rate than Longshan, suggesting a more complex pattern.

The Zhengluo region, despite undergoing internal reorganization, does not show evidence of dramatic collapse; in contrast, Jinnan and Haidai are thought to have experienced more severe disruptions during the Longshan Transformation (e.g., Zhang 2017; Zhang 2018). Should social collapse be driven by nutritional stress, we would expect higher prevalence of osteological stress markers in Jinnan and Haidai and lower levels in Zhengluo. However, the data show the opposite: Zhengluo exhibits the highest prevalence of LEH, while Jinnan and Haidai populations display lower stress indicators and, in many cases, improved health conditions relative to earlier periods.

While several factors caution against drawing firm conclusions—including chronological imprecision (as most samples are only broadly dated to the Longshan Era, without finer subphase resolution), small sample sizes (with most sites yielding fewer than 20 individuals), variability in foodways (which may cause malnutrition independent of agricultural failure), and

the indirect relationship between osteological markers and dietary stress (see above)—the current evidence does not support a direct correlation between food insecurity and the collapse of Longshan society. In fact, regions that underwent more pronounced collapse often show better nutritional conditions, likely due to higher consumption of rice, fish, and meat. Therefore, rather than confirming widespread food stress, the osteological data suggest that food pressure was not a primary driver of collapse.

3. **Evaluating food stress through zooarchaeological records**

3.1 Indicators

Resource depression—defined in foraging ecology as the reduction in availability of essential resources within a given territory (Stephens and Krebs 1986: 17-24)—cannot be measured directly in the Longshan zooarchaeological record. This limitation stems from variations in deposition, taphonomic processes, and recovery methods, which render absolute species counts unreliable for direct numerical comparison (Lyman 1994; Emery 2004; Reitz and Wing 2005; Emery 2008).

Nevertheless, both ethnographic and ecological research show that human responses to subsistence stress are often cross-culturally consistent and can be traced through zooarchaeological evidence (Halstead and O'Shea 1989; Redding 1993; Stiner 2001a; Reitz and Wing 2005; Emery 2008; Ucko and Dimbleby 2017). Three primary avenues are particularly useful: taxonomic diversity, age-at-death profiles, and skeletal element distributions of key domesticates. Through my literature survey, I could not find meaningful differences in skeletal

element distributions that could be related to dietary stress, thus the discussion that follows will focus on the first two avenues.

A key marker of subsistence pressure is a broadening of diet breadth, especially increased reliance on low-ranked prey. Under models such as Optimal Foraging Theory and the Broad Spectrum Revolution (Flannery 1968; Redding 1988; Stiner 2001b; Zeder 2012), a rise in small game—birds, reptiles, rodents, mollusks—and a decline in high-ranked large-bodied species often signals dietary stress. Such shifts reflect decision-making based on availability rather than preference (Emlen 1966; MacArthur and Pianka 1966). Ethnographic studies further support this, showing that during times of scarcity, communities often incorporate "famine foods"—less preferred or marginal resources—into their diets (Minnis 1991; Smith and Wishnie 2000; Zinyama *et al.* 1990). The Longshan diet is primarily based on millet and rice farming as well as raising domestic animals, supplemented with fishing, hunting, and gathering (Deng and Qin 2017; Chen 2022; Jiang *et al.* 2019; Jin 2013; Zheng and Yang 2022). If the Longshan communities were experiencing food insecurity, I expect to see increasing reliance on wild animal food resources, especially those of low pre-ranking as a response to such pressure.

The concept of hunting pressure helps interpret wild zooarchaeological assemblages as well. Sustained human predation can cause demographic and ecological changes in wild animal populations, including reductions in body size, skewed age and sex distributions, behavioral shifts, and even local extinction (Martin *et al.* 2025; Munro 2004; Lyman 1987; Stiner 1990;). These patterns often point to diminishing returns on traditional hunting strategies, consistent with subsistence stress. If there was food insecurity during the Longshan Era, I expect to see

more intensive hunting practices as supplementary food provision strategies, and thus reduction of the body size of prey animals or increased number of premature individuals.

For domesticated animals, age-at-death profiles can provide insights into herd management under stress. In contexts where producer and consumer site distinctions are not yet clearly established—as in the Longshan world (for case study exemplifying the lack of urban-rural distinctions, see Owlett *et al.* 2018)—herds are assumed to include the full range of age cohorts (Crabtree 1990). Anomalously high frequencies of neonate animals or complete lack of older individuals as breeding stock suggest short-term exploitation strategies, possibly driven by the need to meet immediate nutritional needs at the expense of long-term herd productivity. Kill-off pattern also reflects the exploitation strategies, from meat consumption to secondary products such as milk, skin, or wool (Greenfield 2010; Payne 1973). Should an age profile reflect a strategy that mainly aims for wool products, I would assume that there was no immediate subsistence pressure and the people could still afford to use sheep as means for exchange instead of direct meat source.

Crucially, these indicators must be interpreted in context. The presence of wild taxa in an assemblage, for example, does not inherently signify food stress. In elite settings, such as Bronze Age palatial societies, wild game often held symbolic or social value and played a role in ritual or elite feasting (e.g., Harris 2014). Hunting in these cases, therefore, should not be conflated with subsistence pressure.

Similarly, high taxonomic diversity is not always a marker of dietary stress. In stable subsistence systems, it may reflect healthy herd diversification. A sharp increase in diversity

taking place after long-term reliance on a narrow range of taxa, however, may signal a stress response, potentially indicating the need to diversify protein sources due to declining availability of preferred resources.

Like the survey of osteological data, due to inconsistencies in excavation methods, recovery rates, and data reporting across different sites and regions, it is not currently possible to systematically reconstruct these indicators across all Longshan contexts. Instead, what follows is a presentation of fragmentary yet informative data that may reflect dietary stress or resource pressure.

3.2 Evidence that may relate to dietary stress

Increased reliance on wild species

To assess potential indicators of dietary stress and resource depression during the Longshan period, I compiled zooarchaeological data from 26 Longshan sites (Table 6), focusing on the relative proportions of wild and domesticated animals. The interquartile range (IQR) method was applied to establish a statistical baseline, identifying both typical patterns and outliers in faunal assemblages. This method evaluates the spread of values within the middle 50% of the dataset—bounded by the first (Q1) and third (Q3) quartiles—and flags any cases that fall significantly beyond this range.

Table 5. List of sites where zooarchaeological data were collected.

Region	**Site**	**Reference**
Zhengluo	Wangwan 王湾	Beijing daxue 2002
	Xinzhai 新砦	Beijing daxue and Zhengzhoushi 2008; Li 2020

	Wangchenggang 王城岗	Beijing daxue and Henansheng 2007
	Wadian 瓦店	Lü 2009
	Meishan	You *et al*. 2017
	Mazhuang 马庄	You *et al*. 2022
	Xijincheng 西金城	Song and Wang 2011
	Tangyinbaiying 汤阴白营	Zhou 1983
Haidai	Liangchengzhen	Zhongmei lianhe kaogudui 2016
	Houyangguanzhuang 后杨官庄	Song *et al*. 2013
	Jianxin 建新	Song and He 2010
	Xiwusi 西吴寺	Guojia 1990
	Yinjiacheng	Shandong 1990
	Tonglin	Song 2014
	Zhuanglixi 庄里西	Song *et al*. 2012
	Lujiakou 鲁家口	Zhongguo and Shandong 1985
	Jinzhai 金寨	Song *et al*. 2020
	Yuchisi	Zhongguo 2001
	Liangwangcheng	Nanjing *et al*. 2013
Jinnan	Taosi	Yuan *et al*. 2007; Brunson 2015
Ordos	Shimao	Hu *et al*. 2016; Owlett *et al*. 2018c
	Zhaimaoliang 寨峁梁	Owlett *et al*. 2018a
	Muzhuzhuliang	Yang *et al*. 2017; 2022
	Huoshiliang 火石梁	Hu *et al*. 2008
	Xinhua	Shaanxisheng and Yulinshi 2005
Guanzhong	Kangjia 康家	Liu *et al*. 2001

Based on Number of Identified Specimens (NISP), Zhuanglixi emerged as a clear outlier. It yielded a wild animal proportion of 98.6% and a domesticated animal proportion of only 1.4%, exceeding the upper and lower thresholds, respectively. This suggests a subsistence strategy strongly reliant on wild species, possibly reflecting either a cultural preference for hunting or environmental conditions that limited access to domesticated resources. The same pattern holds when the data are analyzed using the Minimum Number of Individuals (MNI), where the normal range for wild species spans from approximately –10.96% to 72.66%, and for

domesticated animals from 27.34% to 110.96%. Zhuanglixi again stands far outside these bounds.

After removing Zhuanglixi from the dataset and recalculating the IQR, Houyangguanzhuang became the next statistical outlier. Once this site was also excluded, the remaining data exhibited a relatively cohesive pattern, with no further anomalies. This refined baseline confirms that, across most Longshan sites, subsistence strategies were anchored in household animal husbandry. Domesticated animals consistently provided the majority of faunal resources, often accounting for over 60% of assemblages. Wild resources such as fish, birds, and mollusks were occasionally used but generally supplemented domesticates. Since many wild taxa yield low caloric returns, the actual dietary contribution of domesticated animals was likely greater than the NISP and MNI values suggest. Unfortunately, due to the limited availability of reconstructions for meat yield, a more precise quantitative assessment of caloric intake remains unattainable.

While a complete rural-urban distinction has not been established in the Longshan Era—certain village sites like Huoshiliang and Muzhuzhuliang also presented highest domesticated animal proportion, an emerging trend appeared: the four largest centers—Shimao, Taosi, Liangchengzhen, and Wangwan—all display very high proportions of domesticates, implying that proto-urban sites relied more heavily on managed animal resources than their rural counterparts.

With this baseline established, I now turn to specific sites whose faunal patterns deviate from the broader trend. These exceptions may indicate increased reliance on wild resources, potentially as a response to environmental, demographic, or economic pressures.

At Houyangguanzhuang, a notable shift occurred in the transition from the Dawenkou to the Longshan period (Song *et al.* 2013). During the Longshan phase, domestic animals contributed approximately 56% of meat resources, while wild animals provided 43%. Based on NISP data, freshwater fish and mollusks dominated the assemblage, with fish accounting for 51.53% and mollusks 22.61%. Given that fish bone is more vulnerable to both biological and environmental degradation than mammal bone (Szpak 2011)—and thus less likely to be preserved in the archaeological record—the actual abundance of fish in the past was likely higher than what current data indicates. Mammals constitute 24.62% of the total NISP. Among these, wild species made up 64.4% by NISP and 69% by MNI. Domestic mammals represented the remaining 35.6% (NISP) and 31% (MNI). Given the significantly higher caloric value of mammalian meat, this transition reflects a substantial change in dietary strategy compared to the preceding Dawenkou phase, where mammals accounted for 93.6% and aquatic species for less than 3% (NISP). It is unclear whether the earlier mammalian remains were primarily wild or domesticated, but the contrast nonetheless suggests a shift toward aquatic wild resources, possibly driven by resource stress or ecological constraints.

This pattern aligns with predictions of optimal foraging theory and prey choice models, where lower-ranked but more abundant resources are targeted when preferred ones become less accessible. That said, caution is warranted when interpreting these results. The Longshan and

Dawenkou faunal samples were taken from different areas of the settlement, which may be the reason for the observed differences in the exploitation of wild resources (Yuan *et al*. 2007: 129).

The transition from domestic to wild resources is also observed at Liangchengzhen, one of the largest sites in southeastern Shandong. As to be discussed in Chapter 3, this site functioned as a regional center, particularly during the Early and Middle Shandong Longshan Phases. By the Late Longshan Phase, many surrounding settlements appear to have been abandoned, population aggregated into the Liangchengzhen, and wild animals likely acquired more habitat. Faunal remains reflect this change. During the earlier phases, domesticated animals dominated the assemblage, accounting for 99.77% by NISP and 92.31% by MNI. By the later phase, these numbers declined to 91.62% and 75%, respectively (Zhongmei 2016: 1065-1066). The wild taxa adopted include deer, small ungulates, and medium-sized birds. The modest rise in wild taxa diversity may suggest that hunting became a slightly more significant part of the subsistence system in the later period.

Several explanations may account for this development. From an ecological perspective, the increased use of wild resources could represent a response to declining availability or productivity of domesticates, possibly driven by intensified pressure within the urban center. Alternatively, this change may reflect demographic shifts, as people from outlying areas with different subsistence traditions migrated into Liangchengzhen. As discussed above, large central sites tend to have higher reliance on domestic resources. Finally, the small sample size from Liangchengzhen (NISP = 623; MNI = 25) must be considered, as the current dataset may underrepresent the full extent of wild resource use in the early phase.

These case studies illustrate that while most Longshan communities adhered to a consistent pattern of reliance on domesticated animals, a few sites deviated markedly from this trend. Such deviations may reflect localized environmental constraints, shifting social dynamics, or strategic adaptations to subsistence pressure. It is clear that such evidence is very limited. On top of that, counterevidence that shows no dietary pressure and appear to maintain stable subsistence systems throughout the Longshan Era can also be found in a number of sites, as presented below.

Evidence for the exploitation of secondary products

At Xinzhai, age-at-death profiles of sheep suggest a herding strategy focused on the exploitation of secondary products, particularly wool. Analysis of bones from Phase II indicates that 83.33% of sheep lived beyond 2.5 years, 65% lived beyond 3.5 years, and only 6.67% died before the age of one (Li 2020: 29). According to Payne's (1973) model, if sheep were raised primarily for meat, most would have been slaughtered between 1.5 and 2.5 years and for dairy production, most males would be killed by the age of one. The extended lifespan of the majority of individuals, especially the 60% that lived past 6 years with a peak at 8–10 years, with only 6.67% being killed by the age of one, indicates a management system oriented more toward wool production than meat or milk (Li 2020: 30–31).[7] The repeated pattern across multiple

[7] The researcher also noted that the near absence of lambs under six months old at Xinzhai suggests sheep were not bred locally but instead acquired from other settlements, possibly through trade or tribute (Li 2020: 30–31). If so, the low proportion of lambs culled before one year of age cannot be taken as evidence of a dairy-oriented

excavation seasons—where the majority of sheep lived well beyond the typical meat-harvesting age—reinforces the interpretation that wool was the primary purpose of sheep husbandry at the site (Li 2020: 30–31).

A similar trend is evident at Taosi, particularly during the Late Taosi phase, when social disruption was most pronounced. Even amid instability, the kill-off pattern of sheep reflects a continued focus on long-term herd management for wool and other secondary products, rather than short-term meat yield. Based on the dental evidence, only 21.88% of the sheep died at or before the age of 1–2 years, while over 40% were slaughtered at 4–6 years old or older (Brunson 2015: 62). The absence of a shift toward early slaughter arguably underscores a lack of dietary stress and suggests that sheep husbandry remained stable and organized during periods of social upheavals.

At Muzhuzhuliang, a total of 64 left mandibles and 76 right mandibles of sheep with identifiable age were recovered from the site. The results show that elderly sheep made up 14.19%. Sheep aged 2–6 months accounted for only 4.26%, those aged 6–12 months for 19.86%, individuals aged 1–3 years for 44.68%, and those aged 3–6 years for 17%, suggesting the exploitation of wool (M. Yang *et al.* 2017).

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production system. In such systems, we would expect more young males to be slaughtered and a higher proportion of older females retained. However, since sex ratio data was not reported, this interpretation remains inconclusive. Therefore, the researcher's original inference should be treated with caution until more comprehensive data becomes available.

Together, the data from Xinzhai, Taosi, and Muzhuzhuliang illustrate a consistent emphasis on secondary-product exploitation in sheep management in different regions during the Longshan Era. This pattern reflects the economic priorities over exchange instead of immediate meat consumption of these Longshan communities, which may be taken as a sign for the absence of food stress at the time.

The size of Equus ovodovi

One proposed indicator of increasing hunting pressure is a measurable reduction in the average body size of wild animals over time, particularly as a result of sustained harvesting of prime-age adults. While zooarchaeological reports often lack detailed measurements for wild species, size data for *Equus ovodovi* (Ovodov's horse) are available from two sites in northern China: Miaoliang, dated to the Miaodigou II period, and Muzhuzhuliang, a Longshan-Era site. If hunting pressure had intensified during the Longshan period, we would expect to see a statistically significant decrease in the size of E. ovodovi specimens at Muzhuzhuliang compared to those from Miaoliang. However, the data reveal no such difference (Table 7), and the hypothesis of increased hunting pressure is therefore not supported in this case.

Table 6 Size data for *Equus ovodovi* (Ovodov's horse) from Miaoliang and Muzhuzhuliang

The numbers indicate the average of the measurement in mm and the size of sample is included in brackets.

	Miaoliang (Miaodigou II)	Muzhuzhuliang (Longshan)
Radius Bp	38.9 (3)	77.5 (1)
Radius Bd	63.5 (4)	63.2 (2)
Pelvis LAR	54.0 (4)	54.1 (4)
Talus GH	53.3 (7)	48.4 (1)

Talus GB	49.4 (7)	48.2 (1)
Talus GFd	42.2 (7)	41.1 (1)
Talus LmT	50.8 (7)	49.3 (1)

In summary, zooarchaeological evidence for dietary stress during the Longshan era remains sparse. A few sites, such as Houyangguanzhuang and Liangchengzhen, exhibit signs of subsistence diversification, particularly an increased reliance on wild resources in contexts that had previously been dominated by domesticates. These changes could suggest dietary stress or shifts in local resource availability. Such interpretations, however, must be approached with caution. Taphonomic bias, excavation strategies that exclude fine-screening, and changes in settlement layout over time may all affect the recovery of fragile remains like fish and bird bones. Moreover, the number of sites exhibiting broadening subsistence patterns is small compared to the dozens of sites reviewed, most of which show consistent and stable reliance on domestic livestock, with local ecological variation accounting for minor differences in animal use.

In addition, biometric data from wild species do not support the presence of intensified hunting pressure during the Longshan period. While this does not categorically rule out increased hunting, it aligns with the general observation that evidence for dietary stress is sparse and scattered.

Stable isotope analyses further support the picture of relative subsistence stability. Pigs, in particular, frequently exhibit isotopic signatures similar to those of humans, indicating that they were often raised on household food waste or surplus crops (Yang *et al.* 2023; Yuan and Flad

2005; Zhao *et al.* 2011). The widespread increase in pig frequency within faunal assemblages may reflect the availability of food surplus and a generally stable subsistence base.

Finally, kill-off profiles for sheep at several Longshan sites—including Xinzhai, Taosi, and Muzhuzhuliang—demonstrate long-term herd management strategies oriented toward wool production or mixed-use systems rather than exclusive meat consumption. At Taosi, this wool-focused economy was particularly prominent during the Late Phase, a period otherwise marked by political disorder. Had dietary stress been severe, one would expect a shift toward early slaughter for meat. Instead, the continued investment in secondary products suggests that meat provision remained adequate even during times of sociopolitical instability. Taken together, the zooarchaeological evidence offers only minimal and isolated signs of dietary stress during the Longshan period. While a few localized shifts in subsistence strategy may suggest adaptive responses to changing conditions, the broader pattern points to a relatively stable and resilient animal economy with limited indication of widespread food insecurity.

4. **Archaeobotanical remains**

4.1 Indicators

Ethnographic and historical studies have documented the use of wild plants as "famine foods" in times of scarcity across diverse cultural contexts (e.g., O'Shea 1989; Guinand and Lemessa 2001). Despite this, Longshan archaeobotanical records rarely capture such plant use. Most wild species identified in the archaeobotanical records during this time are weedy taxa associated with cereal cultivation, while nutritionally significant wild foods—such as fruits and

tubers—are typically underrepresented. This discrepancy likely results from preservation bias and recovery limitations, making it difficult to assess past reliance on wild plant resources in response to agricultural shortfalls.

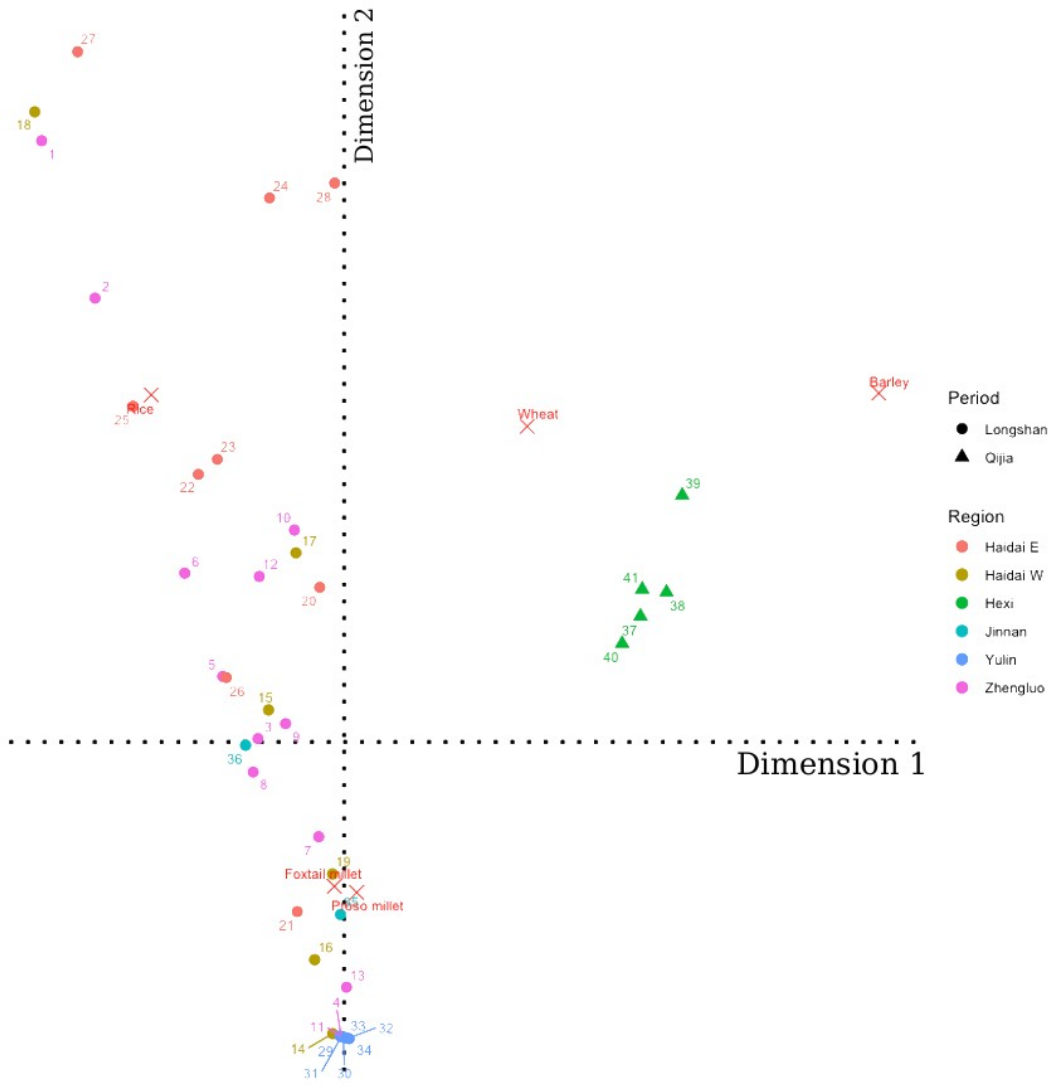
Given the limited availability of direct archaeobotanical indicators of food stress, I instead turn to a broader evaluation of agricultural regimes across the study regions. In particular, I examine crop diversity as a potential proxy for resilience, as it is widely hypothesized that more diverse cropping systems are better able to withstand environmental variability and mitigate the effects of resource instability (An *et al.* 2024; Cooper 2006; Hegmon *et al.* 2008; Walker *et al.* 2004). The data are collected from published reports (Table 4-4) as well as the archaeobotanical samples I analyzed from Taosi in 2020. The diversity of each crop is evaluated based on their Representative Index, a method to unify the contribution of different crop species to cereals (Effenberger 2018; Stika and Heiss 2013). Further, I use Correspondence Analysis (CA) to analyze the temporal and regional variation of the Longshan crop assemblage in order to understand the association between sites and crop preference. The results are plotted on Figure 24. When plotting, sites with RI smaller than 10 are excluded.

Table 7. Sites where plant remains data are collected.

Region	Site	Reference
Zhengluo	Xinzhai	Zhong *et al.* 2016
	Huadizui 花地嘴	Tang *et al.* 2018
	Dongzhao 东赵	Yang *et al.* 2017
	Chengyao 程窑	Zhong *et al.* 2018
	Wangchenggang	Zhao and Fang 2007
	Wadian	Liu *et al.* 2018; Liu and Fang 2010
	Guchengzhai 古城寨	Chen *et al.* 2012

	Xijincheng	Chen *et al.* 2010
	Dalaidian 大赉店	Wu *et al.* 2018
Haidai	Ningjiabu 宁家埠	Wei *et al.* 2018
	Huangsangyuan 黄桑院	Zhang *et al.* 2019
	Pengjiazhuang 彭家庄	Wu *et al.* 2010
	Dinggong	Wu *et al.* 2018
	Fangjia 房家	Jin *et al.* 2011
	Shilipubei 十里铺北	Guo *et al.* 2019
	Zhuanglixi	Kong *et al.* 1999
	Beitaishang 北台上	Wang 2018
	Wutai 午台	Chen *et al.* 2019
	Xuejiazhuang 薛家庄	Jin *et al.* 2009
	Liangchengzhen	Crawford *et al.* 2005
	Liujiazhuang 六甲庄	Shandong daxue 2016
	Houyangguanzhuang	Wnag *et al.* 2013
	Yangbao 杨堡	Cheng *et al.* 2016
	Yuchisi	Zhao 2010
	Gongzhuang 官庄	Cheng *et al.* 2019
	Yuhuicun	Zhongguo and Anhuisheng 2013
	Diaoyutai 钓鱼台	Zhang *et al.* 2018
Ganqing	Jinchankou 金蝉口	Yang 2014
	Lijiaping 李家坪	Yang 2014
	Donghuishan 东灰山	Flad *et al.* 2010; Y. Jiang *et al.* 2017
Jinnan	Taosi	Zhao and He 2006
	Zhoujiazhuang	Jiang *et al.* 2019
Ordos	Shimao	Gao 2017; R. Yang *et al.* 2022)
	Zhaimaoliang	Gao *et al.* 2016
	Muzhuzhuliang	Guo 2017
	Shengedaliang 神圪垯梁	Guo 2017
	Huoshiliang 火石梁	Sheng *et al.* 2020
	Yangjiesha 杨界沙	Sheng *et al.* 2017
	Xinhua 新华	Bao *et al.* 2020
	Zhaimao	Bao *et al.* 2020
	Xiaojiamao 肖家峁	Bao *et al.* 2020
	Ashan 阿善	Bao *et al.* 2020
	Zhukaigou	Bao *et al.* 2020
	Xujiaqu 薛家渠	Bao *et al.* 2020

4.2 Results and Discussion



Plot by author

Figure 21. CA Plots of cereals and sites

The CA biplot (Figure 21) visualizes variation in agricultural regimes across different archaeological regions and cultural phases. We may understand CA biplots as maps that help us understand how different things are related—such as which sites choose which crops—when it is hard to tell such correlation from a big messy table of numbers. In a CA biplot, the two axes—

commonly labeled Dimension 1 and Dimension 2—represent the main patterns of association. Dimension 1 (x-axis) is the strongest axis of variation, explaining the largest amount of association in the raw dataset and separating the most contrasting patterns. As Figure 24 shows, the most contrasting pattern among the Longshan sites appears to be their use of rice versus barley and wheat. Dimension 2 (y-axis) is the second strongest axis of variation, independent of Dimension 1, explaining the second most important pattern—often a subtler distinction. Based on Figure 24, the second most important contrasting pattern here seems to be the use of rice versus millets. Together, the two dimensions help us translate complex tables into meaningful visual patterns.

In Figure 24, each point represents a site, with colors distinguishing geographic regions. The crop taxa—foxtail millet, rice, wheat, and barley—are plotted in red X, positioned based on their statistical associations with the sites. Crops positioned closer to the origin (0, 0) are more commonly represented across all samples. Sites located nearer to a particular crop indicate a stronger reliance on that cereal, while greater distance suggests reduced importance.

In Figure 25, foxtail millet and broomcorn millet appear close to the origin, reflecting their ubiquity across most sites. In contrast, wheat and rice are positioned further away, suggesting they were less uniformly distributed and more selectively cultivated. Barley contributed the least to the Longshan agricultural regime. Sites located near the origin correspond to “generalist” agricultural regimes, which incorporated foxtail millets and broomcorn millets as staple crops regardless of region.

Most regions—except for the Hexi region and the Yulin (榆林) region in the Ordos —display intra-regional diversity in crop use. In eastern Haidai, sites show a notable reliance on rice cultivation, especially in the southern portion of the region. This reliance becomes less pronounced toward the north. Sites in western Haidai, Zhengluo, and Jinnan cluster and overlap together, indicating a broadly shared millet-based regime, but they also distribute widely along Dimension 2, indicating different levels of reliance on rice and millets.

In contrast to the regional variation seen elsewhere, the Yulin group displays internal uniformity. Sites within each of these regions cluster tightly on the CA plot, reflecting highly consistent agricultural practices. In Yulin, subsistence focused almost exclusively on millets, particularly foxtail millet. Although small quantities of charred rice have been recovered along the northern Loess Plateau near the Hutuo River, the quantities are insufficient to have played a meaningful supplementary role in local food production or resilience (Jiang *et al.* 2019).

Overall, the variation in crop regimes across regions corresponds closely to the differences in local hydrothermal conditions, highlighting how subsistence strategies were adapted to environmental contexts. While previous research has proposed a positive relationship between agricultural diversity and social resilience, such a correlation is not clearly observable in this dataset. For instance, the Zhengluo region, which demonstrates relatively high social resilience, does not exhibit higher cereal diversity than regions like Jinnan, or Haidai, which experienced greater sociopolitical disruption.

This lack of correlation may suggest that the decline in resilience observed in certain regions was not caused by limited crop diversity. Alternatively, it may reflect the limitations of the

current methodological approach—highlighting the need for more refined, multi-scalar models to test the relationship between agricultural diversity and sociopolitical stability.

5. **Conclusion**

Advancing our ability to identify and interpret food stress in the past is particularly important given archaeology's disciplinary commitment to understanding the lives of marginalized populations. Yet the archaeology of food stress is inherently challenging. By definition, periods of famine, chronic food insecurity, or subsistence failure leave behind reduced physical evidence: less food consumed means fewer remains deposited, thereby decreasing the likelihood of detection in the archaeological record. As Landon and Opishinski (2020) observe, this creates a paradox in which the most critical moments of food scarcity may be the least archaeologically visible, severely constraining our ability to recognize and interpret episodes of starvation or systemic nutritional deficiency.

Despite these limitations, this chapter has drawn on theories from ecology, ethnography, and resilience theory to identify proxy indicators of dietary stress. The analysis examined osteological, zooarchaeological, and archaeobotanical records across multiple Longshan sites to explore whether food insecurity contributed to the broader sociopolitical collapse. The results indicate that while some localized correlations exist between food economies and social organization, there is no clear or consistent evidence linking the Longshan collapse to widespread dietary stress. This absence of direct correlation can be interpreted in several ways. It may suggest that food insecurity was not a primary driver of collapse; alternatively, it may

point to methodological limitations in how we analyze and interpret faunal, floral, and skeletal datasets.

At best, the current state of evidence does not support the conclusion that the Longshan collapse was precipitated by food scarcity. As such, we cannot confirm the widely assumed—but rarely tested—claim that climate change impacted prehistoric societies through increased agricultural failure. This finding calls for caution in applying climate-driven collapse models without robust, context-specific evidence. More systematic, multi-proxy research is urgently needed to cross-examine different lines of evidence related to subsistence and stress, and to refine our understanding of how environmental and economic factors interacted in the Longshan world.

Having demonstrated in Chapter 2 that food insecurity cannot be confirmed as the primary driver of the Longshan collapse, the discussion now turns to another key line of evidence: settlement data. If subsistence stress alone does not account for large-scale social changes, then the ways in which communities organized themselves spatially, politically, and hierarchically may offer more direct insights into the processes of transformation. Settlement patterns are among the most visible archaeological indicators of sociopolitical change, capturing shifts in population aggregation, hierarchy, and regional integration. Chapter 3 therefore examines how the Longshan–Erlitou transition unfolded through settlement dynamics, situating these patterns within both long-term trajectories and the specific contexts of individual regions.

Chapter 3. Settlement History and its Sociopolitical Implications

This chapter aims to analyze the changes in sociopolitical structures during the Longshan-Erlitou transition through settlement data. As one of the most prominent phenomena of the Longshan "collapse," the changes in settlement pattern have been widely discussed in past research (Jaffe *et al.* 2020; Sebillaud 2014; Zhang 2017; Zhang 2018). This chapter will continue and deepen such discussion. It will start with a brief review of the history of research into settlement dynamics from Longshan to Erlitou and the research areas needing further exploration. This is followed by a discussion on the approaches I use to interpret settlement data. With these methods, I analyze the changes in settlement pattern in seven selected areas, discuss the time frame and pace of the Longshan Transformation as evidenced by settlement-pattern change, and summarize the different patterns of changes of settlements.

As the following will argue and demonstrate, the Longshan Transformation is a prolonged and multi-scalar social process, which, temporally, went through multiple stages and waves, and geographically affected sites and systems of different scales—individual sites, regional social and settlement system, as well as cross-regional networks—to starkly different extents. In each of the regions, the settlement changes reflect marked differences in regional stratification, centralization, unification, diversification processes, and varied levels of fragility and resilience.

1. Research History on the Changes in Longshan-Erlitou Settlement Patterns

Pauline Sebillaud (2014) pioneered the effort to depict the Longshan collapse using settlement data. Based on the Second and Third National General Survey, her exhaustive dataset

from the Central Plains provided unprecedented insights into the decline in settlement numbers and sizes, the shifting locations of central sites, and the elevation of site altitude during this transition over a vast geographical area. Her study revealed that, first, the number of sites and population density (derived from the density, number, and size of sites) had significantly decreased. In the study area in Shandong and southern Shaanxi, this decrease could be as drastic as 90–99%, while in the least affected regions, southeastern Henan and the area where Henan, Shanxi, and Shaanxi abut, the decline in the number of settlements and population density was still above 35% (Sebillaud 2014: 253-4 and Figure 39). Even in the least affected regions, thus, the decline was substantial.

Sebillaud further divided the Central Plains into ten regions and separately delineated the settlement history in the Longshan, Erlitou, and Shang periods in each region. In these ten regions, she identified five different patterns of change based on (1) the level of complexity of the Longshan settlement system of the region under discussion and (2) whether the declining trend continued uninterruptedly from Erlitou to Shang (Table 8).

Table 8. Regional settlement changes (Table summarized based on Sebillaud [2014]: 250–252).

Type	Pattern of settlement change			Regions
A	Settlement systems in these regions were highly developed during the Longshan period but declined during the Erlitou period before reaching another zenith during the Shang period	A1	Settlement system was most developed in Shang	Shandong, N Henan & S Hebei, MW Henan
		A2	Settlement system was most developed in Longshan	SE Henan, Wei River
B	Settlement system remained underdeveloped and continuously declined throughout the study period			SW Henan

C	Settlement system was most developed in Longshan, collapsed in Erlitou, and remained sparsely populated in Shang times.	SE Shanxi, Fen River
D	Settlement system was most developed in Longshan but started declining in Erlitou, followed by a more drastic decline in Shang	Shanxi/ Shaanxi/ Henan border area
E	Sparsely populated in Longshan and remained this state in Erlitou and Shang	W Shanxi

Another important discovery made by Sebillaud concerns the altitude of site locations. On average, settlements during the Erlitou period were situated at higher altitudes, and the lowest regions on plains and in valleys were abandoned. She also inferred that this increase in altitude may have been a result of multiple flooding events, the search for resources located on higher elevation, and the intention to avoid conflicts with neighboring societies (Sebillaud 2014: 109-110). This observation is in accordance with the results revealed in last chapter, which suggests that areas along the river valleys experienced frequent flooding events.

This groundbreaking work effectively demonstrated the extensive scale and profound intensity of the Longshan-Erlitou transformation and the variation among different regions within the Central Plains. However, due to the fact that Sebillaud's research is primarily based on the National General Survey conducted in 1981-1985 and 2007-2011, with a chronological resolution on the scale of rarely less than a millennium, the dating resolution of her research is constrained. Given the limited materials available at the time and the extended duration over which these surveys were conducted, in these surveys, the term "Longshan" may refer to either its broader or narrower definition and regional variation in the beginning and end of the Longshan Era is also not considered. This means, these surveys put a considerable number of

sites into the same basket of the “Longshan,” although they do not necessarily coexist with one another at the same time.

Zhang Chi (2017) took a different approach, relying almost solely on full-coverage systematic surveys rather than National General Survey data to depict changes in settlement patterns. While the area covered by this method was not as extensive as Sebillaud's, Zhang’s study provides a more accurate reflection of regional patterns due to its finer chronological resolution. Zhang Chi’s research primarily focused on what he refers to as the “cultural core zone” (文化核心区域), encompassing the middle and lower Yellow, Huai, and Yangzi Rivers. In comparison, the Crescent-Shaped Cultural-Communication Belt or Crescent Belt for short (so named by Tong Enzheng [1987]) bordering the core area on the north and west in upper Yellow and Yangzi Rivers, has been long considered the “periphery” in the forming the civilization of the core zone. Zhang Chi identified three major changes in such cultural landscape during the transition from the Neolithic to the Early Bronze Age, set against the backdrop of Bronze Age globalization.

First, with the exception of the Luoyang Basin, the entire cultural core zone experienced a decline at the end of the Longshan Era around 1800 BCE. Second, within the core area, the farther a region was removed from the Luoyang Basin, the more drastic the decline was. This was particularly evident in the Jinnan region with the collapse of Taosi. Third, the interaction between eastern and western Eurasia intensified during the Late Neolithic period. He argued, as a result of such intensified interaction, the Crescent began to play a prominent role as one of the major arenas of cultural innovation and political competition. As such, the political scenario of

the Longshan-Erlitou transition was characterized by the fall of the core and the rise of periphery. By highlighting these three changes in the Longshan cultural and political landscape, Zhang Chi's research takes a significant step forward by contextualizing the Longshan world within the interconnected trans-Eurasian network of its time. It delineates the decline, collapse, continuation, and emergence that occurred both within and beyond the Central Plains.

Zhang Li (2018) also utilized regional systematic survey results as her database and proposed that around 1900 BCE, the entire Yellow River region, except for the Ganqing region and the northern Loess highland centering around the Shimao site, experienced a collapse. She argued that this social transformation coincided with the political unrest between the Early and Late Xia dynasties, as reflected in historical records.

Some arguments in Zhang Li's work remain disputable. It is questionable whether the collapse can be precisely dated to around 1900 BCE, as the phenomenon may have spanned for centuries (below). Additionally, although Zhang Li posits that the Xia in historical records is equivalent to the Late Longshan and Erlitou periods defined by archaeological materials, their actual relationship remains open to discussion.

Setting aside these controversies, Zhang Li made an important contribution to the discussion of the Longshan collapse by translating archaeologically defined collapse into political terms. This represents an important step toward understanding the Longshan-Erlitou changes in settlement data as a sociopolitical phenomenon, rather than merely as a collection of discontinuous archaeological materials.

In summary, previous research has effectively demonstrated the magnitude and geographical scope of the Longshan Transformation. Certain aspects of the transformation of settlement patterns, however, have remained understudied. Particularly important is the chronological dimension of the transformation. Past studies contrasted the statistics of Longshan, especially the statistics of the peak Longshan, with that of Erlitou. In doing so, they sufficiently demonstrated the dramatic changes before and after 1800 (or 1900) BCE, and thus justified the use of the term "collapse." But such a manner of comparison also left the inaccurate impression that the dramatic changes took place overnight. Furthermore, while Zhang Li adopted a historical approach to interpret the Longshan Transformation in sociopolitical terms, the correlation between historical texts and archaeological records remains problematic. These limitations in previous settlement-based studies of the Longshan collapse invite a reexamination of the data. In response, I reevaluate the settlement evidence within a comparative framework and employ established anthropological approaches to reinterpret the patterns from a new angle.

2. **Methods**

In order to understand the Longshan-Erlitou sociopolitical changes reflected by settlement data, I will evaluate three different variables or aspects. The first is the changes in the number of settlements, which roughly correlates the population size in a given area. While there is no fixed

or perfectly direct correlation between settlement number and population size,[8] it is difficult to argue that a 50–90% decline in the number of settlements would leave the population of a region unaffected. Therefore, while I do not use settlement data to calculate proportional changes in population size, I do treat these variables as roughly correlated.

The second variable is settlement-size distributions and settlement hierarchies. It has been a common practice to infer the number of administrative tiers from settlement hierarchies.[9] More tiers typically correlate with more complex social organization (Liu 2005; Underhill *et al.* 1998). Following common practice, settlement hierarchies here are defined by natural breaks in settlement-size distributions.

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[8] In archaeology and anthropology, the number of settlements in a given region is often used as a first-order proxy for estimating population size, based on the assumption that more sites generally indicate more people (Berrey 2015; Drennan 1987; Willey 1953). This approach is especially common in regional survey projects, where systematic site counts provide a baseline for demographic reconstruction (Feinman and Nicholas 2018; Chase et al. 2024).

However, the relationship between settlement number and population size is not linear and can be influenced by changes in average site size, patterns of aggregation or dispersal, and mobility strategies. For example, political centralization often leads to fewer but larger settlements (e.g., Feinman 2014; Wright and Johnson 1975), while in mobile societies, numerous small sites may represent seasonal camps rather than population growth (Kelly 2013). Taphonomic processes and survey biases also affect the visibility of sites.

[9] Assessing political complexity through size-based hierarchies has been a longstanding practice in archaeology, with foundational research by Kent Flannery and Henry Wright dating back to the 1960s and 1970s (Smith 2021). In recent years, however, an increasing number of scholars have critiqued this approach for its oversimplification, proposing alternative factors that may shape site hierarchies and new models for conceptualizing site structures (Duffy 2015; Drennan and Peterson 2012; Smith 2021). For instance, Smith (2021) presents several dynamic models for site structures that emphasize different forms of connectivity—such as trade, warfare, alliances, and migration—as key drivers in the emergence of complex societies. In this chapter, I employ the conventional model associating multi-tiered site-size hierarchies with political complexity, as this framework remains effective for comparing different levels of complexity across regions.

The third variable is rank-size distribution, which reflects the level of regional integration. This framework derives from the "Rank-Size Rule" from economic geography (Zipf 1949). In its basic form, a settlement ranked *r* has a size equal to the largest settlement divided by *r*; when log-transformed, the distribution forms a straight "log-normal" line, indicating a balance between the diversification and unification of settlements. In the past, archaeological studies identified two common deviations: primate (concave) distributions, where the largest settlement is oversized, and convex distributions, where it is undersized (Adams and Jones 1981; Liu 1996b; Savage and Falconer 2003). Log-normality suggests highly integrated systems; convex patterns indicate low integration; primate patterns could either result from a very high degree of integration (all settlements connected or controlled by one or a few mega centers) or poor integration (small sites keep their distance from the mega site) and calls for further archaeological investigation (Johnson 1980). Comparing the deviation of observed values from the expected distribution can yield fruitful results. However, when different cases display the same overall pattern (e.g., all showing convex or concave distributions), it becomes difficult to distinguish or compare the relative levels of social consolidation among them.

To address this problem, I introduce a line-of-close-fit,[10] calculated using the Principal Axis method, to measure the level of centralization and the coherence of the hierarchical structure. In

[10] This is comparable to the regression line that is more commonly used in archaeological research. Both are "fit lines," but only the OLS version is technically a regression line, while the Principal Axis is better described as a line of closest fit or total least squares fit. More specifically, the regression line is calculated in the ordinary least squares (OLS) method. In OLS regression, the regression line minimizes vertical residuals and assumes a dependent

this approach, the slope (q) of the line reflects the degree of settlement centralization, while the goodness-of-fit, expressed as the $\sigma_{\perp}$ value, indicates the coherence of the hierarchy (Jones and Lewis 1990). A system that conforms exactly to Zipf's law has a q value of 1. When $q > 1$, the slope becomes steeper, indicating stronger centralization; the larger the q, the greater the degree of centralization. Conversely, when $q < 1$, the slope is shallower, indicating weaker centralization than expected under Zipf's law.

The goodness-of-fit between observed values (site sizes derived from survey data) and expected values is measured as the standard deviation of the orthogonal distances of data points from the fitted line. This scale-free, geometry-based metric indicates that the smaller the value, the closer the observed system is to an "ideal" rank-size distribution. Empirically, a small $\sigma_{\perp}$ value reflects high hierarchical coherence: site sizes align closely with the expected rank-size line, with tiers clearly defined, smoothly filled, and scaled in a predictable manner. Such coherence typically signals a stable, integrated political-economic system in which settlements are effectively coordinated or controlled. By contrast, low coherence is expressed through irregular distributions characterized by missing tiers, oversized or undersized centers, or abrupt jumps between ranks. These patterns often point to instability, fragmentation, or the potential for transformation, such as the collapse of central authority, the sudden rise of a dominant

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variable explained by an independent variable (i.e., this method assumes site size depends on site rank in the rank-size analysis). By contrast, the Principal Axis line minimizes orthogonal distances from all points, treating both x and y axes symmetrically without assuming causality.

center, or the weakening of intermediate towns. Taken together, these measures shed light on both the degree of political centralization and the overall cohesion of the settlement system.

While the first three variables are on macroregional level, the last one delves into individual settlement to trace “crisis architecture.” In understanding the social response to the eruption of Santorini volcano in the Minoan age, Driessen (1995) and Driessen and Macdonald (1997) coined the term 'crisis architecture' to emphasize short-term architectural changes in response to crisis conditions. This concept was adopted by Zukerman (2006) to dissect the destruction of the Bronze Age Hazor, a Canaanite city-state located in the upper Jordan Valley. By employing such a term, Zukerman was able to treat the destruction of a site as a long-term process encompassing several short-term events rather than an all-at-once incident. Material evidence of crisis response can manifest in several ways. These include (1) reduced resource allocation for construction and upkeep, resulting in deterioration or use of lower-quality repair materials, (2) alterations in how spaces are utilized, such as limiting movement and access, changing building permeability, and (3) modifications to structural layouts, such as sealing off functional areas or partially abandoning them (Driessen 1995: 67). Not all these categories of “crisis architecture” could be identified in the context of Longshan collapse, but the approach—viewing the abandonment or destruction of a site as a long-term process of several short-term events—can be applied to the Longshan settlement change.

In sum, in this chapter, on a regional level, I will look into the changes in settlement number, settlement hierarchies, and settlement integration. On a level of individual site, I will trace the history of settlement with a focus on crisis architecture to unpack the intricacy of the

seemingly sudden crisis. The analysis on a regional level takes a processual approach to interpret settlement data. Such a way of interpretation has been under critical re-examination in the past a few decades (e.g., Duffy 2015; Feinman and Neitzel 1984; Smith 2021) and I do agree that such methods need case-by-case evaluation. In this chapter, I do not adopt such methods for the purpose of discussing the evolution of political systems or state formation. Rather, I argue that by applying these consistent methods across all regions showing signs of collapse, it could well demonstrate the regional variations of the seemingly sweeping Longshan collapse. It is for this reason that I chose the methods introduced above.

3. **Study Areas and Data**

Selected regions include Jinnan, Haidai, and northern Loess Plateau. In Jinnan, I will analyze (1) the environs of Taosi in the Linfen Basin and (2) the environs of Zhoujiazhuang in the Yuncheng Basin. In the Haidai region, I will treat eastern and western Haidai as separate units as they experienced distinctive settlement histories. The analysis in western Haidai will be centered on (3) the environs of the Tonglin site, (4) the Xue River, and (5) the environs of Chengziya. In eastern Haidai, analysis will be conducted based on the survey data in southeastern Shandong, especially around (6) Liangchengzhen and its environs. On the northern Loess Plateau, I will present the settlement data in (7) the environs of Shimao and that in (8) the Hutuo River region (Figure 22).

These eight regions are primarily because they are where the “collapse” was most obviously observed. Secondly, the selection of samples is also restrained by the availability of data and

these regions provide high-resolution survey results. Lastly, these selected regions cover a variety of landforms and locations, including highland and lowland, inland and coastal regions. By comparing a diversity of the patterns of settlement change, I hope to demonstrate that instead of a sweeping phenomenon, the Longshan Transformation is a complex process consisting of a variety of regional events.

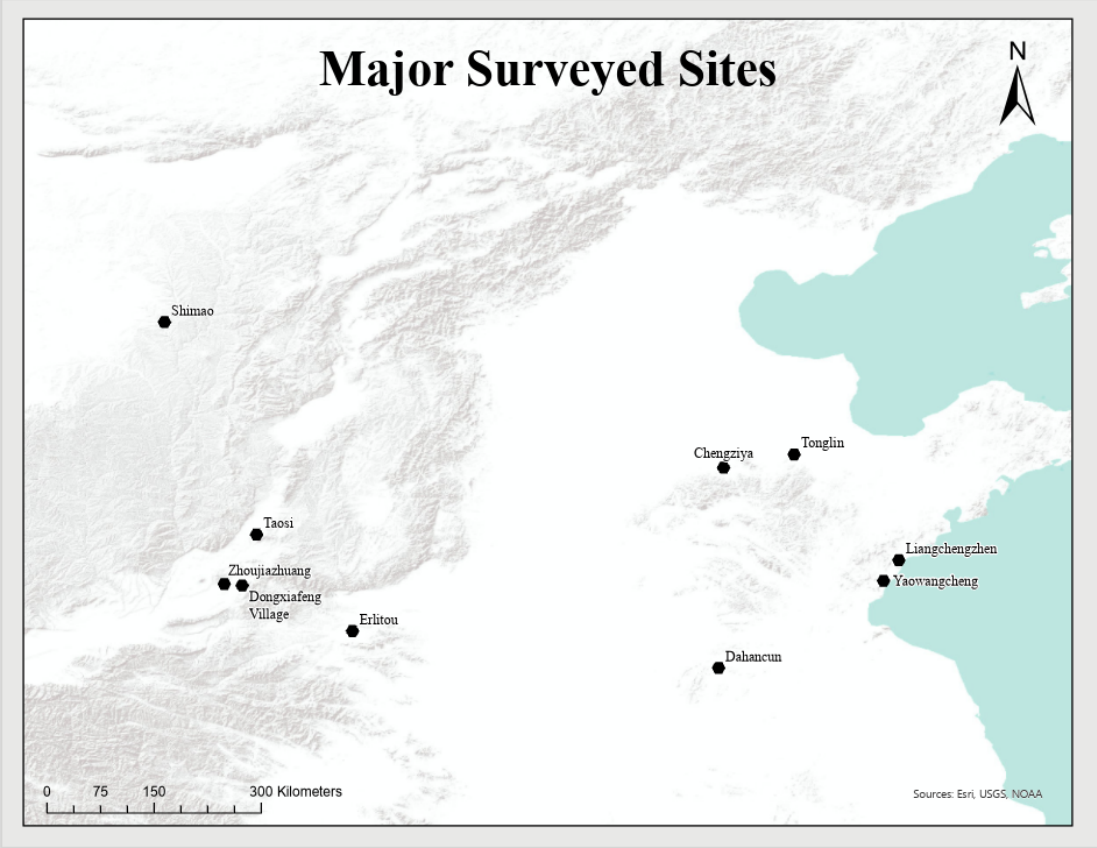


Figure 22. Study areas and major sites mentioned in this chapter

The survey data adopted in this research only contains those from regional systematic surveys, because they provide better chronological control and usually recover sites to a fuller extent. In addition, the discussion of individual sites is based on the full excavation reports and preliminary reports. It should be noted that not all survey teams distinguish the differences

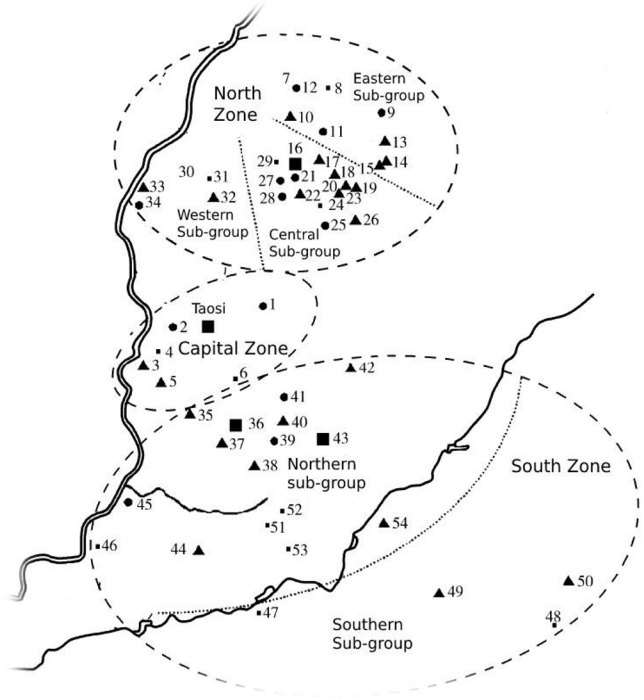
between (a) site size determined by trial excavations and coring and (b) the surface distribution area of the cultural remains. The latter appears to be way larger than the former (Dai Xiangming, personal communication; Luan Fengshi, personal communication). I use (a) size whenever possible, although in most cases (b) size is the only available data. Furthermore, not all surveys distinguish site size by period, but report one size for a given site, despite that the site may expand or contract at different periods. This cast some difficulties in discussing the diachronic changes of settlement hierarchy and integration, because these two variables highly relied on the accurate size of each site. Third, not all surveys distinguish the subphases of the Longshan periods, which cast difficulties in understanding the changes overtime during the Longshan. I will discuss the quality of raw data for each region, and readers should remain cautious with these problems.

4. **Settlement Histories of the Selected Study Areas**

4.1 Taosi and its environs

The Taosi site is situated in the Linfen basin, southern Shanxi province, incorporating the Hui River and the lower reaches of the Fen River valleys, and surrounded by the Lüliang Mountains in the north, the Yellow River in the west, the Emei Mountains in the south, the Zhongtiao and Taiyue Mountains in the east, with the Ta'er Mountains situated in the center of the basin (Figure 23). Settlement data is retrieved from (Gao 2007; He 2011; Zhongguo and Shanxi Sheng 2015). Both projects were conducted by the Shanxi team of the Archaeological Institute, CASS. The systematic survey conducted in 2009-2010 covered an area centering on

Taosi of approximately 1,750 km² between the Fen River and its tributary, the Hui River (He 2011). Within the survey area, totaling 54 sites of the Taosi Culture were discovered. Based on the survey and excavation results, we can observe the following phenomena.



(He 2011: fig. 1)

Figure 23. Survey region the Taosi systematic regional survey (2009-2010).

Site names: 1. Zhangzuan 张纂; 2. Xialiang 夏梁; 3. Dingcun 丁村; 4. Shangzhuang 上庄; 5. Boyu 伯玉; 6. Daguduishan 大崮堆山; 7. Quanpo 泉坡; 8. Beima 北麻; 9. Dayang 大阳; 10. Dongduan 东段; 11. Nanhelizhuang 南合理庄; 12. Beigao 北高; 13. Xiaoyang 孝养; 14. Wangcun 王村; 15. Gao'aojiao 高凹角; 16. Xiandi 县底; 17. Nanqiao 南乔; 18. Huangsitou 黄寺头; 19. Suzhai 苏寨; 20. Zhaobeihe 赵北河; 21. Beixi 北席; 22. Sitou 寺头; 23. Dawangzhuang 大王庄; 24. Xinmin 新民; 25. Duancun 段村; 26. Lijiazhuang 李家庄; 27. Xigou 西沟; 28. Xiaowangzhuang 小王庄; 29. Xixiazhuang 西下庄; 30. Shenliu 神刘; 31. Dahan 大韩; 32. Lingbo 令伯; 33. Dadeng 大邓; 34. Wenquan 温泉; 35. Beixin 北辛; 36. Nanchai 南柴; 37. Zhaoyang 朝阳; 38. Dongxu 东许; 39. Anquan 安泉; 40. Baizhong 白冢; 41. Baqing 八顷; 42. Gushu 古暑; 43. Nanshi-Fangcheng 南石-方城; 44. Tingcheng 听城; 45. Gaoxian 高县; 46. Gaoyang 高阳; 47. Beidong 北董; 48. Xiyan 西阎; 49. Yingli 营里; 50. Yimen 义门; 51. Dongchang 东常; 52. Zhouzhuang 周庄; 53. Dongjibi 东吉必; 54. Hecun 贺村.

Decrease in Settlement Number

As shown by Figure 24, the number of settlements reached its peak during the Taosi period. At the turn to the Erlitou period, the number of settlements dropped by 91% (from 54 sites to 5 sites) and the size of settlements declined by 60%, largely left the region vacant, indicating a sharp population decrease of 8841 people.[11] Such sparse occupation remained until the Han Dynasty in 2nd Century BCE.

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[11] Population estimation in prehistoric contexts remains a challenge. Here I employ two methods to provide readers with a rough sense of the scale of population loss at Taosi. These methods are adapted from Ian Morris's work (1987: 74-75) on "Dark Age" Greece and Lothar von Falkenhausen's (2001: 98-99) study of the Western Zhou Shangma cemetery.

The first method assumes an annual death rate of 30 per 1,000 people, a rate typical for agricultural societies that includes both adults and children. Population is calculated using the formula:

P=1000n/(30*t),

where P is the population per year, t is the length of the phase (Early Taosi = 150 years; Late Taosi = 200 years), and n is the number of tombs attributed to that phase (Early Taosi = 71; Late Taosi = 336).

The results require adjustment. Since only 31% of total tombs were dated, the value must be divided by 0.31. Moreover, because excavations covered just 693.26 m² out of 40,000 m²—or 1.73%—of the Taosi cemetery, the figure must be further divided by 0.0173. This yields population estimates of 2,890 for Early Taosi and 10,441 for Late Taosi.

The second method uses life expectancy as the basis for calculation. At Taosi, life expectancy is estimated at 39.21 years (Zhongguo and Shanxisheng 2015: 1066–1172). The formula is:

P=A*n/t

where A is life expectancy (39.21), t is the phase length, and n is the number of dated tombs. Applying the same adjustments for dated tombs (31%) and the excavated portion of the cemetery (1.73%), the resulting population estimates are 3,410 for Early Taosi and 12,254 for Late Taosi.

Taken together, these methods suggest that the Early Taosi population ranged between 2,900 and 3,500 people, while the Late Taosi population ranged between 11,000 and 13,000 people. During the Early Phase, the site covered 56 ha, while in the Middle and Late phases it expanded to 280 ha. This corresponds to a population density of 51.6–60.9 people/ha in the Early Phase and 37.2–43.8 people/ha in the Late Phase.

From Taosi to Erlitou, the total occupied area in the surrounding region contracted from 492 ha to 198 ha, implying a population loss of approximately 10,936–12,865 people. For comparison, the Book of Han records that



Data from (He 2011)

Figure 24. Changes in the number of sites around Taosi.

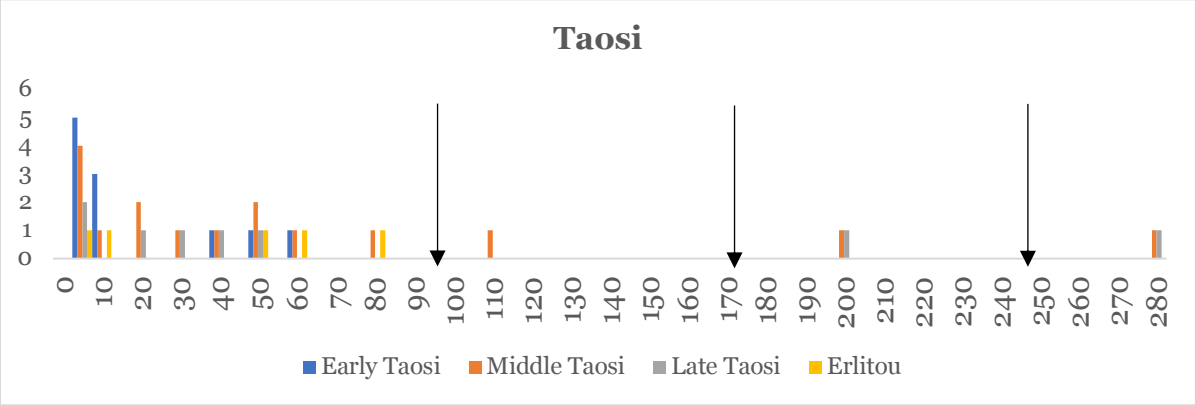
It should also be noted that during the Western Zhou (1042-771 BCE), as the core area of the Jin State, one of the major regional polities of the Zhou kingdom, and the land of many non-Zhou groups (such as the Rong 戎 people), the Linfen Basin was densely occupied with abundant population and walled cities. This is not only as indicated by historical sources such as the *Zuo Tradition* and the *Shiji*, but also attested by archaeological discoveries such as the Tianma-Qucun 天马-曲村 site and cemetery (Beijing daxue and Shanxisheng 2000), Shangma cemetery (Shanxisheng 1994), Hengshui 横水 cemetery (Shanxisheng *et al.* 2006), and Dahekou 大河口 cemetery (Xie 2011). Against this background, the emptiness of the area around the ruins of Taosi during the Western Zhou period begs for further investigation,

the Western Han capital and its county contained 80,800 households, or about 246,200 individuals; estimates suggest that the inhabitants of the city proper numbered somewhat over 80,000 (Loewe 1986: 206).

considering environmental degradation, historical trauma, and the possibility of political buffer zones, although this lies beyond the scope of the present chapter.

Rise and Fall of Settlement Hierarchy

Figure 25 presents a histogram of site size distributions in the environs of Taosi and their changes over time. The red lines mark the natural breaks in site size distribution. The length of the x-axis represents the size of the largest site in each phase, while the gray dashed line serves as a reference for comparing the sizes of the largest sites across phases.



Data from He 2011

Figure 25. Site-size hierarchy in the Taosi environs across the Early, Middle, Late Taosi phases and the Erlitou period.

Note: The sizes are shown in hectors. Same below.

In the Early Taosi phase, the site of Taosi (56 ha) was already the largest in the region, though it had not yet reached its peak size. The settlement pattern at this stage can be roughly divided into two tiers: a smaller tier ranging between 0–10 ha, and a larger tier ranging between 35–60 ha. Overall, the settlement hierarchy remained simple during this period.

In the Middle Taosi phase, the settlement system became more complex: the hierarchy developed into four tiers, with the largest site—Taosi—expanding to 280 ha. During this period, the Early Phase inner city was abandoned, the outer city wall was constructed, and a new inner city was compartmentalized. Another significant development was the rise of the Nanshi-Fangcheng site, which reached 200 ha. This coincided with the introduction of Highland-style pottery (Dai 2022 and Chapter 4), the growing importance of sheep herding (Brunson 2015), the high percentage of non-local population (Zhang *et al.* 2009; Zhao and He 2014), suggesting that the expansion of Taosi and the emergence of Nanshi-Fangcheng may have been driven by the introduction of Highland populations in the Jinnan region.

In the Late Taosi phase, evidence of destruction within the site is prominent (see below). Yet, despite these disruptions, Taosi maintained its scale and remained the largest settlement in the region. Regional survey data show that the number of settlements declined by 50%, from 16 to 8, with small- and medium-sized sites diminishing more markedly than the larger centers. In other words, only the largest and secondary centers, along with the smallest sites, persisted into the Late Phase. The settlement hierarchy contracted from four tiers to three, as the middle tier disappeared. If each tier is understood as representing an administrative level, the demise of the middle tier would have undermined connectivity between levels and contributed to political fragmentation. With the transition to the Erlitou period, the settlement hierarchy was reduced from three tiers to two, with both the size of top-tier sites and the total number of settlements decreasing significantly.

Dynamics in the Regional Integration

Figure 26 illustrates the diachronic dynamics of rank-size distributions. The settlement systems remained highly centralized (the fitted line is consistently steeper than the Zipf reference), but the level of integration or coherence within the hierarchy stayed relatively low. From Early to Middle Taosi, centralization increased as Taosi rapidly expanded from 56 to 280 ha. At the same time, however, integration declined, reflecting the imbalanced growth of Taosi relative to smaller settlements. Although I initially suspected that the rise of Nanshi-Fangcheng 南石-方城 (200 ha) and Nanchai 南柴 (100 ha) competed with Taosi for population, economic resources, and political power—thereby reducing centralization—the rank-size analysis suggests otherwise.

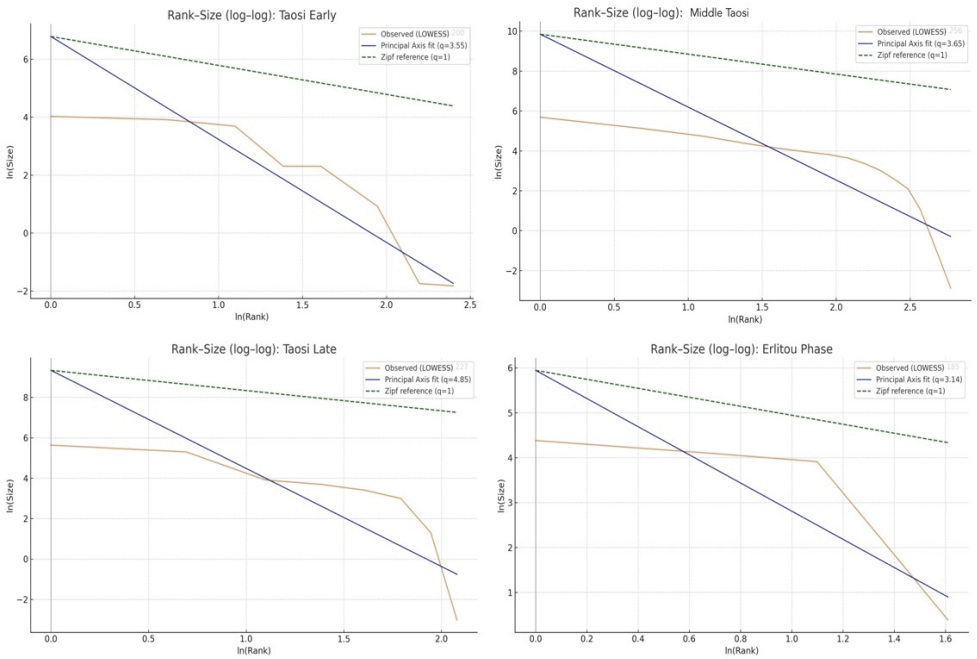


Figure 26. Rank-size plots of the Taosi settlement system from Early, Middle, Late Taosi Phases to the Erlitou period

From the Middle to the Late phase, the level of centralization increased further, driven not by continued growth of the central sites but by the decline of several medium-sized settlements. By the Erlitou period, only five settlements remained, rendering rank-size analysis statistically unreliable, and for this reason it will not be discussed here.

Signs of Destruction and Violence[12]

Current evidence suggests a rather sudden destruction of the Middle Taosi palace (Gao 2007; He 2015) and elite tombs (Gao 2017). In Late Taosi contexts, murals and blocks of rammed earth—believed to be remains of the palace—are frequently found in middens

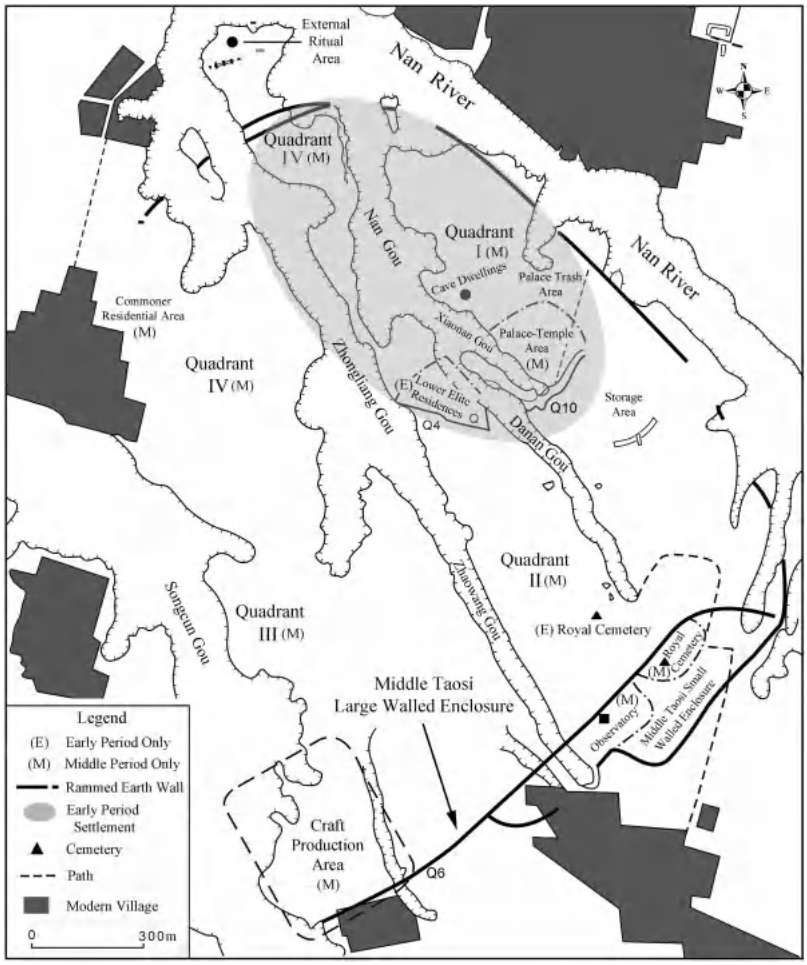
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[12] Signs of destruction frequently appear in collapsed societies cross-culturally, and when destruction layers are found at multiple sites, they are often attributed to large-scale military campaigns. For example, the 701 BCE destruction of several Shephelah cities—such as Beth Shemesh, Lachish, and Beit Mirsim—has been associated with the Assyrian king Sennacherib's campaign (e.g., Bunimovitz and Lederman 2003; Finkelstein and Na'aman 2004; Ussishkin 2015). For this reason, when I observed evidence of destruction in cemeteries beyond the Taosi cemetery in the Jinnan region—such as the Xiajin 下靳 cemetery of the Taosi Culture and the Qingliangsi 清凉寺 cemetery of the Sanliqiao Culture, both showing signs of looting—I considered whether these events might have been the result of a large-scale campaign. The key question, however, is whether these looting activities were related.

I would be very hesitant to answer affirmatively. The looting of the Taosi cemetery occurred at the transition from the Middle to Late Taosi phase, while the looting of the Qingliangsi cemetery dates to sometime in the Late Taosi phase (Shanxisheng, Yunchengshi, and Ruichengxian 2016: 354). These two episodes are roughly contemporary. In contrast, the looting at Xiajin appears earlier: the excavators suggest it took place not long after the latest burials, which date no later than the beginning of the Middle Taosi phase, placing the looting in the Middle phase.

The nature of the looting also differs. At Xiajin, the disturbance appears to have targeted jades and other prestige goods. By contrast, at both Qingliangsi and Taosi, the looting seems aimed at desecrating bodies and tomb structures, with many funerary offerings left untouched. Given these distinctions, the looting at Xiajin was almost certainly unrelated to the other two events. Whether the Taosi and Qingliangsi looting were connected remains uncertain, and future excavations at Sitou 寺头—the settlement associated with the Qingliangsi cemetery—may help clarify this issue.

(Zhongguo *et al.* 2005). Pits from this phase within the palatial area often contain large amounts of burnt ash. One notable feature, IVFJT2, is a rammed-earth structure located in Quadrant IV (Figure 27), which the excavators interpret as a sacrificial altar (He 2013a). In the early subphase of Late Taosi, houses and pits were cut into the altar's foundation, indicating that the feature had already been abandoned by that time.



(He 2013b: fig. 13.2)

Figure 27. Layout of the Taosi site.

In addition to the destruction of architecture, abundant evidence shows interpersonal violence. For example, Pit IHG8, a Late Taosi feature, contained more than 30 adult male skulls

bearing clear cut marks, along with a large number of bone arrowheads. Beneath the layer of male skulls, a complete set of skeleton of a ~35-year-old female was found at the bottom of IHG8. She was lying on her back, with one leg extended and the other flexed, and a 30–cm-long horn had been driven into her pelvis. Although the meaning of such violence remains uncertain—whether sacrifice, internal upheaval against the old elite, or invasion by outsiders—it is evident that Late Taosi society was marked by extreme violence.

Following the destruction and violence, efforts were made to restore certain landmarks as a response to the preceding crisis. The Middle Phase palace, IFJT3, was abandoned during the Late Phase, but to its west the excavators uncovered another rammed-earth structure, IFJT4, dated to the same period. IFJT4 was poorly constructed, with thin and loosely compacted rammed earth (He 2015). Similarly, the wall of the palatial area was rebuilt during the Late Phase in a substandard manner, with shallow and uneven foundation trenches (*ibid*). Despite this reduced investment of labor and resources, the reconstruction of the palace appears to represent an attempt to revive the political order of the Middle Phase.

The palatial area was not the only section restored during the Late Phase. As noted above, IVFTJ2—interpreted as a sacrificial altar—had been abandoned in the early subphase of Late Taosi. In the late subphase, however, a new foundation (IVFTJ3), covering an area of 1,000 m², was constructed on top of IVFTJ2, signaling an effort to revive the old social order after the violent upheaval. Yet IVFTJ3 was also abandoned later in the Late Phase, as it was intruded upon by ash pits, storage pits, houses, and tombs (He 2015). This suggests that the attempt to restore the old social order ultimately failed.

The failure to reconstruct the Middle Phase political order did not mean that all aspects of social life came to an end, nor that the population disappeared. On the contrary, multiple lines of evidence suggest that the Taosi community sustained itself during the Late Phase. Craft production, including stone tool manufacturing and pottery production, not only continued but even increased in productivity (He 2017). Collective efforts in flood management also persisted: new ditches were dug to redirect floodwaters, though this came at the cost of destroying portions of the Middle Phase city wall (He 2019). Compared with the Middle Phase, when flood control involved carefully planned canals and robust city walls (*ibid*), the Late Phase measures reflected reduced energy investment. Nonetheless, the very existence of such efforts demonstrates that community-wide collaboration and administration still functioned in Late Taosi.

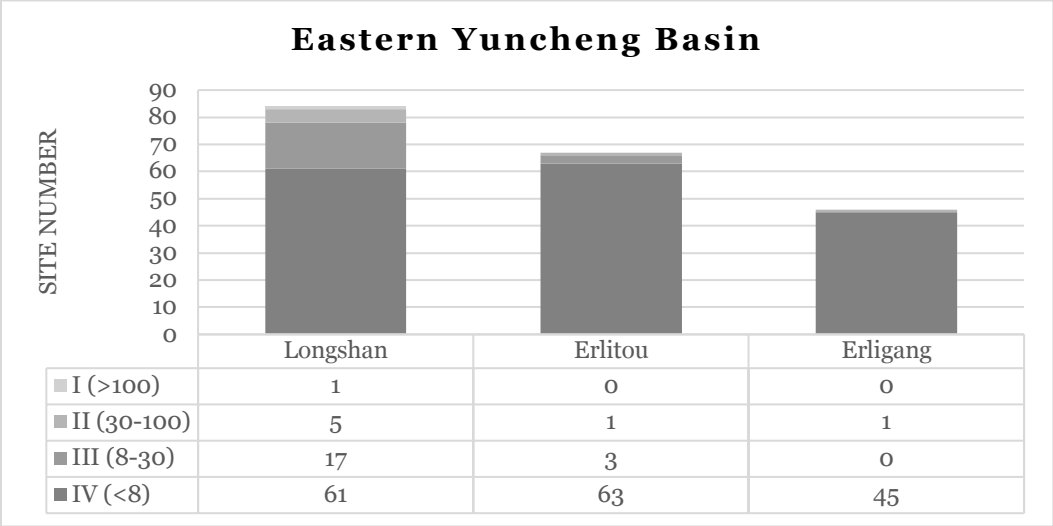
4.2 Zhoujiazhuang and Its Environs

The Zhoujiazhuang site is located on a loess terrace in the northeastern part of the Yuncheng Basin, on the north bank of the Sushui 涑水 River. It is backed by Mount Zijin 紫金山 to the north and faces the Sushui River to the south, with the Zhongtiao Mountains on the opposite bank serving as a natural barrier. To the east, it commands the strategic throat of the Zhiguan Pass 轵关陉; to the north, one can reach the Linfen Basin via the eastern flank of Mount Zijin; to the west, following the Sushui River leads to the Hedong 河东 salt ponds. The site thus occupies a location of great strategic importance. Cultural remains from the Yangshao, Miaodigou II, Longshan, Erlitou, Erligang, as well as the Zhou, Han, and Song periods have been identified.

The settlement history here is reconstructed through a regional systematic survey conducted in the eastern Yucheng Basin (Zhongguo guojia *et al.* 2011) and excavations of Zhoujiazhuang (Zhongguo guojia *et al.* 2021; Zhongguo guojia *et al.* 2015a, 2015b). The site first appeared in the Middle Taosi phase, and during the Late Taosi phase a moat was constructed as the settlement expanded to its peak size of 300 ha (Tian 2021). From these data, the following changes can be observed.

Decrease in Settlement Number

Figure 28 illustrates the changes in the number of settlements. The number of settlements peaked at 84 during the Longshan era, when the total occupied area of all sites reached 1,174.32 ha. By the Erlitou era, however, these figures declined to 67 settlements and 338.83 ha. While the reduction in settlement number was moderate (a 20% decrease), the total occupied area dropped sharply by 71.14%. This drastic decline was largely the result of the fragmentation of Zhoujiazhuang, which disintegrated into two smaller sites during the Erlitou period (Zhongguo guojia *et al.* 2021: 19; Zhongguo guojia *et al.* 2011).



Data from Shanxi Sheng and Yuncheng Shi 2011

Figure 28. The diachronic changes of the number of settlements and the distribution of sites in different size categories in Eastern Yuncheng Basin

Sites of different scales underwent distinct trajectories during the Longshan–Erlitou transition. Large sites (30–100 ha) contracted significantly, being reduced to small or medium-sized settlements. At the same time, about half of the medium-sized settlements declined to small sites, while the other half were abandoned. By contrast, smaller sites appear to have been more resilient, showing a greater capacity to persist and regenerate after the major transformation. Of the 61 small sites recorded in the Longshan period, 20 continued into the Erlitou period. Most of these retained their size, and some even expanded. In addition, 36 new small settlements were established during the Erlitou period.

The trend of decline and destratification in the settlement hierarchy continued into the Erligang period (1600–1200 BCE). During this time, 30% of Erlitou settlements were abandoned, and all medium-sized sites disappeared, reducing the settlement hierarchy from

three tiers to two. In contrast to their persistence during the Erlitou period, small sites also declined, with their numbers dropping by 28%. This suggests that by the Erligang period, the processes of depopulation or dispersal had extended to the village level as well.

Dynamics in Settlement Hierarchy

The settlement hierarchy declined from four tiers in the Longshan period to three tiers in the Erlitou period, with the size of settlements on each tier also reduced (Figure 29). During the Longshan period, the bottom three tiers measured 0–30 ha, 35–50 ha, and 55–60 ha, respectively. By contrast, the three tiers of the Erlitou settlement hierarchy measured only 0–10 ha, 20–25 ha, and 30–35 ha. This reduction in both scale and complexity of the hierarchy reflects a corresponding decline in social complexity.

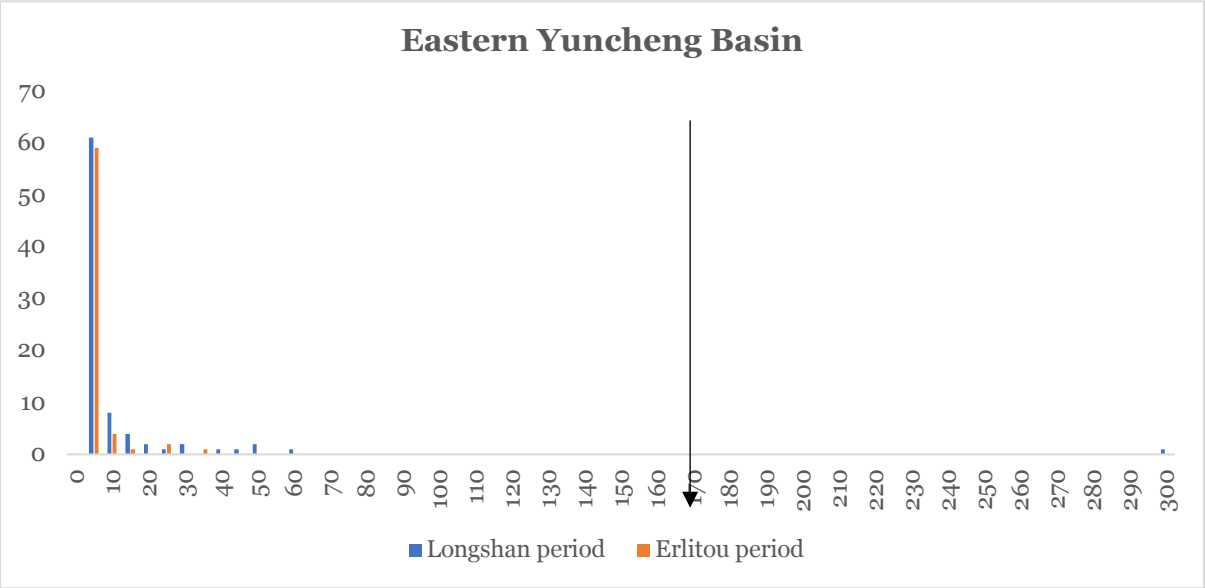


Figure 29. Site-size hierarchy in Eartern Yuncheng Basin during Longshan and Erlitou periods

Dynamics in Regional Centralization and Integration

Figure 30 presents the rank-size plots of the eastern Yuncheng Basin. During the Longshan era, the slope (1.74) was relatively steep, indicating that the largest settlements dominated strongly over smaller ones. This reflects a highly centralized settlement hierarchy, with a small number of core sites controlling a disproportionate share of regional resources and population. By the Erlitou period, the slope flattens to about 1.11, suggesting that settlement sizes were more evenly distributed as the largest centers fragmented and smaller sites proved more resilient. The goodness-of-fit also improves slightly, implying that despite the decline of certain dominant sites, the overall regional integration became stronger.

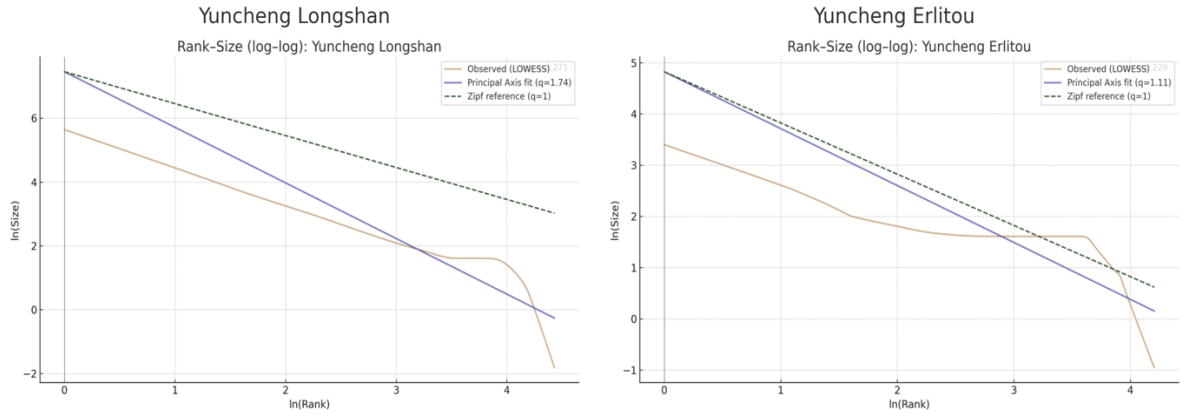


Figure 30. Rank-size plots of the Eastern Yuncheng Basin from the Longshan to Erlitou periods

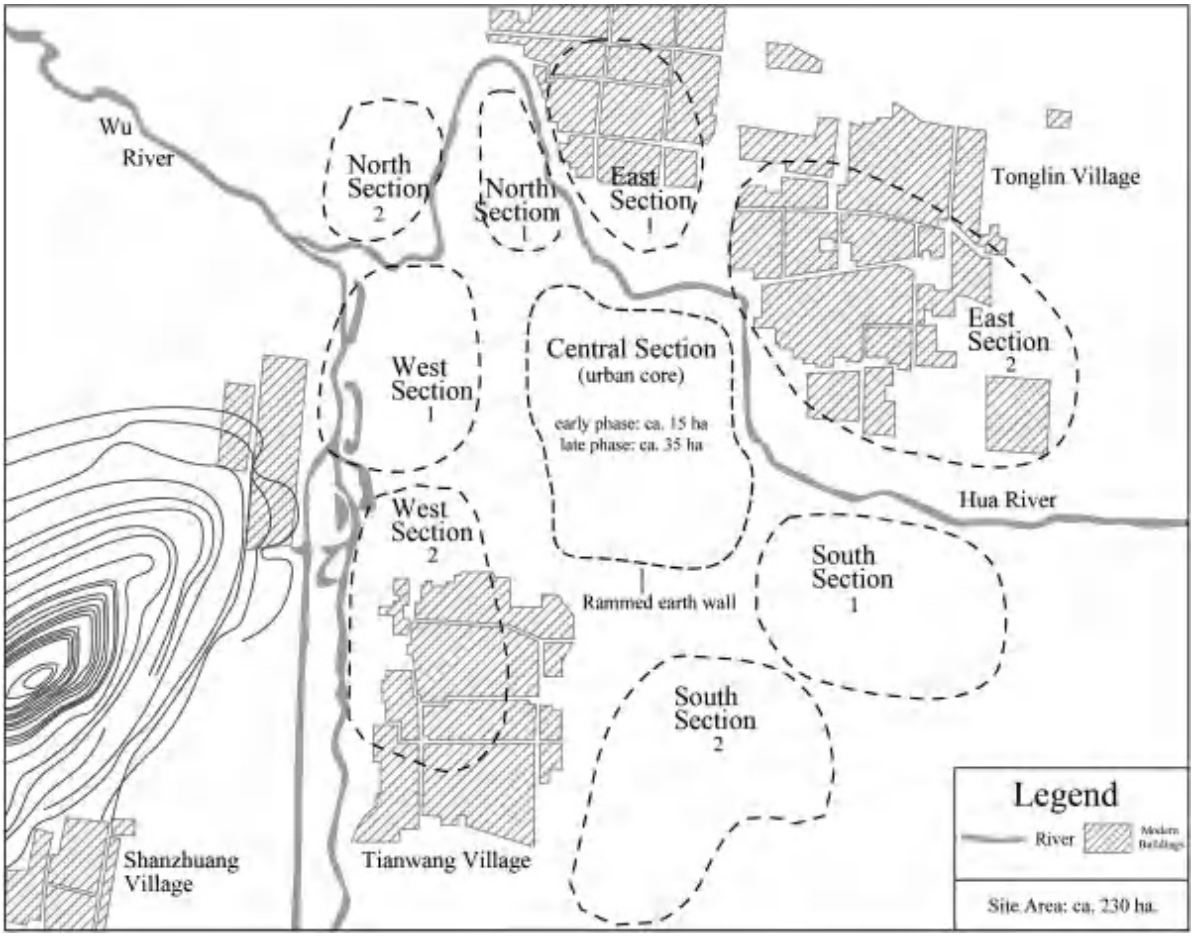
Rearrangement within Zhoujiazhuang

In contrast to Taosi, where destruction and violence occurred during the Late Taosi Phase, the Late Phase at Zhoujiazhuang is characterized by site expansion, moat construction, and the reorganization of functional areas within the enclosure (Tian 2021; Zhongguo guojia *et al.* 2015). The clearest change at Zhoujiazhuang prior to its fragmentation is that during the Late Phase, the area previously occupied by houses, ash pits,

and pottery kilns was converted into a cemetery (*ibid*). While the construction of the moat could be interpreted as a response to violence, most of the changes that took place at Zhoujiazhuang cannot be readily linked to crisis or reactions to crisis.

4.3 Tonglin and its environs in the western Haidai region

The Tonglin site complex is a proto-urban site spanning over 200 ha in northern Shandong. Tonglin was in continuous occupation from the Dawenkou to the Eastern Zhou period. It is located in the confluence area of the Wu River 乌河 and the Huashui River 漷水, with Yugong Mountain 愚公山 to its southwest. The central area of the site is an elevated terrace at an elevation of 39.8 meters, rising about 2–3 meters above the surrounding area. It was later damaged by a cross-shaped trench, which divided it into four sections (Figure 31). To the east of the central area, the river bends, forming a large meander to the north, and after converging with the Wu River flowing from south to north, it continues westward. Around the central terrace are slightly elevated grounds, divided into nine sections by river channels (Shandongsheng and Beijing daxue 2012: 149). As the several sections belong to the same settlement, it is referred to as a site complex. In 2007 and 2008, the Shandong Institute of Archaeology conducted a regional systematic survey in the area covering 170 km^2 centering on Tonglin (Shandong Sheng and Beijing Daxue 2012). The following changes could be observed.



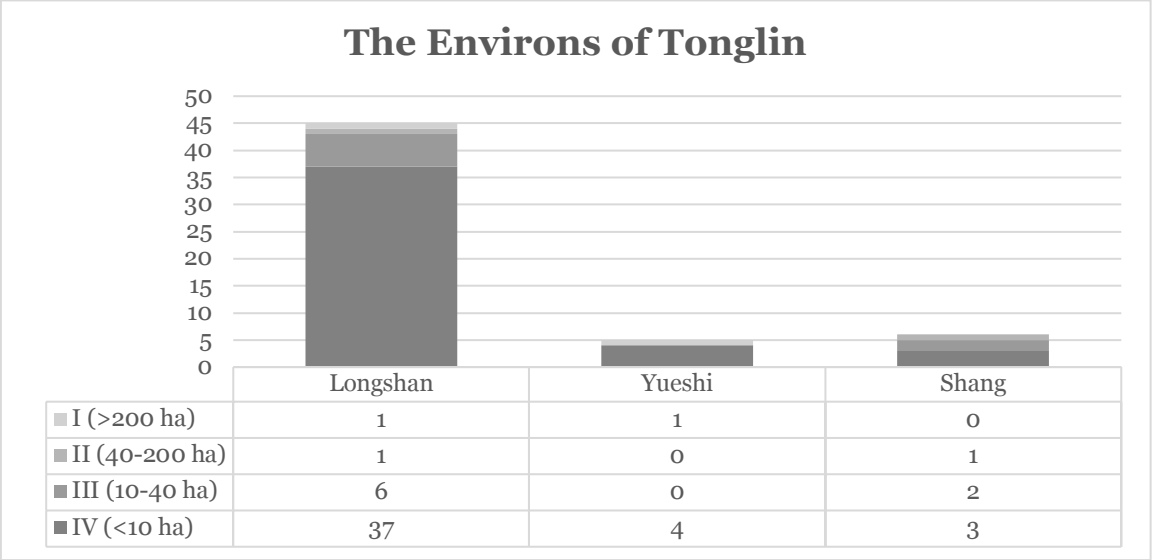
(Sun 2013 fig. 21.3)

Figure 31. The plan of Tonglin site complex

Drastic Drop in the Number of Settlements

The number of settlements around Tonglin declined by 90%—from 45 to 5 sites—at the onset of the Yueshi period around 1800 BCE (Figure 36). The total occupied area was reduced by half, from 428.8 to 211.7 ha. All surviving sites, except for Tonglin itself, were smaller than 5 ha, and no new settlements were established during the Yueshi period. The higher survival rate of small sites may suggest that these small-scale communities were more resilient. In the subsequent Shang period, as people began to reoccupy previously abandoned

sites, some signs of revival appear, although the total occupied area continued to decline, reaching only 84.5 ha.



	Longshan	Yueshi	Shang
I (>200 ha)	1	1	0
II (40-200 ha)	1	0	1
III (10-40 ha)	6	0	2
IV (<10 ha)	37	4	3

Data from Sun Bo 2012

Figure 32. The change in the number of sites in the environs of Tonglin

Reduction of Complexity of the Settlement Hierarchy

During the Longshan period, a three-tiered settlement hierarchy emerged (Figure 36). By the Yueshi period, however, it had been reduced to a two-tiered system. Tonglin remained the largest site in the region, but cultural remains were confined to the moated central section of the site complex, and the settlement's size declined to 30–35 ha (Qin 2007; Shandongsheng and Beijing daxue 2012). In other words, the Longshan–Erlitou transition at Tonglin was marked by population nucleation: residents who had previously lived in the outlying sections of the site moved into the moated enclosure, while populations outside the central site became extremely sparse, with all other settlements measuring less than 5 ha.

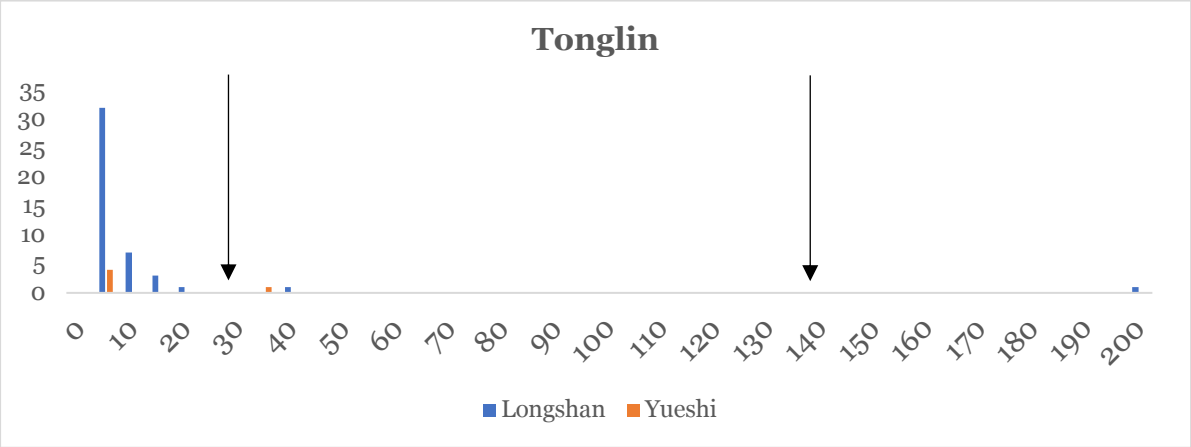


Figure 33. Site-size hierarchy of the Tonglin settlement system across the Longshan and Yueshi periods

Increased Centralization

The rank-size distribution shows very interesting changes during the Longshan-Erlitou transition (Figure 37), during which, both the centralization and coherence improved. This likely resulted from the population nucleation into Tonglin. This is consistent with evidence that, during the Yueshi period, a new moat was constructed, and the central section was partially walled (Shandongsheng and Beijing daxue 2012: 151). At the same time, the ceramics display a gradual stylistic transition from Longshan to Yueshi assemblages, indicating continuous occupation without sudden disruption (Shandongsheng and Beijing daxue 2012: 151). That means, despite the possible population decline, the crisis surprisingly improved regional consolidation in this case.

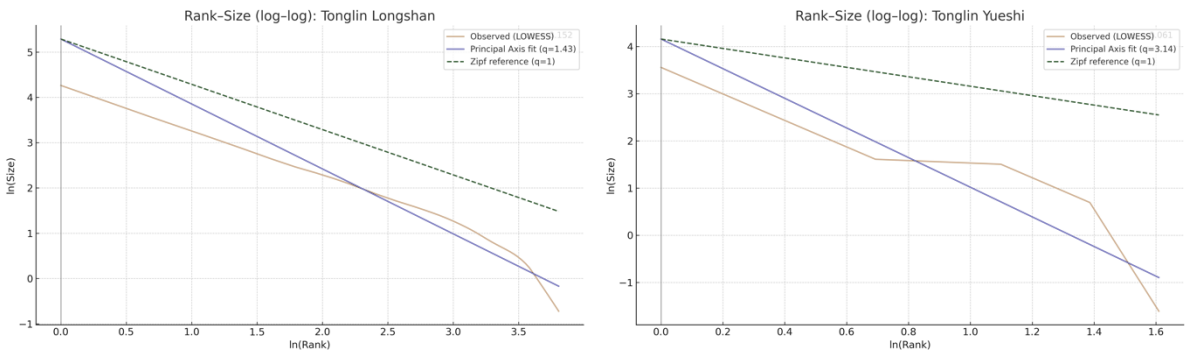


Figure 34. Rank-size plots of the Tonglin settlement system from Longshan and Yueshi periods

Reduction in Construction Quality

In the southwestern part of the central terrace, human activity began in Early Longshan Phase. The earliest houses were built directly on leveled ground without foundation trenches, with round or square floor plans. The round houses had walls built from adobe bricks, and the floors inside were repeatedly resurfaced; the square houses may have had rammed-earth walls. Some houses had a central post, with whitewashed floors and walls, sometimes decorated with red-painted designs. The houses at this stage were distributed rather loosely, with gaps of more than ten meters between dwellings. Scattered burials and ash pits were found nearby, with no clear association to the houses. Most houses covered an area of about 10 square meters, suggesting that the basic residential units were small in scale (Qin 2007: 17).

In the later part of Early Longshan, construction techniques changed. Builders first laid a soil foundation, then dug foundation trenches for wooden posts, creating timber-framed structures with wattle-and-daub walls. The floor plans became more regular squares or rectangles, with consistent dimensions—generally about 4–5 meters deep and an indoor area of roughly 15–20 square meters. Associated features such as storage pits and wells were

located near the houses. These platforms were separated by some distance, though in some cases intentional paving joined them into a plaza, whose fill layers were clean and free of other features. In the northern part of the excavation area, excavators found remains of what appears to be a "courtyard wall" foundation trench, which was expanded outward over time (*ibid*).

This type of house structure continued into Late Longshan, when another marked change occurred. The aforementioned plaza was deserted and the area became occupied by houses. House size decreased to about 10 square meters, with square floor plans. Construction shifted to a shallow semi-subterranean style, with much less energy input. Notably, this shallow pit-house form persisted into the Yueshi period, when house size increased somewhat. In earlier phases, many midden pits were dug around houses and they were made carefully in regular square or round shapes. People in the Late Phase, however, dug fewer but larger pits of irregular shape, indicating less energy expenditure in maintaining the living space (Shandongsheng and Beijing daxue 2012: 155).

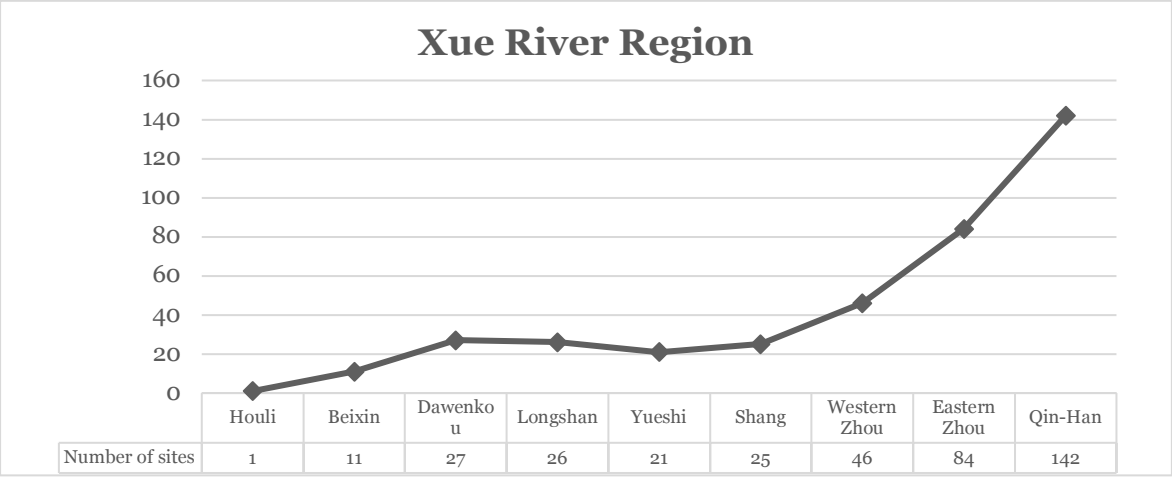
4.4 Xue River region

Located in the central part of southern Shandong, the Zaoteng 枣滕 region lies in the middle reaches of the Si 泗 River, a major tributary of the Huai River, and extends along the eastern shore of Weishan 微山 Lake—the largest freshwater lake in northern China. It occupies a transitional zone between the southwestern foothills of the central-southern Shandong mountains and the Huang–Huai Plain, with the Xue 薛 River flowing through its southern portion. Important archaeological sites in the Xue River basin include the Beixin 北辛 site of the Early Neolithic period, the Qianzhangda 前掌大 site of the Shang dynasty,

and the Xuecheng 薛城 site of the Eastern Zhou period. In conjunction with the construction of the Beixin Site Archaeological Park, Shandong University and the National Museum of China conducted a regional systematic survey of the Xue River basin between 2010 and 2012 (Zhongguo guojia and Shandong daxue 2016: 10–11). The results, published in 2016, reveal the following changes.

Settlement Decline

From the Longshan to the Yueshi period, the decrease in the number of settlements was moderate (19.2%), but the total occupied area dropped sharply by 75.9%, indicating that the remaining sites experienced major population shrinkage (Figure 35). In the subsequent Shang period, the number of settlements remained low, but the total occupied area increased significantly to 324.8 ha, marking the revival of the region and the beginning of a process of continuous growth that lasted for more than a millennium.



Data from Zhongguo and Shandong 2016

Figure 35. Changes in the number of sites in the Xue River region

During the Longshan – Yueshi transition, smaller sites proved more durable than larger ones. The largest site, Dahancun 大韩村, though not abandoned, contracted to only two

hectares. By contrast, small sites (below five hectares) that persisted into the Yueshi period often experienced slight expansion. In addition, one medium-sized site and four small sites were newly established during the Yueshi period. When the contraction of larger sites is accompanied by the persistence or expansion of smaller ones, such changes can perhaps be interpreted as population dispersal, with previously aggregated populations spreading into smaller village sites or adopting more mobile lifeways, although this inference calls for further investigation through excavation.

Reduced Settlement Hierarchy

A four-tiered settlement hierarchy emerged during the Longshan period (Figure 39), but by the Yueshi period it had collapsed to a single tier, with only the bottom level remaining. This represents a clear destratification of the settlement hierarchy, reflecting a marked decline in social complexity.

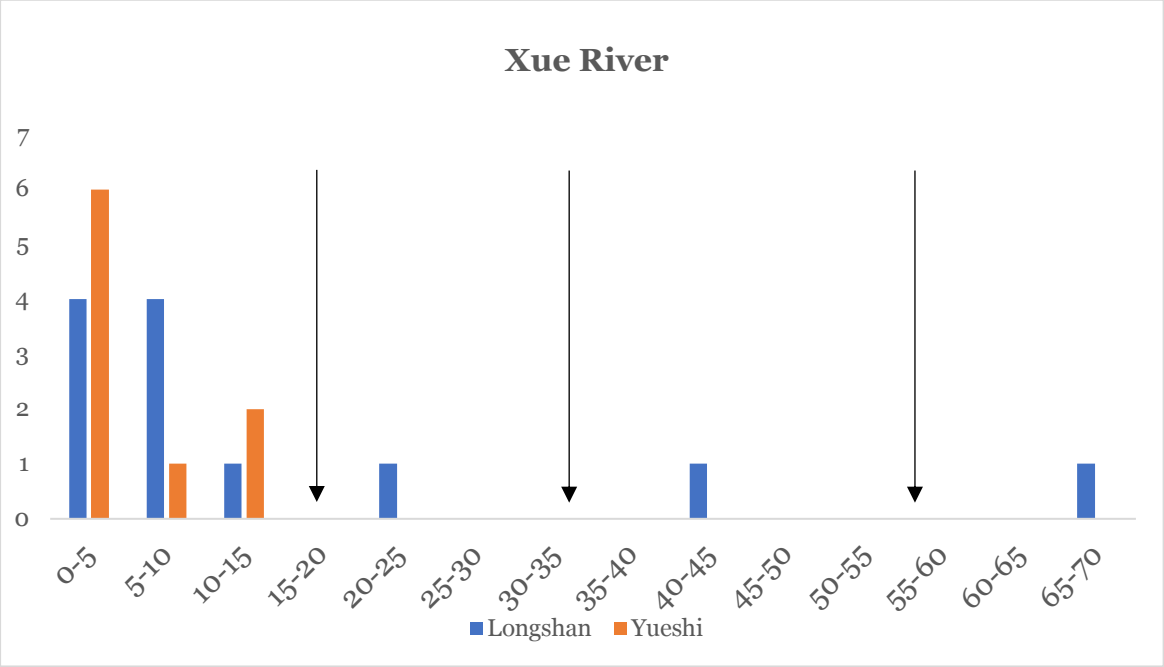


Figure 36. Site-size hierarchy in the Xue River region across the Longshan and Erlitou periods

Stability in Regional Centralization and Integration

The rank-size distribution of sites in the Xue River basin shows no significant changes (Figure 40). In the Longshan period, the settlement system appears moderately centralized and highly hierarchically coherent—a pattern that also characterizes the Yueshi period. In other words, despite the decline in total occupied area and the abandonment of several of the largest sites, the system as a whole remained integrated. However, because very little excavation data have been published from this region, it remains unclear what role the large Longshan sites may have played during the Longshan period and what this stability in rank-size distribution indicates in sociopolitical terms.

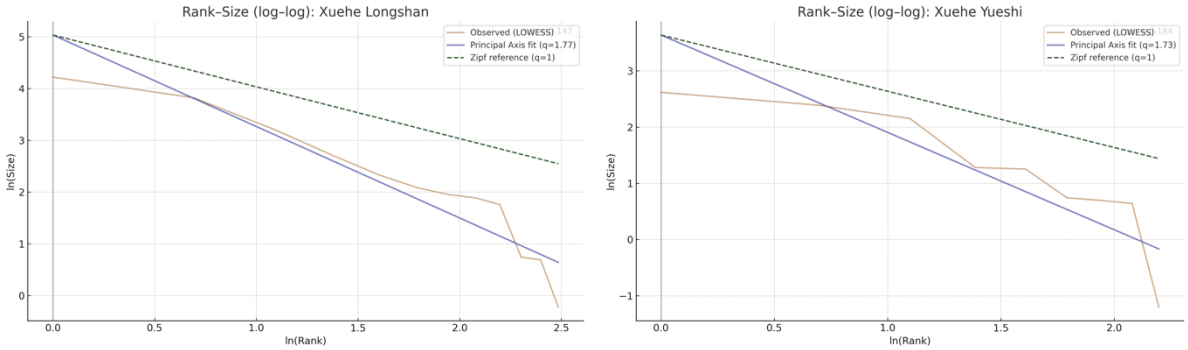


Figure 37. Rank-size plots of the Xue River settlement system in the Longshan and Yueshi periods

4.5 Chengziya and Its Environs

The site of Chengziya 城子崖 is one of the proto-urban centers of the Haidai region. It is situated on a loess terrace rising above the surrounding floodplain. This slightly elevated position provided natural drainage, reducing the risk of seasonal flooding while keeping the community close to fertile alluvial soils for farming. The site is also near the Wuyuan 武源 River, a tributary of the Yellow River. In the early 2000s, the Shandong Archaeological Institute conducted a survey of the Chengziya area, covering 100 ha (Shandongsheng 2013).

Site sizes were estimated based on the surface distribution of cultural remains, without differentiation by time period. From these data, the following phenomena can be observed.

Settlement Decline

The number of settlements peaked during the Longshan era and began to decline thereafter (Figure 38). From the Longshan to the Yueshi period, the number of settlements decreased by 33% (from 14 to 8 sites), followed by a further 50% reduction (from 8 to 4 sites) during the transition to the Shang period. In comparison with the hinterland of Liangchengzhen (see below), where more than 90% of sites were abandoned within roughly two centuries, the transformation of the Chengziya settlement system appears relatively moderate.

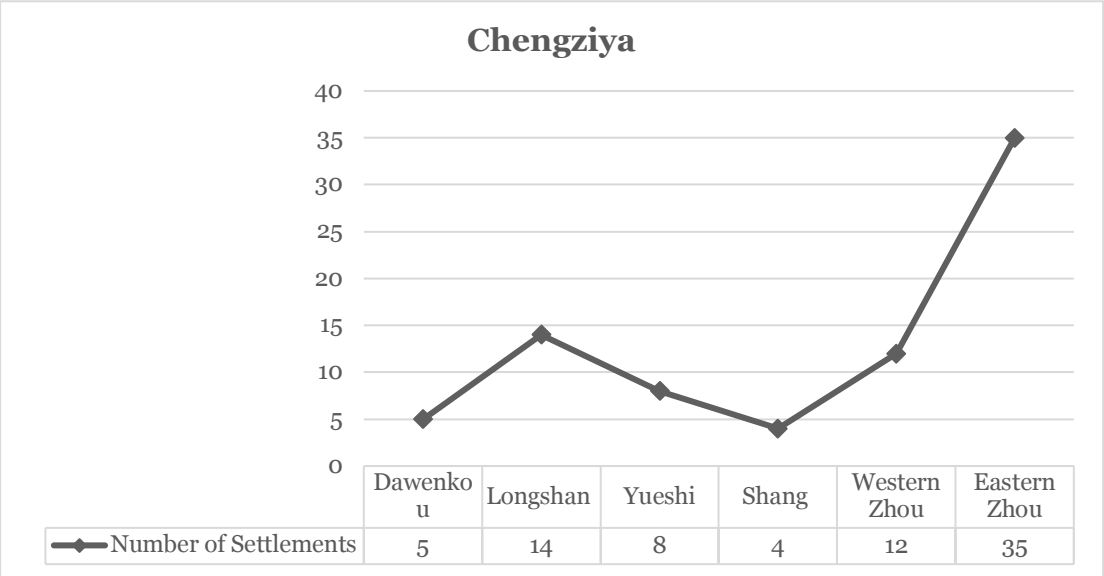


Figure 38. Changes in the number of settlements in the environs of Chengziya

Increasing Settlement Hierarchy

Current site-size histograms suggest a two-tiered settlement hierarchy during the Longshan period and a three-tiered one during the Yueshi period (Figure 39). However, it

should be noted that the top-tier site, Jiaojia 焦家, flourished primarily during the Middle to Late Dawenkou period and remains from the Longshan and Yueshi periods are sparse at the site, although pottery sherds from these later periods have been recovered (Shandong daxue and Jinanshi 2019). Given the limited evidence of Longshan and Yueshi occupation at Jiaojia, it is reasonable to infer that its size during these periods was far smaller than the reported 56 ha. We may therefore tentatively exclude Jiaojia from the settlement hierarchy. Once removed, the Longshan settlement system appears unstratified, while the Yueshi period saw a two-tiered hierarchy. In either case, the site-size analysis points to only a low level of stratificatio.

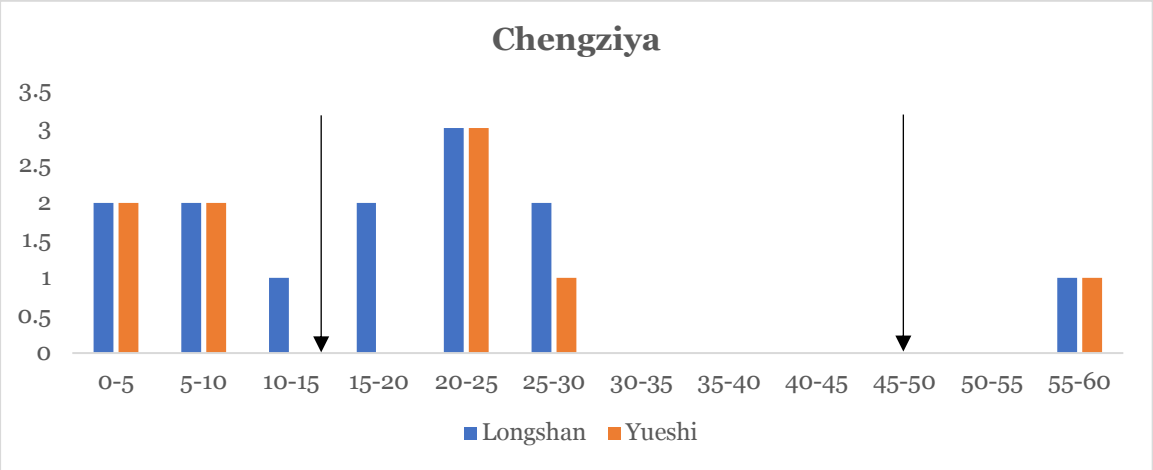


Figure 39. Settlement hierarchy in the environs of Chengziya from Longshan and Yueshi periods

Dynamics in Regional Centralization

In the Longshan period, the settlement system was moderately centralized but poorly integrated (Figure 40). Chengziya is the only fortified settlement with moat and walls in the surveyed region, and thus is believed to be the region center, but Chengziya (22 ha) is only of medium-size. Other unwalled sites, such as Lanjia 兰家 (28 ha), Weidong 卫东 (21 ha),

Sunjia Dongnan 孙家东南 (20 ha) were larger or comparable to Chengziya in size. In contrast to many other regions, where the walled-sites also appeared to be on the highest rank, Chengziya is only of the upper tier within the rank, but not on the highest rank. Considering that, apart from black pottery, Chengziya has not yielded typical Longshan-period prestige goods such as jades, white pottery, or turquoise (Shandongsheng and Beijing daxue 2019), its role as a political center may need to be reconsidered. It is possible that while Chengziya fulfilled primarily a defensive or fortification function, other economic and political roles were assumed by sites of comparable size in the region, suggesting a more decentralized form of organization. This accords with the rank-size distribution: the high standard deviation indicates poor alignment with the expected model of strong integration.

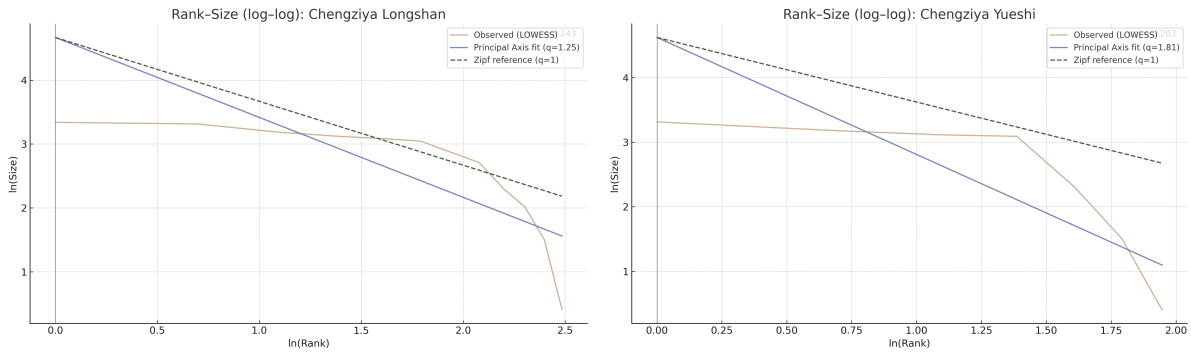


Figure 40. Rank-Size plots of the Chengziya settlement system during the Longshan and Yueshi periods

Note: Jiaojia is removed from analysis.

In the Yueshi period, both centralization and hierarchical coherence increased slightly. This coincided with the continued expansion and maintenance of fortification facilities (more details below). Although the total number of settlements declined somewhat, the system as a whole displayed stronger regional consolidation. What is often described as a

"crisis" may therefore be reinterpreted as a process of reorganization toward greater regional integration.

Sustained Administrative System

Chengziya demonstrated remarkable durability during the Longshan–Erlitou transition. The site continued to function as a fortified center through the Yueshi and even the Shang period, with evidence of city wall renewal and maintenance indicating a sustained capacity to mobilize labor and resources (Zhu 2020). Settlement changes during the Shang period appear to have been linked to the rise of Daxinzhuang as an eastern outpost of the Shang capital in Henan; the concurrent decline of settlements around Chengziya likely reflected a shift in the political center rather than social collapse. Overall, although the Chengziya polity experienced a moderate population decline, the change was far less drastic than that of the Liangchengzhen polity in eastern Haidai.

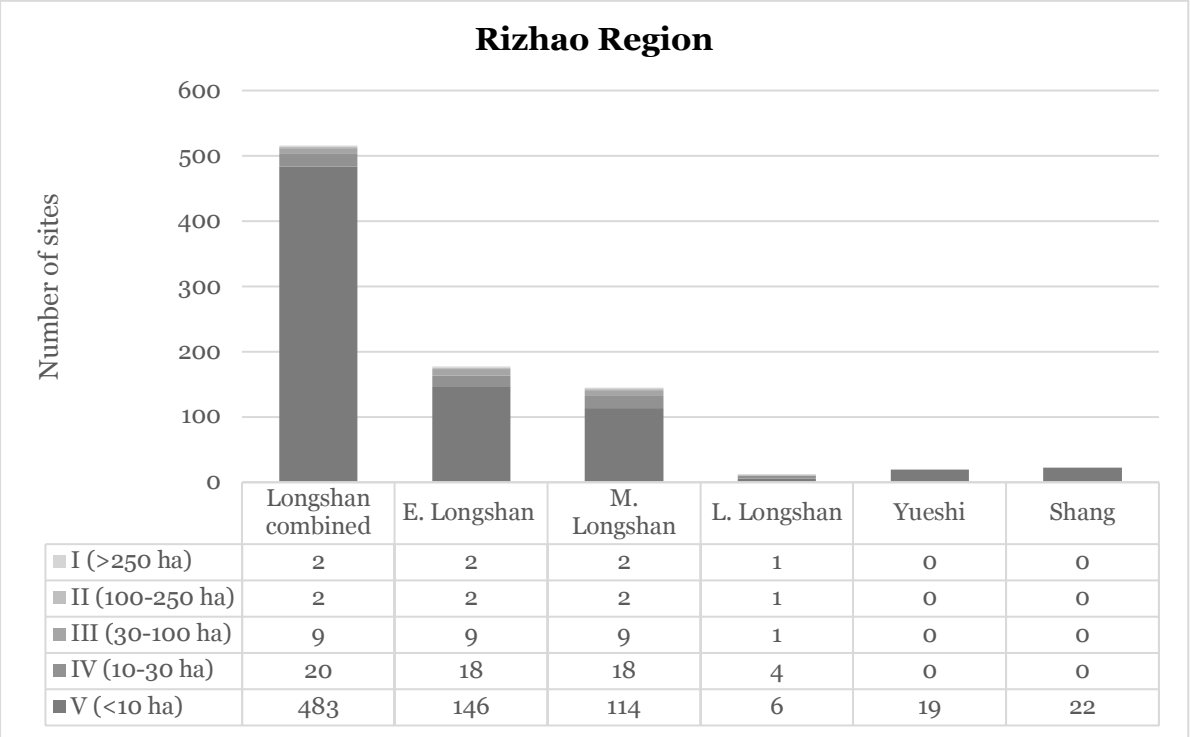
4.6 Southeastern Shandong and the Liangchengzhen polity

In eastern Haidai, survey data come from the regional systematic survey of southeastern Shandong conducted jointly by Shandong University and Yale University beginning in 1995. Most of the surveyed area is in the modern city of Rizhao 日照. By 2007, the survey had covered 1,400 km² and identified more than 500 Longshan sites, 19 Yueshi sites, and 31 Shang sites (Zhongmei 2012). Of the 500 Longshan sites, 244 were dated more precisely to the Early, Middle, and Late Longshan phases, allowing for a discussion with finer chronological resolution. Among these, 177 sites belong to the Early Shandong Longshan phase, 148 to the Middle phase, and only 13 to the Late phase (Figure 44) (Zhongmei 2012).

Settlements remained sparse until the Mid–Western Zhou period, when the number of sites returned to around 500. During the Eastern Zhou, the number continued to rise, reaching 900, and by the Han dynasty the total impressively exceeded 1,600. Site sizes were determined by the surface distribution of cultural remains, and the size of each site was reported period by period.

From the Early to the Middle Shandong Longshan phase, both the number and total size of sites declined slightly (from 158 to 144 sites), as shown in Figure 41, but the density of pottery sherds at these sites increased (Zhongmei 2012). The coexistence of fewer settlements with higher artifact density may suggest a process of population nucleation during the Middle Longshan phase. By the Late phase, the number of settlements dropped dramatically to 13, most of which were concentrated in the environs of Liangchengzhen. Settlements of different sizes experienced such disturbance in varied ways. The severity of the decline of small sites was more significant than with large sites.

Beyond Liangchengzhen 两城镇, the Longshan–Yueshi transition in the region was marked by the near-total abandonment of sites across all size categories. None of the Longshan settlements were reoccupied in the Yueshi period; instead, all 19 Yueshi sites were newly established in previously unoccupied locations. Moreover, there was no clear size differentiation among either Yueshi or Shang sites, as all remained uniformly small. Unlike Longshan communities, which often occupied the same sites continuously for centuries, Yueshi villages were quickly abandoned during the subsequent Shang period. It was only from the Western Zhou onward that continuous site occupation over long spans of time became common again.



	Longshan combined	E. Longshan	M. Longshan	L. Longshan	Yueshi	Shang
I (>250 ha)	2	2	2	1	0	0
II (100-250 ha)	2	2	2	1	0	0
III (30-100 ha)	9	9	9	1	0	0
IV (10-30 ha)	20	18	18	4	0	0
V (<10 ha)	483	146	114	6	19	22

Data from Zhongmei 2012

Figure 41. The change in settlement number and the distribution of sites of different sizes

Declined Settlement Hierarchy

During the Early Longshan phase, a four-tiered settlement hierarchy emerged (Figure 45), with Yaowangcheng 尧王城 in the south and Liangchengzhen in the north at the top of the system. Yaowangcheng, founded in the Late Dawenkou period, grew to become the largest site in the region during the Early Longshan. Liangchengzhen, by contrast, was first established in the Longshan era, and its rapid development was likely linked to its relationship with Dantu, which had been the largest settlement in the Late Dawenkou period. The large-scale fortifications and exquisite jades discovered at Dantu attest to its prominence on the local cultural–political stage, and Liangchengzhen was probably established as an accompanying settlement to Dantu (e.g., Falkenhausen 2008: 215; Zhongmei 2012: 302).

Centered on each of these two major sites, a four-tiered settlement hierarchy took shape in the Early Longshan period.

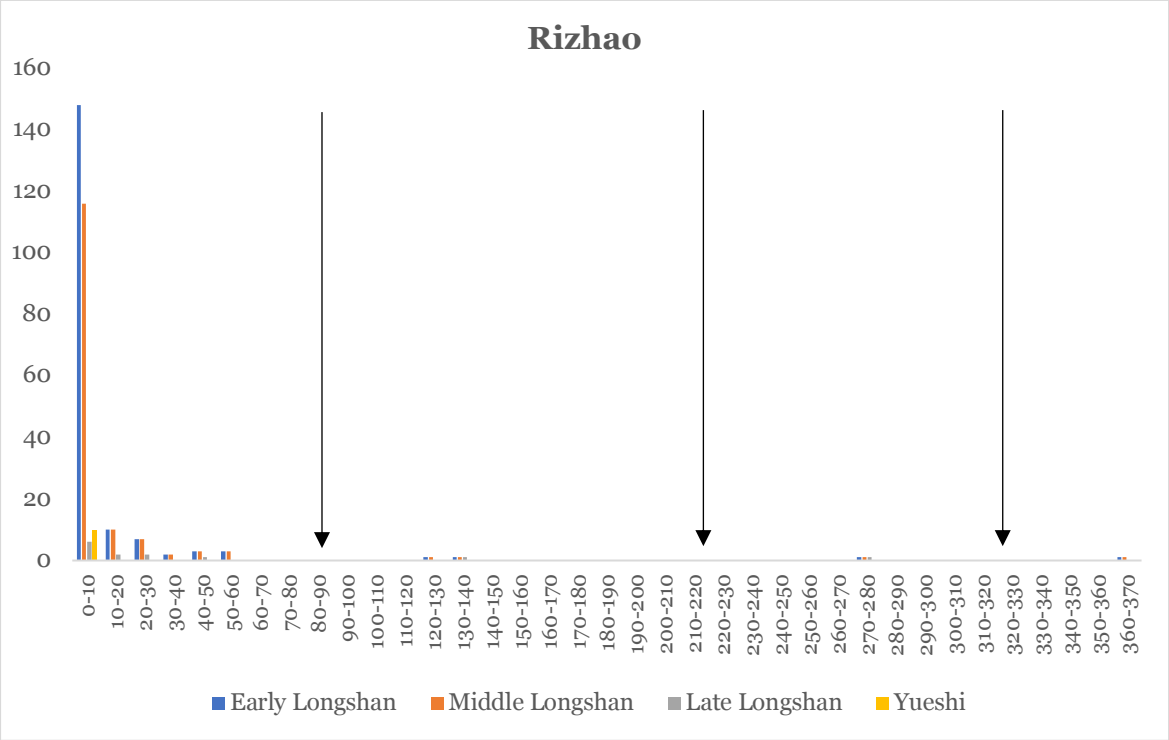


Figure 42. Site-size hierarchy in the Rizhao region across Longshan and Yueshi periods

During the Middle Longshan period, the four-tiered settlement hierarchy persisted, but the second- and third-tier settlements declined. While Liangchengzhen and the sites in its immediate vicinity expanded, the secondary centers in the hinterland of the Dantu–Liangchengzhen polity contracted. The six secondary centers within 15 km of Liangchengzhen either disappeared or diminished considerably in size. Even so, most sites directly surrounding Liangchengzhen retained their scale, and one small fourth-tier site (LCZ-2/3) even grew into a second-tier settlement during this period. These patterns suggest that Liangchengzhen, Dantu, and their immediate surroundings became increasingly integrated, with the population concentrating in Liangchengzhen and Dantu themselves and their hinterland.

By contrast, the settlement hierarchy around Yaowangcheng became less nucleated during the Middle Longshan. While three settlement clusters had existed south of Yaowangcheng (in the zone between Liangchengzhen and Yaowangcheng) during the Early Longshan, they contracted significantly during the Middle Longshan. Meanwhile, there is no evidence for an increase in population density or site size at Yaowangcheng.

During the Late Longshan phase, the settlement hierarchies around both Liangchengzhen and Yaowangcheng collapsed, with most remaining sites measuring less than 10 ha. Within the Liangchengzhen system, Liangchengzhen itself largely retained its scale, in sharp contrast to the decline of other sites in the region. Dantu, by contrast, appears to have been abandoned. Although a few Late Longshan sherds were recovered there, excavations indicate that the stratigraphic sequence ended in the Middle Longshan (Liu and Wang 2001), suggesting that any subsequent human activity was sparse and intermittent. The abandonment of such top-tier settlements resulted in a system composed of one large central site surrounded by several small villages in the Liangchengzhen hinterland. In the south, the abandonment of Yaowangcheng was confirmed by both survey and excavation.

From a comparative perspective, this is an uncommon phenomenon. As in most cases of societal collapse, rural sites were more resilient than large sites, as the former were self-sufficient and independent, while the sustaining of large urban sites relied heavily on the service of surrounding rural sites and provision of resources from peripheries (Tainter 1988). The rarity of the Liangchengzhen case deserves further discussion. We will return to this point in the discussion section.

Increased Centralization and Integration

Figure 5-22 shows the changes in rank-size distribution in the Longshan and Yueshi periods. In Early and Middle Longshan Phases, the system in the Rizhao region presents characteristics of moderate centralization and relatively good integration. When the collapse took place in Longshan, the level of centralization further strengthened. While the number of settlements drastically declined, the selective continuation but also abandonment of settlements seemed to have followed some sort of law that further consolidated the hierarchical coherence.

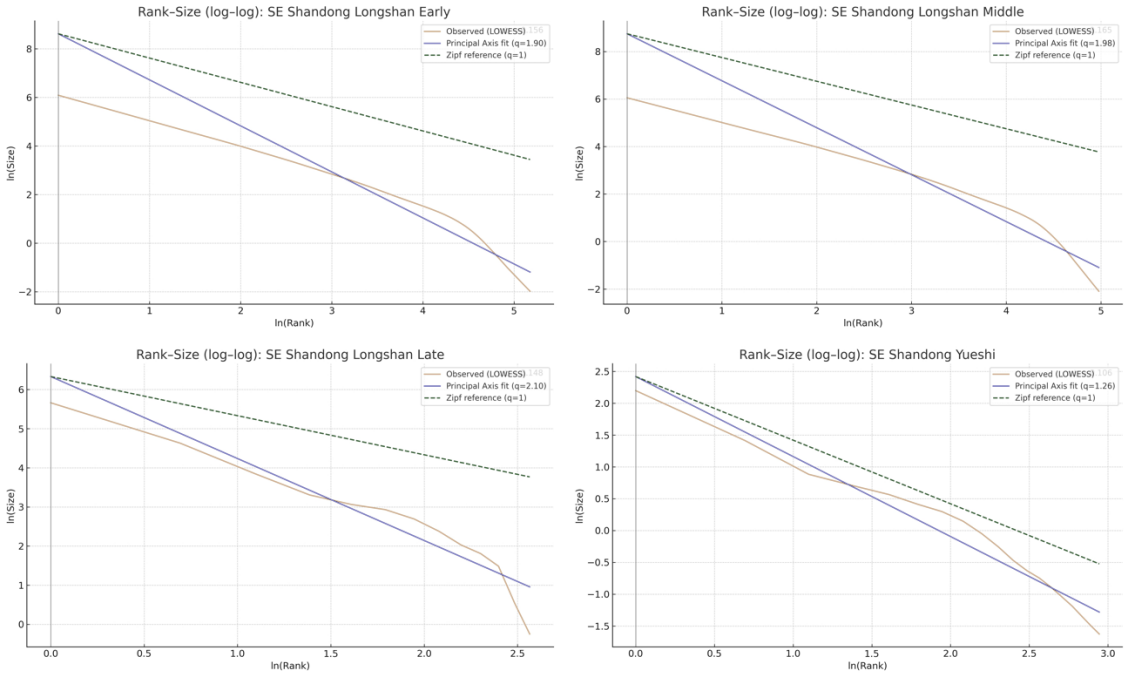


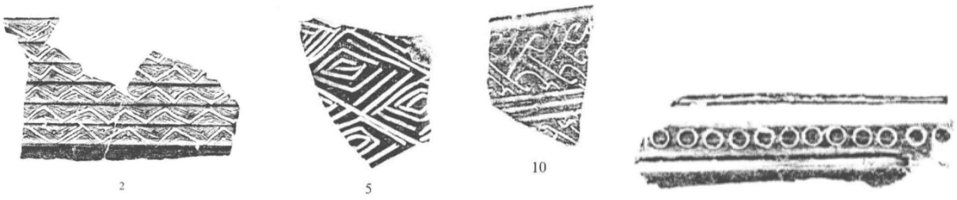
Figure 43. Rank-size plots of the Rizhao region in Early, Middle, Late Longshan Phases and Yueshi period

Minimum Signs for Crisis within Liangchengzhen

While the Liangchengzhen polity already declined during the Late Longshan, there are few signs of crisis within this mega settlement, at least not in the excavated area. The

excavation of Liangchengzhen shows that not only did the site continue into the Late Longshan period, but its scale expanded, and the human activities on site remained as intensive as previous. For example, the largest moat was constructed during the first half of the Late Phase. The construction of the outer moat indicates the Liangchengzhen dwellers' need to expand the city at this time. Later, in the second half of this phase, while people stopped maintaining this moat and started using it to dump trash, the quantity of cultural remains remained abundant. This suggests that while the function of the moat had changed, nearby human activities remained intensive.

Take the quality of ceramic production, which remained high level during the Late Phase as another example. Pottery sherds with fine imprints that resembled the patterns on stoneware from the Shang and Zhou periods were found in the outer moat (Figure 44), suggested that fine-quality pottery production continued in Late Longshan (Zhongmei 2016: 970–972). The inhabitants of Liangchengzhen were thus able to maintain their living standards for a while (probably about a century) before abandoning their settlement.



From left to right: T10G10②:36, T005G6②:30, T007G7:423, and T007G7:405 (Zhongmei 2016: fig. 5-184 and 5-185)

Figure 44. Pottery sherds with fine patterns from the outer moat.

4.7 Northern Loess Plateau: Hutuo River and Tuwei River

Although survey and excavation data indicate that the northern Loess Plateau also underwent major social transformations in the second millennium BCE, the available

evidence from this region remains fragmentary. Surveys along the Hutuo River 滹沱河 and in the environs of Shimao on the Tuwei River 秃尾河 provide some basis for reconstructing local settlement history, but limited publication leaves many details uncertain. The following section will briefly introduce the settlement patterns of the Shimao area and the Hutuo River region, respectively.

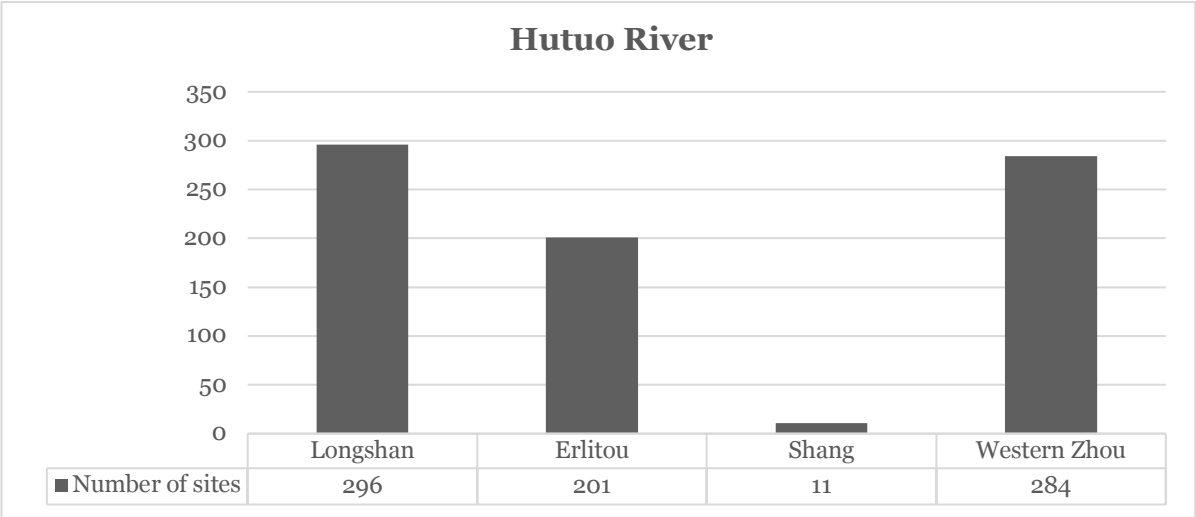
Shimao is located in the northeastern sector of the Ordos region, within the great bend of the Yellow River. It occupies the upper reaches of the Tuwei River valley, a major tributary of the Yellow River. Recent surveys along the Tuwei valley have identified 11 walled Longshan settlements (including Shimao) and 193 unwalled settlements, varying in size and collectively forming a hierarchical settlement system with Shimao as the principal center (Sun *et al.* 2017). This wave of regional fortification, however, came to an end with the abandonment of Shimao and the other walled sites in the region around 1800 BCE.

Along the Hutuo River in northern Shanxi, social transformations occurred several centuries later. The upper reaches of the river lie mainly within the Xinding Basin 忻定盆地 on the Loess Plateau. Owing to the fragmented terrain, the river frequently changes course. Originating from Taixi Mountain 泰戏山 on the plateau, the Hutuo River first flows westward, then turns south upon entering Yuanping 原平, and later turns east, passing through the Taihang Mountains before finally emptying into the Bohai Sea. From 2006 to 2008, a joint team conducted a regional survey covering 226,300 ha across the five counties and cities through which the upper Hutuo River flows (Shanxisheng *et al.* 2012). Site sizes were determined by the surface distribution of cultural remains, and site sizes were not classified by period.

Moderate Decline in the Size and Number of Settlements

The survey indicates that the transition from the Longshan to the Erlitou period in this region was characterized not by collapse but by relative stability. Of the 296 sites with Longshan remains, 201 continued into the Erlitou period, representing a decline of about 32% (Figure 45). In contrast, only 11 sites yielded material from the Shang period (Erligang and Yinxu). Settlement activity peaked again during the subsequent Zhou period, when 284 sites were recorded (Shanxisheng *et al.* 2012a; 2012b).

The sharp decline in settlement number during the Shang period suggests that the major "collapse" in Hutuo River region occurred significantly later than in other regions discussed in this chapter. However, the survey team noted that site identification was based primarily on Central Plain Shang material culture. As a result, contemporaneous sites associated with local cultural traditions may have gone unrecognized (Shanxisheng *et al.* 2012b: 923)). Consequently, the apparent decline in site numbers during the Shang period may not have been as severe as currently indicated.



Data from Shanxisheng *et al.* 2012a and 2012b

Figure 45. Changes in the number of sites in the Hutuo River basin

No Clear Change in Settlement Hierarchy

The site-size distributions show very similar structures in both the Longshan and Erlitou periods. The largest site, Gucheng 古城, appears disproportionately larger than the others. However, site reports note that Longshan cultural remains are sparse and confined to the western part of the site, Erlitou remains are similarly sparse and limited to the west, while Eastern Zhou remains are widespread across the site and occur at much higher density. This suggests that the reported size of 582.8 ha does not accurately reflect the Longshan and Erlitou occupations; the actual extent of the site in these periods was likely much smaller. Accordingly, the settlement hierarchy of these periods may have consisted of only two tiers, with minimal differentiation between them, indicating weak stratification. For this reason, I tentatively exclude Gucheng from the following analysis, since its overestimated size could significantly distort the rank-size distribution of the region.

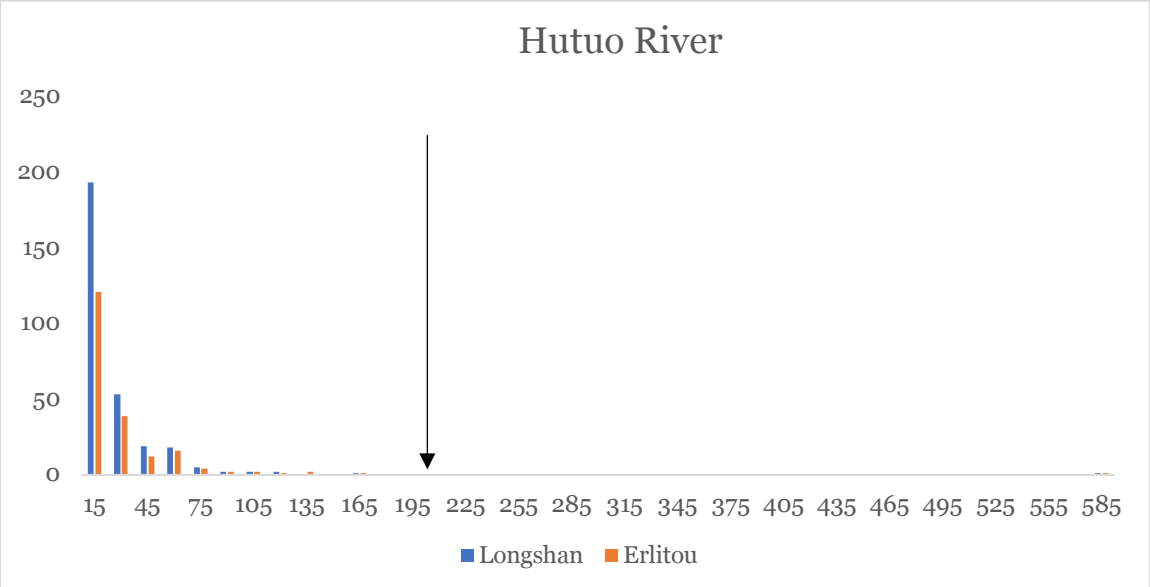


Figure 46. Site-size hierarchy of the Hutuo River basin across the Longshan and Erlitou periods

Regional Integration

As in the Xue River region, no significant changes in rank-size distribution can be discerned during the Longshan–Erlitou transition (Figure 47). In both periods, the system remained moderately centralized but poorly integrated. Because so little excavation data are available from this region, further analysis of the nature of settlement change at this time is not possible.

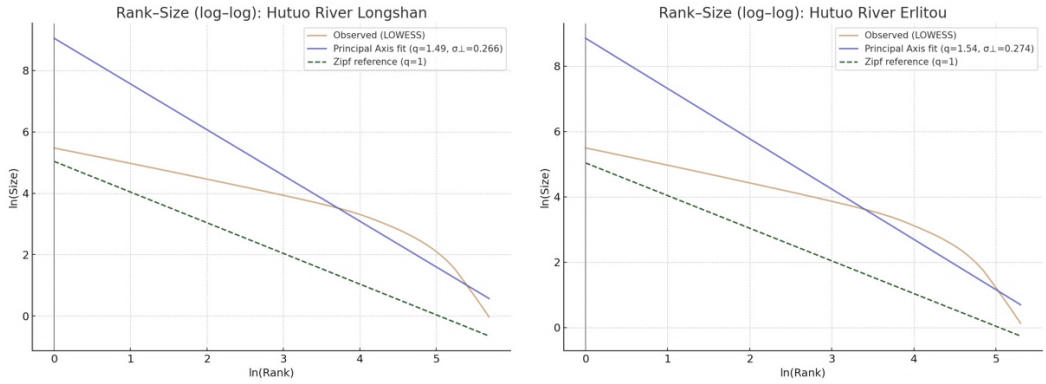


Figure 47. Rank-size plots of Hutuo River basin settlements from Longshan and Erlitou periods

In summary, limited data are available on settlement pattern dynamics in the northern Loess Plateau. What can be said is that while Shimao was part of the broader Longshan–Erlitou collapse, the Hutuo River region appears to have followed a different trajectory. Although both regions lay within zones sensitive to declining precipitation, the decline in their settlement systems occurred at different times.

5. **Discussion**

In the discussion, I hope to summarize and discuss three topics: (1) the temporality and (2) regional variability of the Longshan Transformation, as well as (3) some patterns that need further exploration.

5.1 Longshan collapse as a multi-scalar and multi-stage process

Drawing on the settlement data reviewed above, two major waves of transformation can be identified during the Longshan Transformation. The first occurred during the transition from the Middle to Late Shandong Longshan phase, or from the Middle to Late Taosi phase, in the 20th century BCE. This wave is most clearly visible in eastern Haidai and Jinnan. In the Rizhao region, the number of settlements declined by more than 90%, as Yaowangcheng and most small sites were abandoned and populations concentrated in the central large site, Liangchengzhen, after ca. 2000 BCE. At the same time, Taosi experienced major destruction and cultural reorganization, while medium-sized sites in its hinterland were abandoned.

The second wave took place at the end of the Longshan era, around 1800 BCE. This wave affected a much wider area, including eastern Haidai (Liangchengzhen), western Haidai (Tonglin, Xue River, and arguably Chengziya), Jinnan (Taosi and Zhoujiazhuang), and the northern Loess Plateau (Shimao). Its impact was also more profound: in many regions—such as the environs of Taosi and Liangchengzhen—settlement remained sparse for centuries, and several mega-sites, including Taosi, Liangchengzhen, Zhoujiazhuang, and Shimao, were not only disrupted but ultimately abandoned.[13] This demonstrates that the Longshan Transformation was not a sudden event, as earlier research has indicated, but rather a multi-stage process, with each wave of transformation differing in scale and severity.

[13] The Shimao site was abandoned around 1800 BCE (Sun et al. 2020a), but it was later reoccupied by a different group, characterized by the use of shewenli 蛇纹鬲 (snake-patterned tripodal vessels). This reoccupation lasted until around 1600 BCE (Shaanxi Sheng et al. 2020).

5.2 Regional Variability

As shown in Table 9, each region followed its own trajectory of decline, collapse, and regeneration. At Tonglin and Liangchengzhen, settlement change took the form of population nucleation in the face of crisis, whereas at Zhoujiazhuang in the Xue River basin it manifested as population dispersal. Although all of these regions experienced declines in the number and size of settlements—suggesting population loss to some extent—the contrasting processes of nucleation and dispersal reflect different modes of mobility among the remaining populations.

Regional differences also appear in levels of centralization and integration. In some areas, declines in site number and total occupied area corresponded with reduced regional integration, while in others these same declines produced higher levels of consolidation. Even within zones of similar temperature and hydrological conditions, settlement systems followed distinctive paths. For instance, Shimao and the surrounding smaller sites were abandoned around 1800 BCE, while the Hutuo River basin experienced only moderate decline. Such variability indicates that the Longshan Transformation cannot be understood as a single, monolithic macroregional collapse, but rather as a mosaic of regional events unfolding in sequence across a broad territory, reflecting varied experiences in regions that were environmentally and sociopolitically diverse.

The factors underlying this variability remain unclear, but the observation itself suggests a shift in research perspective. Rather than viewing the Longshan Transformation as a unified phenomenon, we should adopt region-focused, multi-scalar, comparative, and connective approaches. This allows us to see that there may not have been a single

overarching cause. Instead, a series of small-scale factors produced local changes which, when viewed together, add up to the large-scale transformation we call the Longshan–Erlitou transition.

Table 9. Summary of regional differences during the Longshan Transformation.

Supra-large sites and their environs	Total number and size of sites	Settlement hierarchy and difference between large and small sites	Rearrangement of the central site
Taosi	Moderately declined in Late Taosi but drastically dropped by 90% after the turn to the Erlitou period.	Disturbance first appeared in the central site and then expanded to impact on small sites at the turn to the Erlitou period, which eventually resulted in depopulation in the region.	Destruction towards palace and elite tombs at the turn to Late Taosi. In Late Taosi, the elite class "disappeared." Collaborative actions remained functional, but the energy put in infrastructure maintenance reduced.
Zhoujiazhuang	Modestly declined by 20% in number in the transition to Erlitou then another 25% at the turn to Erligang. The total size drastically dropped by 71% in Erlitou and another 10% in Erligang. Dispersal replaced aggregation.	Destratification of settlement hierarchy from four-tier to three-tier in Erlitou and to two-tier in Erligang. Large sites either abandoned or reduced to small sites, while smaller sites became more developed.	Very little signs for crisis before fragmentation. Residential area was replaced by burial before site fragmentation, but it is unclear whether the change of site plan is a response to crisis situation.
Tonglin	Total number of settlements declined by 90% at the turn to Yueshi. Small and medium-sized sites	A well-integrated and centralized settlement system in Longshan and became more centralized in Yueshi.	In Late Longshan, ceremonial plaza in the walled area was abandoned and quality of

	abandoned. In Yueshi, the unwalled sites of the Tonglin settlement complex were abandoned and people contracted to the walled area. The process appears to be a population nucleation.		construction declined.
Chengziya	Total number of settlements declined by 42% at the turn to Yueshi and another 28% in Shang.	A poorly integrated and centralized settlement system in Longshan but became more centralized and integrated in Yueshi.	City walls and moats continuously built and maintained. Quality of construction remained high, indicating sustained administrative system.
Liangchengzhen	Settlements declined by 90% in size and number at the turn to Late Longshan. Liangchengzhen remained central in Late Longshan. In Yueshi, even the large sites were abandoned, resulting in regional vacancy.	Small sites were abandoned in Late Longshan before it shows any signs for decline.	Outermost moat was constructed which expanded the enclosed area of the site. The quantity and quality of cultural remains suggest the quality of life and the intensity of human activities remained the same level as previous periods.

5.3 There is no perfect term: revisiting the nature of the Longshan Transformation

In the introduction, I briefly reviewed the scholarly history of how "collapse" has been defined. Here, after examining the Longshan phenomenon in detail, we can revisit this definitional issue. Once the regional and staggered nature of the Longshan Transformation is

revealed, we face a dilemma: there is no single term that perfectly captures such a complex process.

Given that the declines in population and social complexity were drastic and that regeneration in most regions was either very slow or occurred only after a long hiatus, the term collapse does have merit in conveying the severity of the Longshan decline. The problem is that collapse often carries the connotation of abruptness and finality—as if change happened overnight and the end, at least in political terms, was complete. In this sense, collapse fails to express the prolonged and regionally varied nature of the changes to the Longshan world.

A second reason for hesitation comes from Tainter's (2013) critique that the term "collapse" assumes the loss of complexity as a form of failure, rooted in a progressivist framework prevalent in earlier scholarship. Within a Resilience Theory framework, however, the loss of complexity is not necessarily failure but rather an adjustment of and by the system. In the Longshan case, while individual Longshan polities may have failed to persist, it makes little sense to say that the Longshan world—a system of dozens of regional polities of different sizes and natures networed with one another—failed or succeded. The system, instead, transformed.

Turning to the term transformation: my use of the word derives directly from Resilience Theory. Within this framework, resilience is defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks" (Walker *et al.* 2004: 4). By contrast, transformability is "the capacity to create a fundamentally new system when ecological,

economic, or social conditions make the existing one untenable" (Walker *et al.* 2004: 5). In other words, a resilient system continues to function through change; when changes require fundamental restructuring, the system transforms.

The transition from the Longshan to the Erlitou era was precisely such a transformation: the changes were drastic, and interregional interaction shifted from a peer-polity model—in which centers like Liangchengzhen, Taosi, and Shimao were roughly equal—to a core–periphery model dominated by the emerging Central Plains core. It is therefore reasonable to describe this process as the Longshan Transformation.

A related, archaeological definition of transformation builds upon RT. McAnany and Yoffee (2010) first proposed that, given the judgmental tone of collapse, archaeologists should adopt more neutral terms such as social change or transformation. Later, Faulseit (2016: 6), in *Beyond Collapse*, theorized societal transformation as "a broadly defined concept encompassing the full range of possible outcomes (e.g., collapse, reorganization, revitalization) associated with societies in transition." Under this definition, societal transformation functions "as an umbrella term that captures diverse sociopolitical trajectories" (*ibid*). Under this definition, "transformation" is still well suited for describing the Longshan case, which encompassed a wide range of social changes across regions.

The term transformation, however, is not without problems. It is a generalization that can obscure the devastating nature of the changes at the end of the Longshan Era. While the concept implies dramatic change, transformation can also refer to positive development or growth—much like how a caterpillar transforms into a butterfly—which is clearly not the meaning intended here. This raises the question: is there a term that can both avoid the

suddenness and completeness embodied in “collapse,” while not being so generic that it loses descriptive efficacy?

One promising candidate is “slow collapse.” Storey and Storey (2012) coined this term to challenge the tendency to deny collapse altogether in the cases of the Western Roman Empire and the Classic Maya. They argue that “due to the inherent inertia of cultural change in large and complex systems… collapse takes a long time, ranging from a couple to several centuries” (Storey and Storey 2012: 10). Such gradual disintegration may feel like a transition or transformation, but the underlying processes—political fragmentation, significant demographic decline (though not total depopulation), and the end of a shared ‘great tradition’ of material culture and ideology—constitute collapse nonetheless.

This concept fits the Longshan case quite well. On one hand, it captures the fact that most core Longshan communities experienced severe and prolonged political and demographic decline; on the other, it recognizes that this decline unfolded asynchronously across regions over the span of several centuries. Yet, the term “slow collapse” is itself somewhat contradictory: if a collapse is slow, is it still a collapse? By its dictionary definition, collapse implies sudden and complete breakdown.

Ultimately, we must acknowledge that there is no perfect term to define the Longshan Transformation. As Middleton (2012: 263–264) rightly observes, none of the alternatives to collapse are free from bias or conceptual baggage. And as Tainter (2013) cautions, despite our desire for better terminology, each scholar must clarify what they mean by the terms they employ.

Accordingly, in this dissertation I use Longshan Transformation to emphasize that the Longshan world—as an interconnected system of dozens of independent polities—transformed. Within that system, individual communities underwent a range of downward changes in social complexity: sudden collapse, slow decline, gradual population dispersal, and settlement fragmentation. The term transformation thus reflects both the severity of the overall decline of the Longshan world and the diversity of local experiences within it.

5.4 Centralization, Integration, and Fragility

If we measure the level of centralization and hierarchical coherence by the q slope and the $\sigma_{\perp}$, and the severity of collapse by the percentage of decline in site number and size, evidence of destruction and violence at central sites, and the time required to recover previous settlement density, a pattern begins to emerge. Very high centralization—as at Taosi, with q above 3, and at Liangchengzhen, with q approaches 2—appears to have made systems fragile, producing catastrophic site losses of about 90% at the turn to the Erlitou Era. In both such cases, the abandonment of Longshan centers resulted in sparse occupation of their regions for centuries. These highly centralized polities thus exemplify the most severe collapses of the Longshan world, with correspondingly high human cost.

By contrast, regions with lower levels of centralization—such as the Hutuo River basin, Chengziya, and Tonglin—show stronger signs of continuity. In the Hutuo River basin, the decline in settlement number was only moderate; at Chengziya, the settlement system contracted but the site itself seems to have maintained effective administrative functions; and at Tonglin, the transition to Yueshi-style pottery was smooth, with city walls maintained and even newly constructed.

This is, of course, a preliminary and theoretical observation: it links human cost and resilience to the degree of sociopolitical centralization. More empirical evidence and larger comparative samples are needed for robust statistical analysis. Nonetheless, future research may show that the political experiment of building highly centralized polities during the Longshan Era ultimately failed because such systems were inherently fragile, while more moderately centralized systems proved more resilient.

6. **Summary**

In this chapter, I analyzed systematic settlement survey data to advance two key arguments about the Longshan Transformation. First, rather than a sudden and uniform collapse at the end of the Longshan era, the transformation was a protracted, multi-scalar, and regionally staggered process. It began in the Late Longshan around 2000 BCE, reached a major turning point around 1800 BCE, and in some areas extended into the Erligang period. Second, contrary to earlier portrayals of this transition as an empire-wide contraction in settlement numbers and sizes, the data reveal substantial regional variation shaped by local dynamics. In the environs of Liangchengzhen, disruptions began at peripheral sites while the center remained stable, whereas at Taosi, political instability originated in the core and spread outward. These contrasting patterns demonstrate that what has often been treated as a single, uniform moment of change was in fact a mosaic of overlapping and divergent trajectories unfolding over several centuries.

In addition to these two more straightforward conclusions, I propose some frameworks for understanding the causes of regional variation. Based on the observed correlation between high centralization and severe social change, I suggest a positive correlation

between regional centralization and the severity of social collapse. By outlining these possibilities, I aim to draw attention to future research avenues that can further explore the relationship between centralization, integration, and regional trajectories of resilience or collapse.

By demonstrating that the Longshan Transformation consisted of a series of regionally distinct events, the inquiry shifts from asking what caused a single, overarching social transformation to considering why so many regional changes unfolded in succession over the two centuries between 2000 and 1800 BCE—and, in some areas, even longer. Given these significant regional variations, it is crucial to analyze the Longshan Transformation through specific case studies. Accordingly, the next two chapters shift focus to Taosi, examining how this polity changed during the transformation, both through its own internal developments and in response to broader shifts across the Longshan world.

Chapter 4. Zooming into the Social Transformation at Taosi

1. Introduction

RT stresses that transformation unfolds through adaptive cycles of growth, conservation, release, and reorganization, and these dynamics are rarely uniform across social sectors (Redman and Kinzig 2003). Some institutions may exhibit rigidity while subsistence strategies remain adaptive, and cultural traditions may persist even amid political contraction. Reviewing diverse forms of evidence therefore makes it possible to identify such asymmetries, trace the uneven distribution of resilience, and recognize that collapse is not an absolute end but part of a cyclical process in which disruption, continuity, and renewal coexist.

Therefore, building on the settlement data reviewed in the previous chapter, this chapter continues discussing changes reflected in ceramics and mortuary evidence. Sections 2 through 4 present a qualitative narrative of pottery styles, elite mortuary practices, interregional interactions, and the forms of social consolidation they reveal in Early, Middle, and Late Taosi respectively. Section 5 offers a quantitative assessment of social differentiation. This is followed by a brief discussion of the legacy of Taosi in the aftermath of the Longshan collapse. The key takeaways from these discussions are synthesized in Section 7, the Summary. By combining the discussion of Taosi ceramics and mortuary practices in this chapter with the settlement analysis from the previous one, we can begin to put together a comprehensive narrative of the social transformation of Taosi.

2. Early Taosi

2.1 Pottery Style

A Short Review

Past research on Taosi ceramics is voluminous, and the following consensus has been established. First, given the formal similarity in ceramic assemblages, the Early Taosi Phase is contemporaneous to the Late Miaodigou II Phase (Dai Xiangming 2019 and 2022; Zhai Shaodong 2022; Wang Xiaojuan 2017; Dong Xiaolei 2019), both dating to sometime between 2450–2300/2200 BCE. Second, *li* tripods, a type of cooking vessel, originated in somewhere in central and northern Shanxi, northern Shanxi, or southern Inner Mongolia (Dai Xiangming 2022), began to appear at Taosi during its Middle Phase and became predominant in the cooking assemblage during the Late Phase, indicating more intensive interaction with Highlanders (e.g., Dai Xiangming 2022; Han Jianye 2006). Third, during the Erlitou Era, the Dongxiafeng remains were distributed in the Jinnan region and a clear rupture in pottery style exists between Taosi and Dongxiafeng remains (e.g., Liu Xu 1992). A great deal of previous research has focused on establishing chronology through ceramic typology. This chapter, however, does not aim to revisit chronological debates (for a discussion of Taosi chronology, see Time and Space). Instead, it examines how ceramic styles illuminate lifeways, strategies of social consolidation, and patterns of interregional interaction. In the Early Phase, the development of pottery assemblage reflects an intensive interaction with the communities in the east as well as culinary elaboration, which will be discussed in more detail below.

Strong Dawenkou Influence

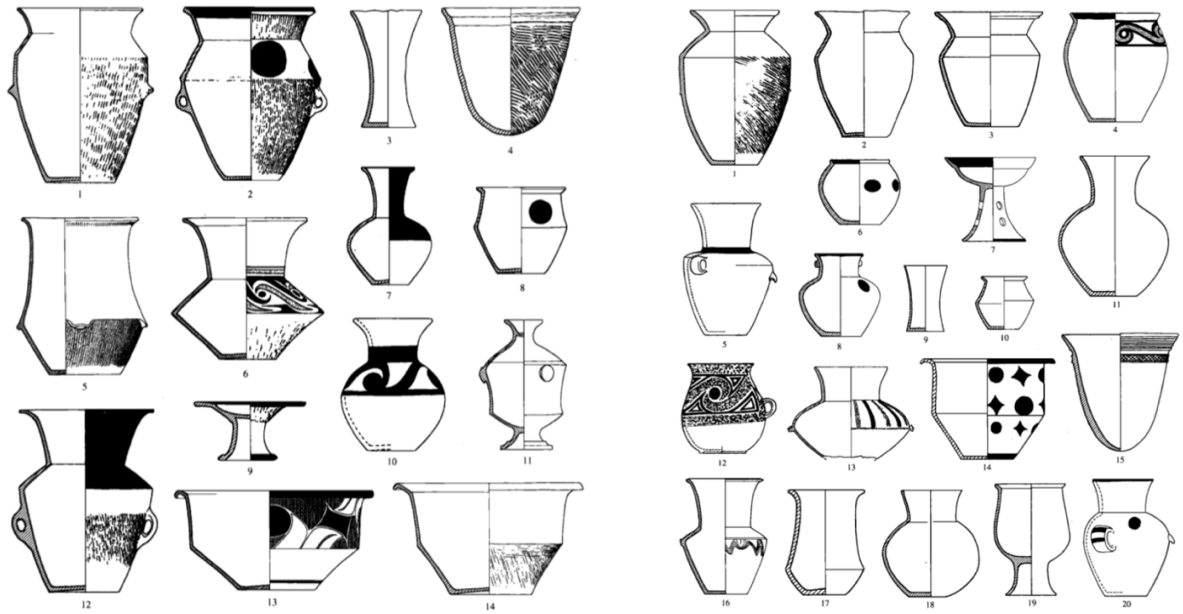
At the risk of oversimplification, I divide Taosi pottery into two categories: (1) utilitarian vessels, distributed across the palace, elite and commoner residences, and craft production zones and also used as burial offerings; (2) delicate painted pottery as prestige goods, found exclusively in tombs. Although scholars debate whether Miaodigou II and Early Taosi should be considered part of the same archaeological culture, there is a broad consensus that the the utilitarian vessel assemblage developed from the Miaodigou II tradition and retained a local style (Bu 1990; Dai 2022; Dong 1998; Gao *et al.* 1984; Gao 1992; He 2004; Luo and Tian 1994; Wang 2017; Zhongguo and Shanxi Sheng 2015).



Zhongguo 2022: 16, 17, 19, 21, ,26, 30, 32, 34.

Figure 48. Early Taosi painted pottery vessels

a-d. *Pen* basins with geometric pattern (a. M2103: 2; b. M2063: 4; c. M3073: 28; d. M2035: 1) e. *Guan* jar with red band (M2001: 48); f. *Guan* jar with large orifice and red dots (M2001: 45); g&h. *Hu* bottle with interlocking wave pattern (g. M3016: 1; h. M2001: 42); i. *Ping* vase with geometric pattern (M3009: 1).



Group A. Early Taosi assemblage

Group B. Dawenkou assemblage
Zhongguo and Shanxi Sheng 2015: fig. 5-2

Figure 49. Comparison of typical Early Taosi and Dawenkou ceramics

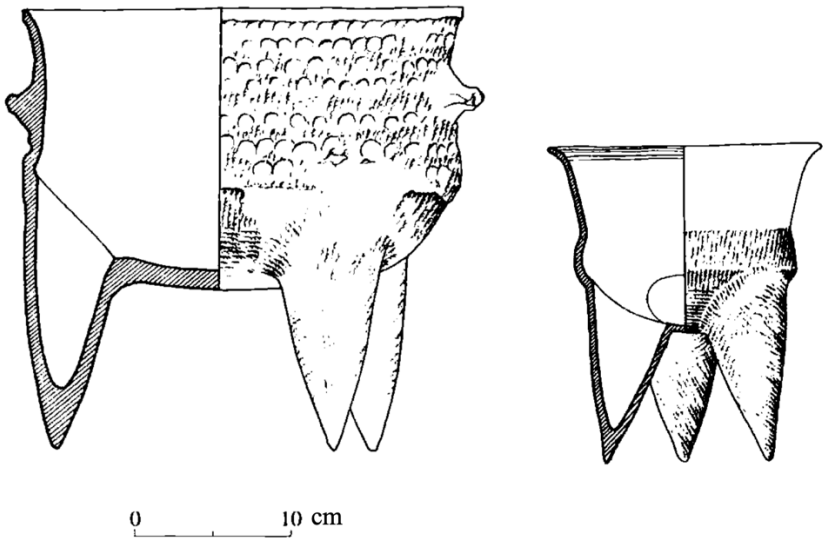
Note the similarity in vessel shape and decorative patterns between Group A and Group B. Shared vessel forms include *guan* jar with outward-turning rim and carinated shoulder (A1, A2, B1, B2, and B3), *gu* goblet(A3 and B9), *gang* urn with (A4 and B15), *dakou zhefuzun* vessel (A5 and B17), *zhefu xiaoguan* jar (A8 and B10), *gaolingzun* vessel (A12 and B16), *dou* dish (A9 and B7), *zhefupen* basin (A13, A14, and B14). Shared patterns include large spots (A2, A8, B6, and B8), interlocked waves (A6, A10, B4, and B12).

The second category, painted pottery, by contrast, represents a borrowed style. Characteristic Taosi painted designs include polychrome geometric motifs in red, black, and green, often arranged as triangles and rhombi (Figure 48 a–d), as well as red dots on jar shoulders (Figure 48 f). Some vessels are painted entirely in red from mouth to shoulder (Figure 48 e). Both the vessel forms and decorative patterns were introduced from the Dawenkou Culture of the Haidai region (Zhongguo and Shanxi Sheng 2015: 1092–1093). Figure 49 illustrates the similarities between the Taosi and Dawenkou painted pottery assemblages.

I understand the appearance of Dawenkou painted pottery at Taosi as the result of borrowing the Dawenkou elite mortuary practices, which emphasized culinary elaboration in the afterlife through the interring of a diversity of ceramics. The culinary elaboration, more specifically, is expressed in two ways: functional specialization and formal complexity.

Functional specialization and Formal Complexity

Functional specialization is exemplified by the development of *zunxingjia* 尊形罍 (urn-shaped hollow-footed tripods, abbreviated as ZXJ) and *penxingjia* 盆形罍 (basin-shaped hollow-footed tripods, abbreviated as PXJ) (Figure 50), the two most important types of cooking vessels at Taosi. ZXJ were likely used for warming wine, while PXJ were employed for cooking meat. PXJ are generally larger, made with coarse paste, whereas ZXJ are smaller, made with finer paste, and often retain traces of liquid residue, indicating that this might have been used as wine warmer.



Zhongguo and Shanxi Sheng 2015: figs. 4-84 and 4-88

Figure 50. P*enxingjia* basin-shaped hollow-footed tripods (left) and *zunxingjia* urn-shaped hollow-footed tripods (right).



From left to right: M2001, M2168, and M2172
(Zhongguo and Shanxisheng 2015: fig. 4-38, fig. 4-40, and fig. 4-41).

Figure 51. Selected tomb layout from Taosi cemetery.

The red circle indicates the location of PXJ tripods and green circle indicates ZXJ. Note that these two types of vessels are generally placed in different groups of burial offerings indicating different functions in the feasting paraphernalia.

Their spatial arrangement in tombs further supports this differentiation. At Taosi, funerary goods were grouped by function and placed in distinct areas of the tomb, and the two types of *jia* tripods are rarely found together. ZXJ, often associated with drinking cups (Figure 51), suggest individual use in wine consumption, whereas PXJ, typically found alongside other cooking vessels and often containing pig bones, indicate a role in meat preparation.

Function and formality are two interconnected aspects of pottery design, and Early Taosi ceramics display both increasing functional specialization and growing formal complexity. During the Miaodigou II period, pottery assemblages consistently followed local traditions. By the Early Taosi period, however, the repertoire incorporated influences from the Dawenkou Culture in the Haidai region and the Shijiahe Culture in the Middle Yangzi (Zhongguo and Shandongsheng 2015 and He 2004), resulting in more diverse pottery styles.

In addition to stylistic variation, the number of subtypes within each vessel category also expanded. For example, the Miaodigou assemblage at *Gucheng Dongguan* 古城东关 contained five subtypes of *jia* tripods, whereas the Early Taosi had 19. Likewise, the *fuzao* stove-pot composite vessel increased from five to ten subtypes. Similar diversification occurred among other vessel types, collectively enriching the Early Taosi repertoire.

Implication of the Early Taosi Changes

Feasting and conspicuous display in funerary contexts were not indigenous to the Jinnan region. Before the rise of Taosi, material wealth differentiation was minimal. Liu Li (2004: 38) characterizes Jinnan communities prior to the Longshan period as "egalitarian," while Li Min (2018: 36–40) describes Yangshao Highland societies as having a "communal ethos." Both terms emphasize the minimal social differentiation expressed through personal wealth in mortuary context.

By contrast, feasting as a social institution to promote elite status had become increasingly prominent in the Haidai region in the Lowlands by the Late Dawenkou period, as noted by Anne Underhill (2002). At Taosi, the adoption of Dawenkou-style painted pottery in mortuary contexts, along with increasing formal complexity and functional specialization, collectively points to trend of "culinary elaboration" (Li 2018: 120-124). Conspicuous displays involving delicate vessels, abundant meat, and musical instrument set (see below) created a performative dimension to feasting. Such practices echo Dawenkou elites' strategies, representing a form of cultural borrowing that Koch (2014) calls "elite emulation," that Goldstein (2000) describes as the behavior of "aggrandizers," or more

generally, that Renfrew (1986) defines as peer polity interaction. This theme will be revisited in the discussion of elite mortuary practices below.

2.2 Elite Mortuary Practice

An Overview

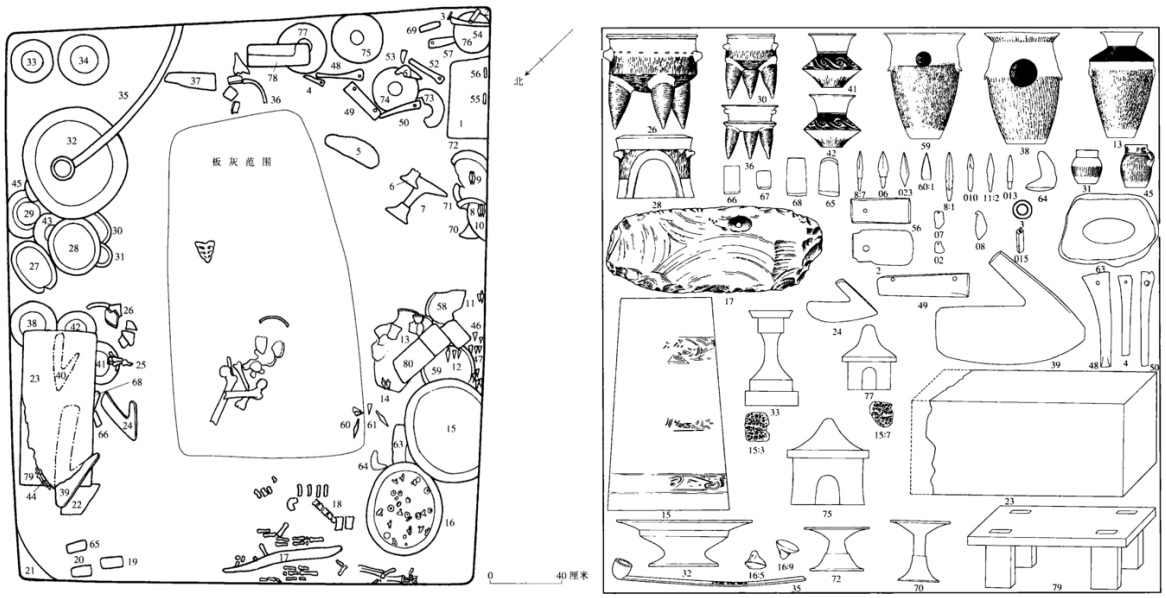
Taosi burials typically feature individual shaft tombs with the deceased laid in an extended position. Some tombs include *ercengtai*, earthen ledges and niches along the four walls, while higher-ranked burials may also contain various forms of coffins. Burial goods can be grouped into six categories: (a) personal ornaments, (b) functional or ritual weapons, (c) pigs (primary meat parts or mandibles), (d) cooking and serving vessels, (e) animal (deer or sheep) and human retainers, and (f) musical instruments. Each of these categories of burial goods went through different trajectories of change overtime.

Categories (a), (b), and (c) are common across all phases. Among them, categories (a) and (b) are most stable throughout the three phases, while pig offerings (c) decline significantly in the Late Phase. Pottery (d) is common in the Early and Middle Phases, though its types and display shift over time; by the Late Phase, ceramics are rarely included in mortuary contexts. Animal and human retainers (e) are generally deposited in the tomb filling dirt rather than the chamber itself, suggesting they were offerings made during funerary ceremonies rather than items directly associated with the deceased. Although this practice already began in the Early Phase, it became far more frequent in the Late Phase. Musical instruments (f), the most representative Taosi prestige goods, appear only in the highest elite tombs in the Early Phase, but soon disappeared in the Middle Phase.

Taken together, the varying combinations of these burial goods reflect two complementary strategies of status construction in mortuary contexts: first, reconstructing the feasting scenes that consolidated local social relationships in life, and second, symbolizing the access to a broader world to which only elites were connected.

Feasting Scenes Reconstructed for Afterlife

The feasting scenes are reconstructed for afterlife through the offering of feasting paraphernalia, abundant meat, and musical instruments in tomb chambers. For example, tomb M3015 contained not only food preparation vessels and equipment—*jia* tripods, *fuzao* stoves, meat cleavers, cutting boards, serving vessels and utensils, but also serving vessels such as painted pots, mounted dishes, a wooden ladle, and small jars (Figure 52). Musical instruments such as an alligator-skin drum and a chimestone were also included. Primary cuts of pork were placed in the tomb as meat provisions for the afterlife (pig mandibles may symbolize different meanings, which will be discussed later). Collectively, these elements vividly created a feasting scene. Among the items that constitute the feasting scene, two categories of burial offerings—painted plates with serpent motifs and musical instruments—warrant particular attention because of their distinctive role in defining Taosi elite culture.

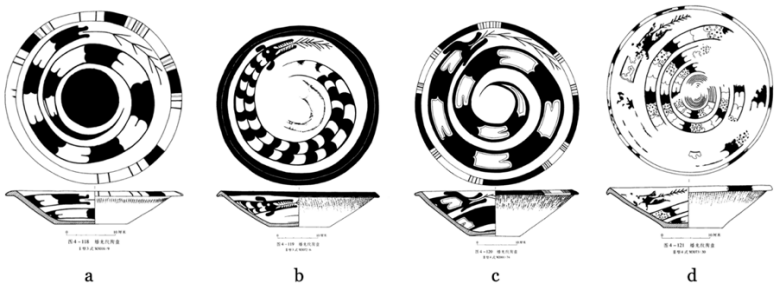


(Zhongguo and Shanxisheng 2015: fig. 4-36)

Figure 52. Representative Early Taosi elite tomb M3015

Serpent-motif plates

The painted plates with coiled serpent motif are exclusive to the core elite group. The motif depicts a serpent with its mouth open, showing teeth curved inwards. The tongue split into many breaches, resembling a stalk of ephedra. Two rows of scales cover the body of the snake (Figure 55). On the earlier motif (M3072:6, Figure 55 b), the scales are comparatively realistic, whereas on later examples, two rows of side-by-side scales are stylized as one row of irregular-shaped blocks.



a. M3016:9; b. M3072:6; c. M2001: 74; d. M3073:30.
(Zhongguo and Shanxisheng 2015: figs. 4-118, 119, 120, and 121)

Figure 53. Coiled serpent basins from Early Taosi

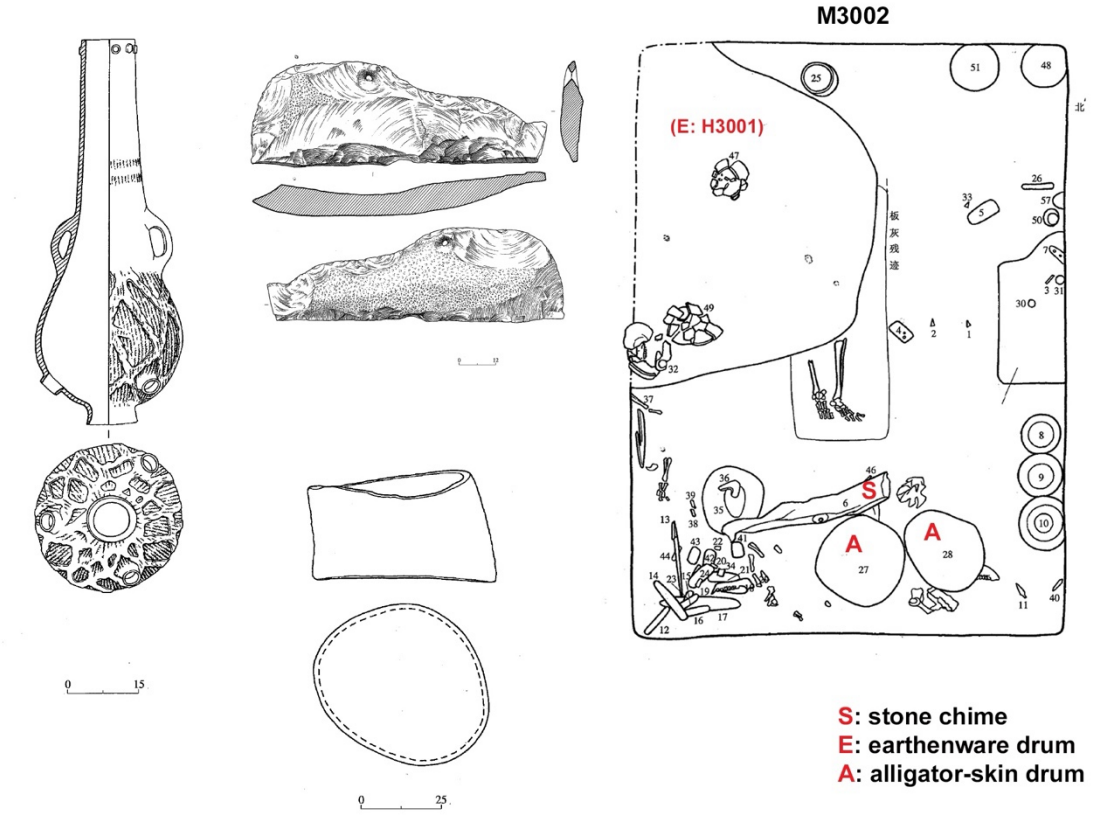
The chargers with such a motif painted on the inside of the vessel, often called serpent chargers or dragon chargers, represents one of the most identifiable status markers in Early Taosi. They were only found in four tombs, the highest-ranked and the second highest-ranked tombs from Early III to Early V subphase (Zhongguo and Shanxisheng 2015: 873-898). No painted motifs before Early III subphase could be definitively identified as the prototype of the coiled serpent, suggesting a rather sudden appearance and quick institutionalized use of the motif.[14] Although serpent motifs are not uncommon in Neolithic China, such as those found in the Hongshan (e.g., Liaoningsheng 2012: 211, Pl. 69; Wengniuteqi 1984: 9-10), Lingjiatan (Anhuisheng 2006: pl. 157), and Liangzhu (Shi 1938) cultures, apparent temporal and formal gaps exist between these earlier cases and the Taosi motif. For this reason, the coiled serpent is arguably an innovative and unique motif that was created by and exclusive to the Early Taosi elites.

Musical Instruments

Taosi musical instruments include chimestones, pottery drums, and alligator-skin drums. Figure 54 illustrates a typical musical set and its placement within a tomb. Such sets generally consist of one pottery drum, one chimestone, and two alligator-skin drums, though

[14] In addition to the coiled serpent, two other pieces of pottery sherds with zoomorphic motifs were found at Taosi. One of them is a base piece of a painted basin. On the bottom, the back view of a lizard is depicted. This was found in a tunnel caused by bioturbation in the cemetery and thus its date is unclear. Another piece (unclear of which type of vessel) with zoomorphic motif was found in the "ice cellar" in the palatial zone. Both represent a lizard-like composite creature viewed from the back of the lizard and the latter highly resembles the "dragon" banner found at Erlitou. The depiction of the claws, scales, the length of body, as well the perspective of depiction suggests they are a different type of iconography than the coiled serpent, but it is unclear to what extent they could serve as the prototype of the Bronze Age dragon motifs.

heavy looting during the Late Taosi period often left the set incomplete. The intentional inclusion of musical instruments reinforced the tomb as a performative space (Stromberg 2023: 95-102) and, by situating the deceased at its symbolic center, elevated their status.



Left: pottery drum; upper middle: chimestone; lower middle: the decayed wooden body of an alligator-skin drum; right: the plan of tomb M3002.
(Stromberg 2023: fig. 30)

Figure 54. Typical musical instrument set in Taosi elite tombs.

While musical instruments had been placed in tombs elsewhere in Neolithic China, what makes the Taosi case special is that at Taosi this practice became formalized and institutionalized: instruments were deposited in stable combinations and systematically integrated with feasting paraphernalia (He 2020; Stromberg 2023). Through this innovation—coupled with the introduction of special motifs on serving vessels—the Taosi elite were not simply acculturating to Dawenkou traditions. Rather, they were actively

constructing new institutions that set them apart both from surrounding local communities and from other contemporary elite traditions.

Reconstructing the Network of Interaction

The second pillar of Taosi elite identity construction was the incorporation of borrowed styles and exotic objects into funerary assemblages. In M3015, for instance, these included painted pottery and ritual jades such as *yue* battle-axes and double-perforated *dao* knives, likely borrowed from the Dawenkou Culture. The alligator-skin drums may also have been adopted from Dawenkou, while the L-shaped meat cleaver perhaps reflects connections with the Liangzhu Culture (for alligator-skin drums and meat cleavers, see Chapter 5). At this stage, the "exotic" styles were primarily associated with traditions from the east—the lower Yellow River, lower Huai River, and lower Yangzi regions—and the elite interaction networks remained relatively limited. By the Middle Phase, however, elite tombs began to encapsulate a more diverse and expansive networked world.

3. **Middle Taosi**

3.1 Pottery Style

While Early Taosi utilitarian vessels are indicative of culinary elaboration, the most significant ceramic development of the Middle Taosi everyday-use vessels was the introduction of hollow-footed Highland-style tripods. The Early Taosi cooking repertoire had centered on *jia* tripods and *fuzao* (pot-stove composite vessels), but in the Middle and Late Phases the assemblage shifted. *Jia* tripods remained important, yet *fuzao* vessels declined significantly (Zhongguo and Shanxisheng 2015: 1102–1103). At the same time, *li* tripods of

various forms appeared in the Middle Phase and became the dominant cooking vessels by the Late phase.

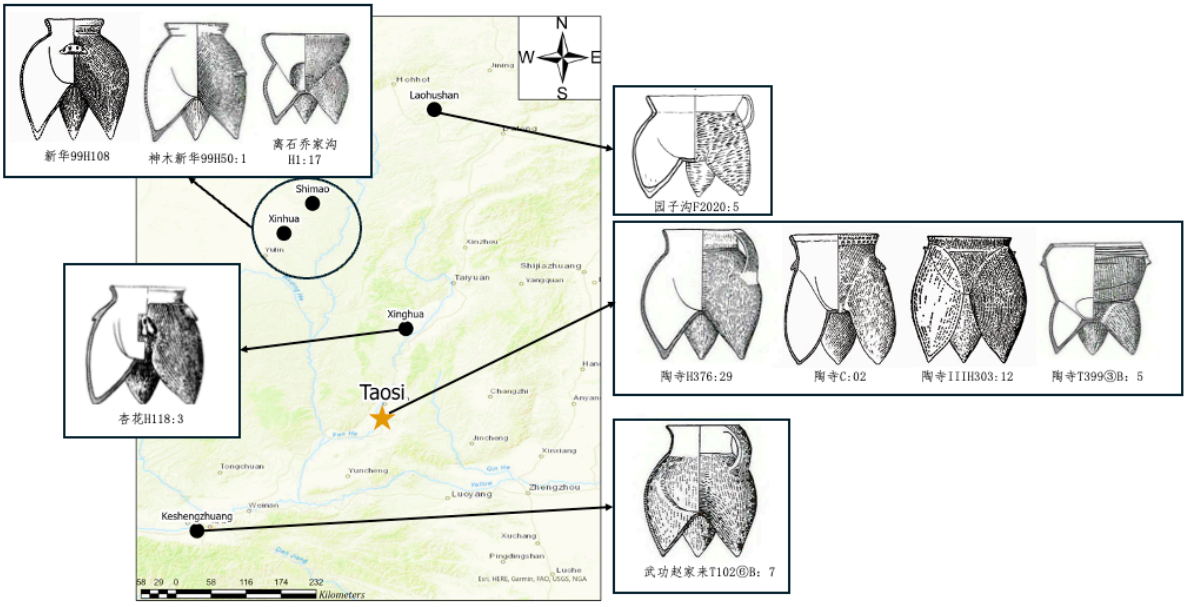


Figure by author

Figure 55. The comparison of Taosi *li* tripods with examples from other Highland sites

Li tripods are representative of multiple archaeological cultures in the Highlands, such as the Shimao Culture (Sun *et al.* 2020a), Xinghua Culture(Zhang 2004; Shaanxisheng and Yulinshi 2005), Keshengzhuang Culture(Zhang and Yang 2002). Figure 55 illustrates the range of *li* tripod types at Taosi and compares them with examples from other Highland sites. Notably, the single-handled *li* commonly found in the Keshengzhuang Culture, the wide-legged *li* characteristic of the Shimao Culture, and the double-eared *li* typical of the Xingzhuang Culture are all present at Taosi. The diversity of li tripods at Taosi demonstrates the broad and increasing interconnectivity between Taosi and Highland communities.

Such a shift towards incorporating Highland-style pottery is not only observed at Taosi, but also at other sites in the Jinnan region. Despite minor differences in the percentage of

different types of *li* tripods, the Zhoujiazhuang site yields an assemblage that closely resembling Middle and Late Taosi repertoires (Zhongguo, Shanxisheng, and Yunchengshi 2021, 2015a, and 2015b). A similar discovery is found at Nanshi-Fangcheng (Shanxisheng 1996; Zhongguo and Shanxisheng 1988). Additionally, smaller sites, such as Xiaoling 孝陵 (Dong 2024), Xiyangcheng 西阳呈 (Shanxisheng 1996), Qushetou 曲舌头 (Shanxi daxue 2002), Houcun 侯村 (Shanxisheng and Hongtongxian 1996), Dongxu 东许 (Shanxisheng and Quwoxian 1996), Nanshi 南石 (Shanxisheng 1996), and Zhoujiazhuang 周家庄 (Zhongguo *et al.* 2015a and 2015b) also show similar changes in pottery assemblage during the Middle Taosi phase.

By comparing two major sites—Taosi and Zhoujiazhuang—it is noticeable that the reception of the Highland material culture varied from site to site. For example, Zhoujiazhuang contains considerable amounts of flared-appliqué vessels (*huabian guan* 花边罐), but their presence at Taosi is almost negligible (only one *huabian guan* fragment was discovered at Taosi). In addition, there might also be a significant gap in time. According to Zhoujiazhuang excavators, compared to Taosi, the *li* tripods in Zhoujiazhuang more commonly have a solid tip (*shizugen* 实足跟) at the end of each leg, the wide-legged li tripods are also more common than Taosi, and the upper body of single-handed li tripods (*danbali* 单把鬲) appear to be wider (Zhongguo Guojia *et al.* 2021: 59). The formal differences indicate a time difference in the introduction of these pottery type. These suggest that the introduction of Highland culture in the Jinnan region might have been a long-term process in Middle Taosi.



a&b. double-looped *guan* jar with simplified interlocking wave (a. IIM26: 5; b. IIM32: 2); c. *pen* basin with geometric pattern on the rim (IIM32: 1); d. *zun* vessel with three decorative bands, from top to bottom are feather pattern (*yuwen* 羽纹), abstract geometric pattern, and interlocking wave pattern (IIM22: 15); e. *guan* jar with carinated shoulder (IIM26: 2).

Figure 56. Middle Taosi painted pottery

Shifting from everyday cooking vessels to painted pottery, during the Middle Phase these items continued to serve as markers of status, although their vessel types and forms underwent notable changes. Certain types of pottery vessels (*guan* jars with carinated shoulder and pen basins) continued from the Early to the Middle Phase, while other vessel types (*pen* basins with carinated body, *dou* mounted dishes, *ping* vases) were abandoned. The newly added forms, double-looped guan jar (Figure 60 a and b), were apparently borrowed from the Ganqing region in the Upper Yellow River region. The interlocking-waves motif has changed to horizontal bands of abstract waves (Figure 58 a, b, e and the middle-lower band on d), which are more simplified and angular than the Early prototypes. The most characteristic motif, the serpent motif, however, disappeared in Middle Taosi.

During the Middle Phase, except for one heavily looted burial, all painted ceramic vessels are placed in niches. Due to heavy destruction of Early tombs, it is unclear to us whether this practice had started in the Early Phase, but given what could be observed at this point, all painted pottery vessels are found on the bottom of the tomb chamber in the Early Phase, and none was found in niches. Should this accurately reflect the way they were originally interred, then we could say that the niche display of painted pottery only began during the Middle Phase, when intensive communication with the northern Highland communities began. This might suggest the reception of the Highland funerary custom, as a very similar practice could be found in the Shimao Culture (Shaanxisheng *et al.* 2016; Shaanxisheng *et al.* 2022) and the Zhukaigou Culture (e.g., M3043) (Neimenggu and E'erduosi 2000).

3.2 Elite Mortuary Practice

In the Middle Taosi phase, the dual strategies persisted, and the presentation of lavish feasting scenes continued to play a central role in affirming elite status. Tomb IIM22 provides clear evidence: along the southern side of the chamber were four meat cleavers and seven cutting boards, each cleaver placed over pig bones and decayed meat. Along the western side lay 20 halves of pigs (representing 10 complete pigs), symbolizing abundant provision for the afterlife.



(Zhongguo, Shanxi Sheng, and Linfen Shi 2003: figs. 1-8)

Figure 57. Representative Middle Taosi tomb IIM22 and selected burial objects



(Qin 2022: fig. 15)

Figure 58. Painted pottery with jade disc as a "stone lid."

At the same time, access to interregional networks became equally—if not more—important in defining elite identity. The scope of the reachable world expanded beyond that of Early Taosi. A jade mask (Figure 57: 5) and a *huang* arc-shaped pendant (Figure 57: 7), both clearly in the style of the Xiaojiawuji Culture of the Middle Yangzi (Shao 2021), were found in one tomb niche. In another niche of the same tomb, a double-looped painted pottery jar in the style of the Qijia Culture of the Upper Yellow River was discovered, with a jade *bi* disc placed on its mouth as a “stone lid” (Figure 58). A similar practice is documented in another Middle Taosi tomb, IIM26 (Wang and Yan 2006). This custom of capping pottery vessels with stone discs in tomb niches is a typical Highland practice, also seen at several Shimao Culture sites, such as Zhaishan 寨山 (Shaanxi Sheng *et al.* 2022) and Shengedaliang 神圪垯梁 (Shaanxi Sheng *et al.* 2016). Taken together, these objects suggest that IIM22 actively incorporated diverse cultural elements from the upper and lower Yellow River, northern Loess Plateau, and Middle Yangzi, revealing the broad world to which Middle Taosi elites were connected.

Bringing together the analyses of pottery styles and burial practices, it is clear that Middle Taosi came under growing Highland influence and increasingly embraced Highland traditions. This trend—what I refer to as "Highland-ization"—continued into the Late phase, as demonstrated below.

4. **Late Taosi**

4.1 Pottery Style

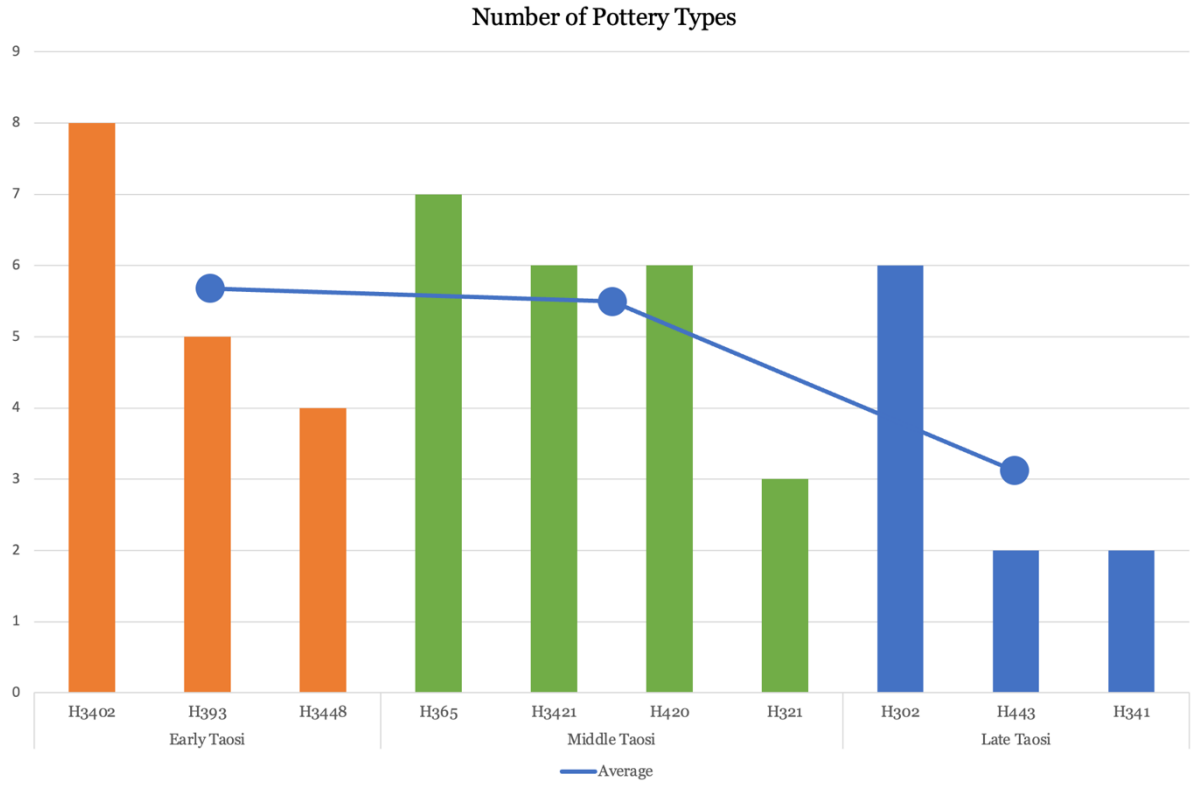
Reduction of Pottery Repertoire

Accompanying the process of "highland-ization" that continued through the Middle and Late Phases, a new phenomenon emerged at Taosi in the Late phase: the reduction of the pottery repertoire. By "reduction," I refer to both a decline in stylistic diversity and a decrease in the variety of vessel types. The former is evident in the shift away from incorporating styles from multiple regions—such as the Dawenkou Culture in the east, the Shimao Culture in the north, and the Shijiahe Culture in the south—toward an assemblage based almost exclusively on the Highland styles.

The decrease in the number of vessel types can be more effectively demonstrated by examining representative loci and observing how many pottery types coexisted within these units, as well as their proportions in the assemblage based on identifiable samples. For this analysis, I consider only pottery assemblages from residential contexts, excluding funerary assemblages, in order to rule out the influence of shifting burial customs.

Table 10. Selected units from Taosi and Dongxiafeng

Unit #	Number of pottery types	Number of pottery sherds	Period
H393	5	1012	Early Taosi
H3448	4	1812	Early Taosi
H3402	8	3070	Early Taosi
H3421	6	2450	Middle Taosi
H365	7	1366	Middle Taosi
H420	6	5183	Middle Taosi
H321	3	702	Middle Taosi
H341	2	1100	Late Taosi
H302	6	5400	Late Taosi
H443	2	126	Late Taosi



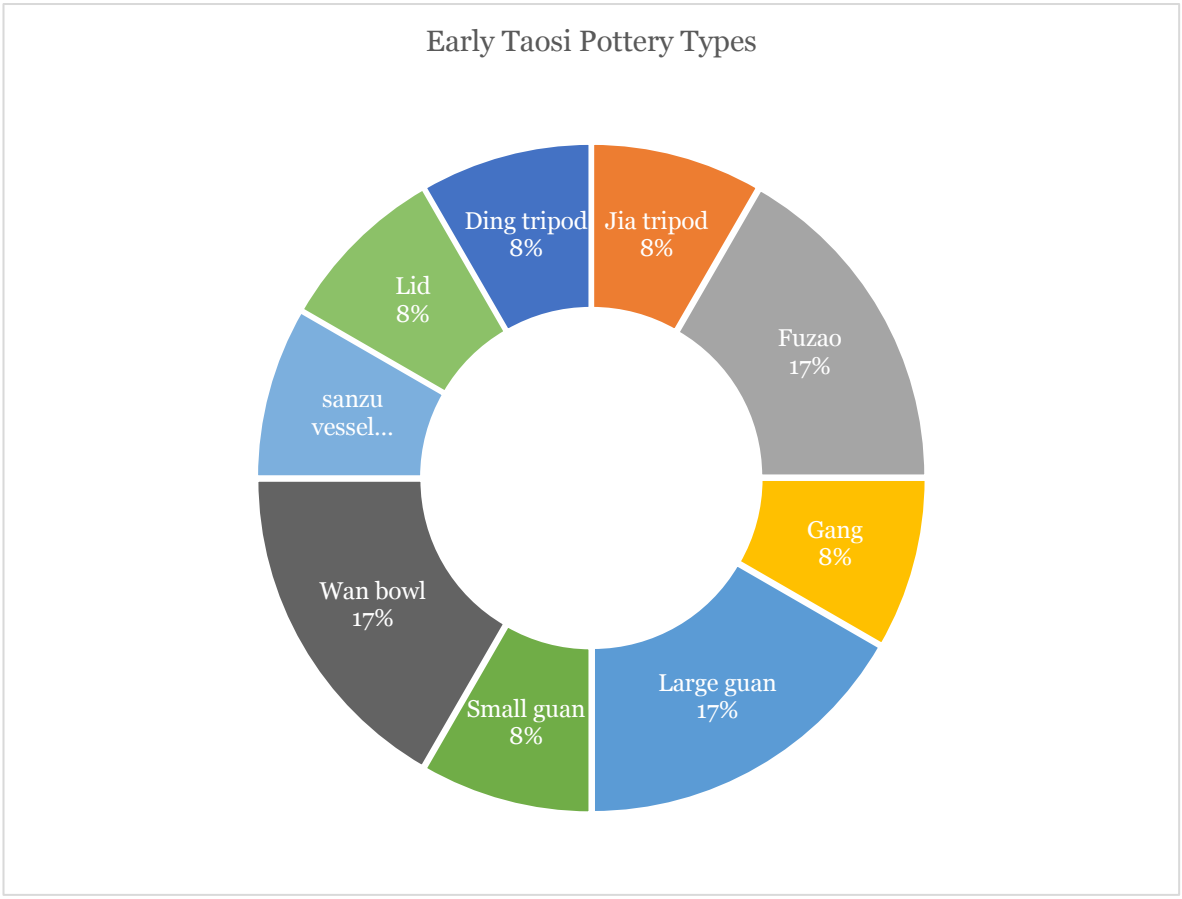
Data from Zhongguo and Shangxi Sheng 2015

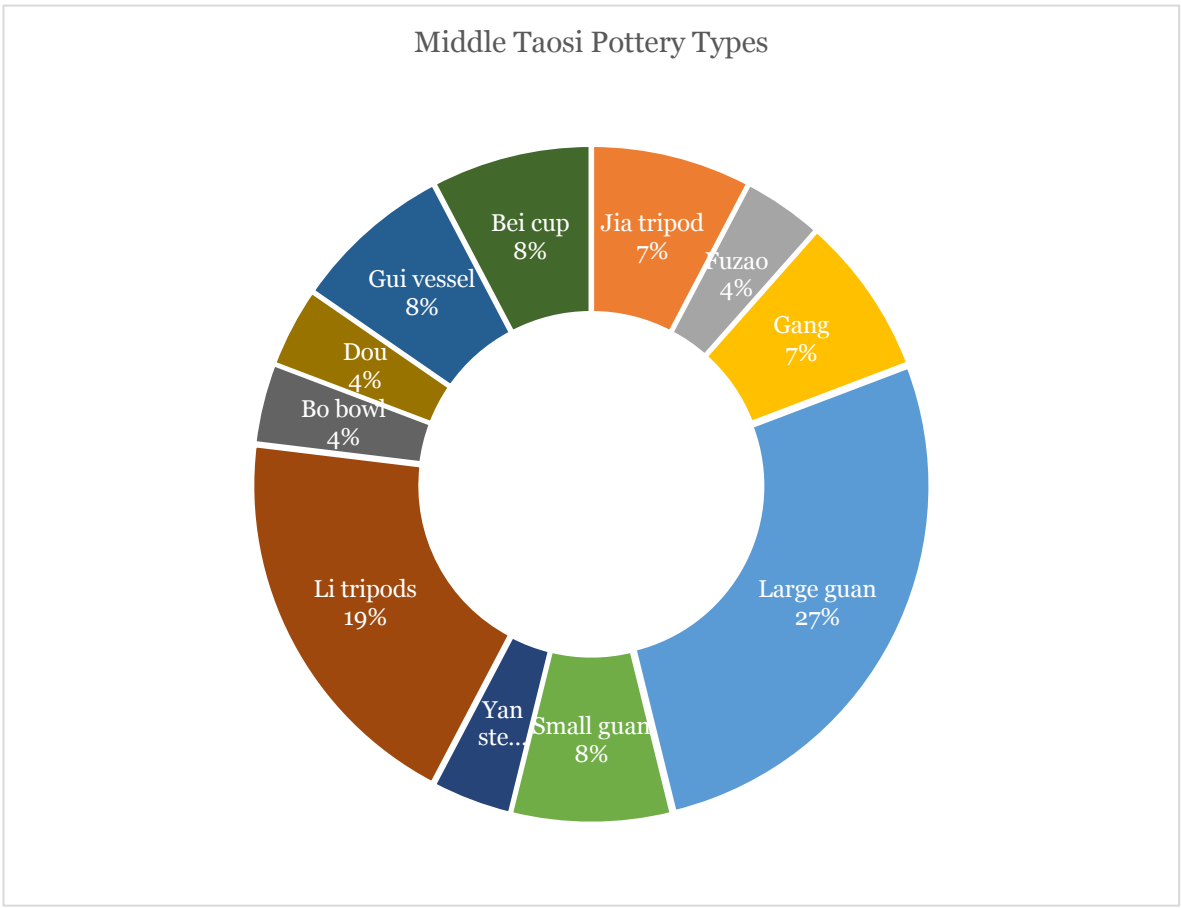
Figure 59. Number of pottery types from selected units in Taosi

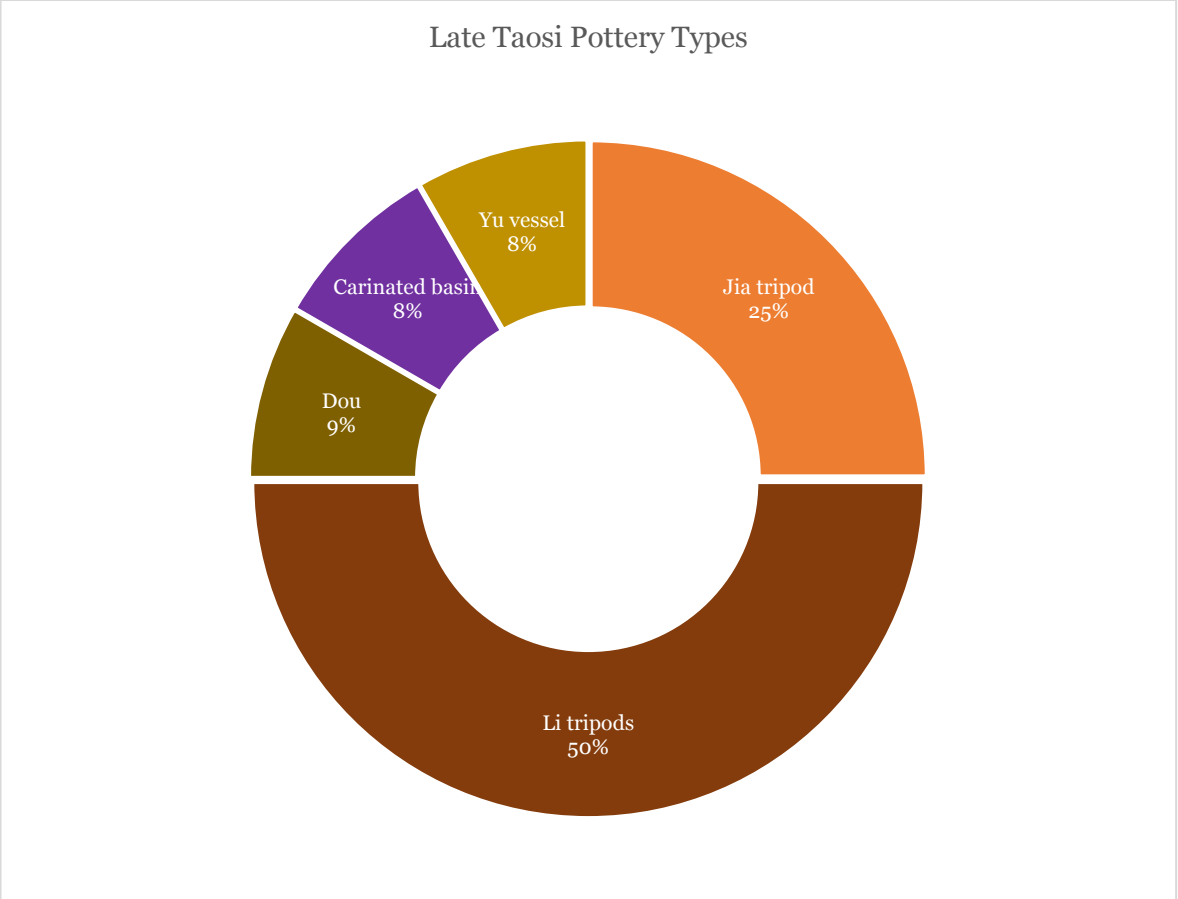
In Figure 59, each column represents the number of pottery types in a selected locus from Taosi, while the blue line indicates the changing trend in the average number of pottery types per phase. In calculating the number of types, only general categories are counted. For example, although *li* tripods can be divided into multiple subtypes, all subtypes are counted as a single type. As the figure shows, the number of pottery types per unit remained relatively stable from the Early to the Middle Phase but declined markedly in the Late Phase. In both the Early and Middle Phases, the units with the most diversified pottery repertoires, as well as those with the least, still contained more complex assemblages than their counterparts in the Late Phase.

Looking beyond the selected units, the excavators identified 14 pottery types in the Early Phase, 15 in the Middle Phase, and 10 in the Late Phase. Although this method of counting does not strictly control for contemporaneity, the general trend aligns with that observed in the specific units. In both cases, the evidence indicates that the average number of pottery types in use declined significantly in the Late Phase.

Figure 60 presents this change from a different perspective by specifying each pottery type and visualizing their configuration in the Early, Middle, and Late Taosi phases. The percentage of each type is calculated as: Type Percentage=Number of identifiable samples of each type/Total number of identifiable samples of all types × 100%. Due to the limited sample size, these statistics reflect only the basic framework of each phase's ceramic assemblage. Even so, the diachronic changes are readily apparent.


Early Taosi Pottery Types
Ding tripod 8%
Jia tripod 8%
Fuzao 17%
Gang 8%
Large guan 17%
Small guan 8%
Wan bowl 17%
sanzu vessel...
Lid 8%


Middle Taosi Pottery Types
Bei cup 8%
Jia tripod 7%
Fuzao 4%
Gang 7%
Large guan 27%
Small guan 8%
Yan ste...
Li tripods 19%
Bo bowl 4%
Dou 4%
Gui vessel 8%



Data from Zhongguo and Shangxi Sheng 2015

Figure 60. Pottery type configurations from selected units across the Early, Middle, and Late phases

The transition from the Middle to the Late Taosi phase can be summarized in two major changes. First, the number of pottery types in each category—cooking, serving, and storage—declined. Overall, the assemblage remained functional but lacked the degree of specialization that had characterized the Early Phase. If a more diverse cooking apparatus reflects a more elaborate culinary culture, this reduction suggests a decline in competitive feasting and the emergence of a different culinary tradition, one more closely aligned with the foodways of the Loess Highlands. Second, the Late Taosi repertoire shows the increasing prominence of Highland-style pottery, with various subtypes of *li* tripods accounting for approximately 50% of all identifiable samples.

Disappearance of Painted Pottery

In Late Taosi, painted pottery nearly disappeared and was largely absent from funerary traditions. Exceptions are rare: for example, in the niche of M2064, a broken narrow-necked jar with a red-painted shoulder was recovered, and in the niches of M2064 and M2384, painted ceramic vessels were found. These instances could be interpreted as the continuation of Middle Taosi painted pottery practices. Although the excavation report assigns Burial M2384 to the Late Phase, more recent research—drawing on Middle Taosi data excavated in the 2000s and considering evidence of bioturbation in M2384—suggests that it should instead be dated to the Middle Phase (He 2018: 28-31). This revised dating makes the cases of using painted pottery in Late Taosi tombs even rarer, demonstrating that the use of painted pottery in mortuary contexts was almost entirely abandoned by the Late Taosi phase.

4.2 Elite Mortuary Practice

The "disappearance" of painted pottery is part of broader crisis in Late Taosi: the elite culture once expressed through abundant prestige objects had largely vanished. Although personal ornaments continued to be valued, the lavish feasting paraphernalia that had marked the distinctiveness of the high elite disappeared. M2384 (Figure 61), one of the wealthiest Late Phase burials, illustrates this shift. When compared to the richest Early Phase tombs, the decline in burial wealth is striking. This reduction coincided with the destruction of palatial structures and the systematic looting of elite tombs—acts that suggest a rejection of conspicuous markers of elite status (discussed below).

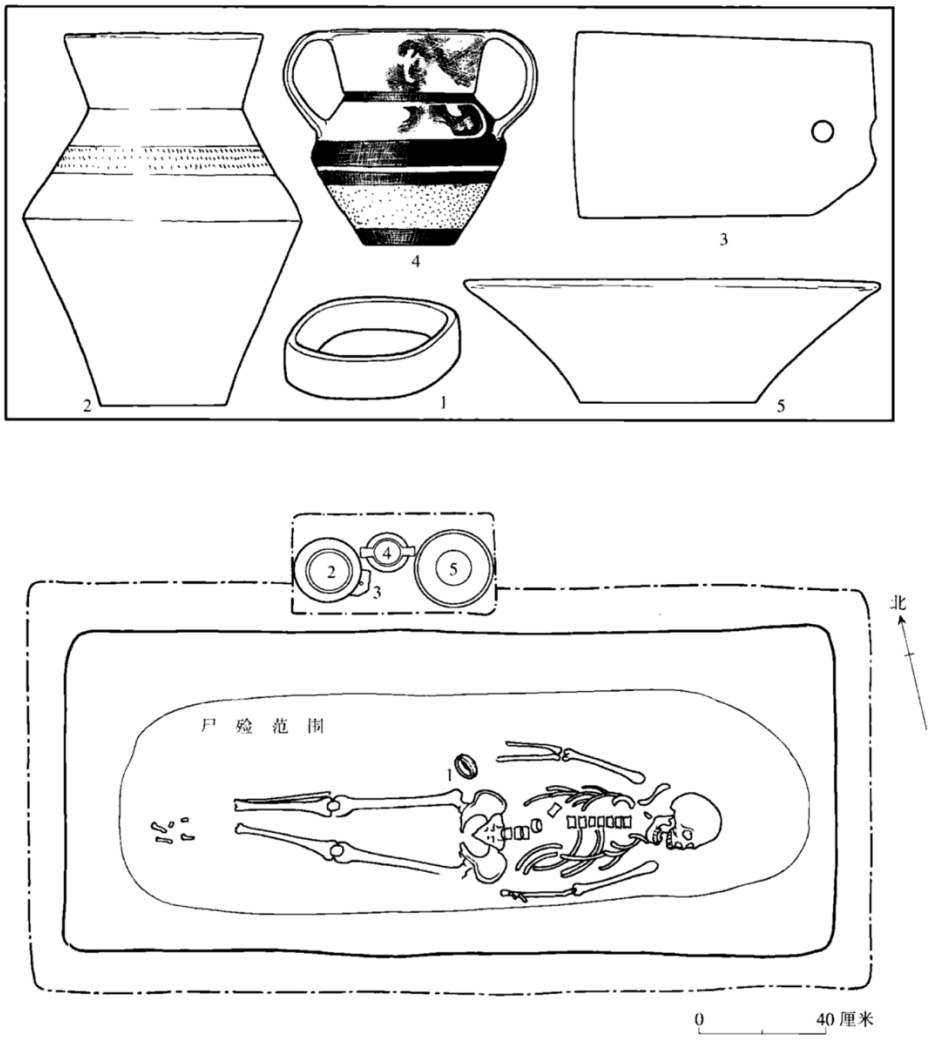


Figure 61. Representative Late Taosi tomb M2384 and its burial offerings (Zhongguo and Shanxisheng 2015: fig. 4-64)

While Taosi remained engaged in broader networks, adopting bronze metallurgy and incorporating diverse bronze objects (rings, bells, a frog-shaped sheet, and a vessel fragment) likely introduced from the steppe through the Longshan interaction network, access to such networks was no longer emphasized in mortuary practice. With both of the earlier elite cultural traditions—lavish feasting and interregional connections—absent in the Late Phase, Taosi witnessed the dissolution of its elite culture. The Early–Middle Taosi elite group, or at least its ideological foundations, effectively came to an end.

While the Early–Middle Taosi elite mortuary tradition disappeared, this should not be interpreted as the decline of social differentiation. Rather, it marked a transition from emphasizing hierarchy through lavish burial offerings in tomb chambers and niches to focusing on ceremonies that likely involved human and animal "sacrifice." In the following section, by adopting Rowan Flad's (2001) synthetic and quantitative method for assessing differentiation among tombs, I will demonstrate this shift in strategies of status construction.

5. **Quantitative Evaluation of Social Differentiation through Grave Values**

5.1 Theories and Methods

Tombs serve as a microcosm of Taosi elite culture, and debates on their interpretation draw from two approaches outlined by Flad (2001): "direct interpretation" and "ritual." The direct interpretation approach assumes that mortuary patterns intentionally reflect social distinctions of the deceased, an idea rooted in Saxe (1970) and O'Shea (1984). Within this framework, disparities in labor investment, wealth symbols, and demographic patterns are viewed as markers of rank (Tainter 1978; Brown 1995). Grave goods, especially rare or labor-intensive items, are interpreted as signs of high status (Appadurai 1986; Brumfiel 1994). Lars Jørgensen's (1988; 1992) quantitative method exemplifies this approach: assigning "grave values" based on the rarity of objects, with higher values corresponding to higher social standing.

The ritual approach, on the other hand, emphasizes that burial remains are products of ceremonies shaped by cultural traditions, not transparent reflections of social order. Ethnographic studies show that resources may be directed more toward funeral performances than tomb furnishings (Flad 2001). Scholars such as Metcalf and Huntington

(1991), Humphreys and King (1981), and Morris (1992: 106-108) stress that death is a social experience in which meanings are conditional, constructed, and negotiated. Research on Natufian burials, for example, demonstrates that funeral rites served to renegotiate social relations and structures among the living (Kuijt 1996). Similarly, Chinese funerary practices in historical times were not merely reflections of cosmology or religion but social performances that negotiated hierarchy, morality, and community membership (Watson 1988). In other words, tombs reveal as much about the practices and beliefs of the living community as they do about the deceased.

Both the direct interpretation approach (which emphasizes the status of the deceased) and the ritually oriented perspective (which emphasizes the behaviors and beliefs of the living) acknowledge that burial practices are tied to broader social dynamics. Burial attributes may at once reflect the status and demographic traits of the deceased, embody socio-religious practices, and serve as occasions for negotiating power among the living. The burials at Taosi provide an example of this dual function. Inspired by Flad's (2001) research on the Dadianzi burial ground of the Lower Xiajiadian Culture, I propose that in cases like Taosi, burial analysis can incorporate both the deceased's social identity and the actions of the living by examining the sequence in which burial goods were deposited within individual tombs.

If we view a tomb as both a product of the actions of the living and a reflection of the status of the deceased, it becomes essential to distinguish which features and remains derive from funerary activities and which represent displays of wealth. James Watson (1988: 12-13) identifies a temporal order in Chinese funerary rites that includes the preparation and

display of the body, the procession and burial, and subsequent mourning periods marked by ritualized stages. Archaeological tombs partially capture this process, particularly the treatment of the body and the act of burial. Watson further distinguishes two components within the broader funeral sequence: “rites of disposal,” which concern the treatment of the body through burial, cremation, or coffin storage, and “funerary rites,” which encompass the actions of the living “from the moment of death to the formal expulsion of the deceased from the community.”

Accordingly, Flad (2001: 25) identifies disposal rites and funerary rites within material culture. He suggests that the spaces used for disposal and performative rituals reflect the different stages of these activities in the funeral sequence. Disposal rites are directly tied to the handling of the body and the items buried with it, occurring in the same space at the same time. In contrast, funerary rites might take place in entirely different areas. The impact of these ritual activities on burial patterns is typically separated from the corpse by both spatial distance and temporal differences, as indicated by stratigraphy. Flad (2001: 30–31) proposes that the spatial arrangement within a tomb preserves the sequence of activities and this sequence reflects the progression of the funeral ceremony. Initially, items such as clothing or jewelry may be placed with the deceased, while mourners may intentionally position certain objects nearby. Then, additional items might be added at a distance or even placed within the grave’s filling dirt. While burial practices vary widely, Flad (2001: 30–31) argues that objects buried early in the sequence are more directly linked to the individual’s status in life, whereas later additions reflect the way the deceased is perceived by the living and the broader funeral practices.

Inspired by this understanding of burial space and sequence, I suggest that in simple shaft-pit burials such as those at Taosi, the body and its immediate belongings at the bottom of the tomb chamber represent the earliest stage of interment. Objects deposited later appear higher in the stratigraphy and farther from the body—placed in niches, on the ercengtai earthen ledge, or within the fill of the shaft.

In other words, treating all objects in a grave as equal indicators of the deceased's "social identity" is misleading and Jørgensen's method of ranking burials by the total value of grave goods fails to account for differences in the timing and purpose of object placement. To address this problem, Flad (2001: 31) develops two distinct categories of grave values for each burial: a "deceased grave value," which measures the elaboration of the deceased person's burial, and a "ceremony grave value," which reflects the elaboration of the funeral ritual itself. In evaluating the construction of value, Flad emphasized that these two categories of values need to be calculated separately.

Later on, Peng Peng (2011) made another revision by separating "sumptuary items" from other burial offerings. As defined by Levy (1979) in *Evidence of Social Stratification in Bronze Age Denmark*, sumptuary laws refer to social regulations that restrict access to specific artifacts to certain societal groups. These restrictions are based on factors other than wealth, such as rank, political authority, occupation, or religious power. In Bronze Age China, it has been shown that sumptuary rules controlled how and how much of these items could be consumed by those entitled to them (e.g., Yu and Gao 1978). If such rules existed in Neolithic China, we would expect to see regulated quantities, specific combinations, and particular placements of certain burial goods. At Taosi, musical instruments and painted

serpent plates appear to have been restricted to the highest elites. Moreover, even among those permitted to use them, their numbers were tightly controlled: each high-status individual typically had no more than two alligator-skin drums, one chimestone, one pottery drum, and one serpent plate (Table 11). Tombs that deviate from this pattern are often heavily disturbed, likely due to the social upheavals during the Middle–Late Taosi transition. The regulated use of these items suggests the emergence of sumptuary rules as early as the Early Taosi phase. Accordingly, following Peng Peng's revision of Flad's method, I calculate the type value of sumptuary items independently rather than subsuming them under broader categories such as painted pottery.

Table 11. The musical instrument sets and serpent plates in Early Taosi graves

	Period	Dragon charger	Alligator skin drum	Stone chime	Pottery drum	Notes
M3072	Early III	1	1	1	1	Heavily disturbed
M3073	Early IV	1	1	0	1	Heavily disturbed
M2001	Early IV	1	0	0	0	
M3002	Early V	0	2	1	1	
M3016	Early V	1	2	1	1	Heavily disturbed
M3015	Early V	0	2	1	1	Heavily disturbed

Another clarification concerns the categorization of jades. Previous studies of grave value at the Taosi cemetery classified jade and stone objects according to whether the raw material was "real jade," i.e., nephrite, and grouped burials by the number of real jade objects they contained, so the type value of nephrite objects is elevated (Shen 2021: 94). At Taosi, however, nephrite ornaments were used interchangeably with other broadly defined "jades" (e.g., serpentine, tremolite, shale, talc), rendering such distinctions meaningless.

In this chapter, therefore, I categorize jades into two functional groups: ornaments and ritual weapons. The first includes various types of bangles as well as *cong* cylinders, *bi* discs,

and composite *bi* discs made by piecing together three or four arc-shaped jades. Although these jade objects originally had distinct ritual functions in the Liangzhu and Dawenkou Cultures, at Taosi they were employed interchangeably as bangles or armbands and are thus treated as a single type for calculating type value. The same principle applies to the ritual-weapon category, which encompasses *yue* battle axes and double-perforated *dao* knives.

A last clarification I would like to make regards the interpretation of pig remains. It has been well-established that the interment of pig remains in burials during the Dawenkou and Longshan periods served as a display of individual wealth and inequality in the rise of political elites (Kim *et al.* 1994). In addition, pig remains might also be provided by the kin groups of the deceased as sacrificial offerings (Liu 1996). Pig offerings were previously not seen in the Jinnan region and its sudden appearance at Taosi indicates that this custom might be inspired by the Lowlands communities. At Taosi, 42 tombs yielded pig remains (Table 12). I divide these pig remains into three categories: (1) dismembered whole pig, (3) primary meat parts, such as ribs and legs, and (3) pig mandibles. Dismembered whole pigs were only found in the highest elite tombs and are placed with feasting vessels, suggesting they served as the meat for feasting. Pig parts (e.g., head, feet, legs, and ribs) were also placed with feasting apparatus, suggesting a similar purpose of offering. The difference between whole pig and pig parts indicates different status; pigs served in the former fashion only appear in the highest elite tombs. Given that they served for the same purposes, I combine categories 1 and 2 together and count them towards deceased value.

Table 12. Burials with pig remains

Burial No.	Class	Size (m^2)	Sex (Age)	Funerary objects	Placement	Period
M2053	2B	2.8	M (Adult)	Pottery feasting vessels (2), stone arrowheads (8), pig mandibles (23)	Foot end, tomb chamber - Separate from feasting vessels	Early (I)
M2135	2B	3.9	M (25+)	Pottery ding tripod, wooden vessel, stone arrowhead (14), unidentifiable stone pieces, bone arrowhead, pig mandibles (7)	Foot end, tomb chamber - Separate from feasting vessels	Early (I)
M2063	2B	3.8	M (35±)	Pottery feasting vessels (4), wooden *gu* goblet, stone *dao* knife, arrowheads (9), pig mandibles (86) and one unspecified pig bone	Foot end, tomb chamber - Out of the 86 mandibles, only one is placed on the right side of the coffin - One pig bone is placed in the ding tripod in the right-foot corner	Early (I)
M2043	2A	3.1	?	Pottery feasting vessels (10), wooden *gu* goblet, stone cleaver, bone hair pin, bone *bi* knife, half pig head	Right side, tomb chamber: Half pig head in a *jia* tripod on the right side of the coffin	Early (IIA)
M2103	2A	3.6	M (45-50)	Pottery feasting vessels (15), wooden feasting objects (8), jade *yue* axe, *fu* axe, stone *ben* adze, bone *bi* knife, pig mandible, ribs (3)	Foot end, tomb chamber: - Ribs on the foot end towards the left side - Separate from feasting vessels Left side, tomb chamber: - Pig mandibles on the left side of the coffin, separate from feasting vessels	Early (IIB)

M2035	2A	4.6	M (30–35)	Pottery feasting vessels (15), wooden feasting objects (2), jade yue axe, dao knife, red-painted round lithic piece, pig mandibles (9), pig head, rib, and spine.	Foot end, tomb chamber: -Nine pig mandibles at the right foot corner of the tomb -Pig ribs on the foot end - Separate from feasting vessels Right side, tomb chamber: - Pig head in a *jia* tripod on the right side of the body.	Early (IIB)
M2168	2A	5.6	M (50–70)	Pottery feasting vessels (18), wooden feasting objects (9), jade yue axe, chan spade, dao knife, bone bi knife, pig head, ribs, hooves, and teeth (2)	Left side, tomb chamber: All pig remains are placed among feasting vessels, on the left side of coffin, near foot end.	Early (IIB)
M2172	2A	9.5	M (40–50)	Pottery feasting vessels (20), wooden feasting objects (10), jade axe, spade, knife, bone bi knife, pig mandibles (58), pig head, legs and ribs	*Ercengtai* earthen ledges: - Five piles of totaling 58 pig mandibles Left foot corner: - pig head, ribs, and legs were placed on the wooden table.	Early (IIB)
M2180	2A	3.5	M (35-40)	Pottery feasting vessels (14), wooden feasting objects (12), jade yue axe, dao knife, stone arrowheads (19), pig mandibles (18)	*Ercengtai* earthen ledges: - 18 pig mandibles on the *ercengtai* ledges	Early (IIB)
M2014	2A	5.6	?	Pottery feasting vessels (7), wooden feasting objects (3), lithic *fu* axe, *dao* knife, half pig head and ribs	Foot end, tomb chamber: - Separate from feasting vessels	Early (III)

M1111	2A	3.6	?	Pottery feasting vessels (5), unidentifiable wooden object, stone cleaver, pig mandibles (29)	Foot end, tomb chamber Separate from feasting vessels	Early (III)
M3072	1A	6.1	?	Pottery feasting vessels (15), alligator skin drum, wooden feasting objects (4), stone chime, fu axe, dao knife, pig head	Foot end, tomb chamber: -Pig head placed in a wooden box on the wooden table. The table is placed among other funerary objects on the foot-end of the tomb.	Early (III)
M2001	1B	7.3	M (Adult)	Pottery feasting vessels (31), wooden feasting vessels (28), jade *dao* knifes (3), composite headdress, wristband. Shell spoons (4), finger rings (2), arrowhead. Unidentifiable body ornaments on arms and the waist, dismembered whole pig.	Right side, tomb chamber: All pig remains are placed on wooden tables among other feasting vessels on the right side of the coffin.	Early (IV)
M3002	1A	8.0	M (22-24)	Pottery feasting vessels (14), wooden feasting objects (5), alligator skin drum (2), stone chime, jade yue axes (3), shu (2), fu axe (7), stone ben adze (13), grinding wheel and pestle, dao knifes (2), arrowheads (4), bone hairpin (1), dismembered whole pig, pig mandibles (8), pig heads split in half, pig scapula, ribs, legs and hooves (these parts are most likely from a dismembered whole pig).	Right side, tomb chamber: All pig remains were placed alongside feasting vessels and the musical instruments on the right side of the coffin towards the foot-end.	Early (V)

M3015	1A	8.7	M (40±)	Pottery feasting vessels (15), alligator skin drums (2), wooden feasting objects (25), stone chime, jade yue axes (4), double perforated dao knife, stone ben adze (6), stone grinding wheel and pestle, dao knifes (3), arrowheads (129), huan ring, guan tube, adze-shaped plate, perforated turquoise plates (2), bone arrowheads (18), dismembered whole pig bones	Right side, tomb chamber: -Pig head split in half placed in a *jia* tripod. Pig hooves and a stone cleaver both in a wooden box. All feasting vessels and the pig remains are on the right side of the coffin.	Early (V)
M3016	1A	8.5	M (40–45)	Pottery feasting vessels (11), pottery drum, alligator skin drum, wooden feasting objects (4), stone chime, fu axes (4), ben adzes (4), zao chisels (2), stone grinding wheel and pestle, arrowheads (2), stone slab, shell arrowhead, dismembered whole pig bones	Right side, tomb chamber: The tomb is severely interrupted, but based on what remained, dismembered pig parts were mixed with feasting vessels on the right side towards the foot end.	Early (V)
M2200	2B	10	M (35±)	Wooden rod, bone arrowheads (18), teeth ornaments, pig mandibles (132)	All pig remains on the *ercengtai* ledges, on the foot end.	Early (subphase unclear)
M3084	2	1.5	?	Pig mandibles (43)	Foot end, tomb chamber	Early (subphase unclear)
M22	1A		M (50±)	Pottery feasting vessels, jades, whole pigs (10), pig mandible	Right side, tomb chamber - Pig bones along with stone cleaver Head end	Middle (late phase)

					- Ten whole pigs split in half placed against the wall Center of the foot end - One boar mandible hung in the center of the foot-end	
M1282	3A	3	?	Jade cong cylinder, comb, jade and stone pieces (2), pig mandible	Head-end niche	Late
M1361	3A	1.62	F (35-40)	Jade bi discs (3), jade and stone pieces near head (6), pig mandible	Head-end niche	Late
M1650	3A	3.1	M (35-40)	Pig mandible	Head-end niche	Late
M2087	3C	3.2	M (Adult)	Pig mandible	Head-end niche: one mandible Filling dirt: - Three layers of totaling 74 mandibles were buried in the filling dirt.	Late
M2108	5	2.5	M (?)	Pig mandible	Head-end niche	Late
M1436	5	Not clear	M (50–55)	Jade ornament on head, pig mandible	Filling dirt - Towards the right head corner	Late
M1677	5	0.46	M (20–24)	Pig mandible	Right side	Late
M3141	5	1.1	?	Pig mandibles (6)	Left side - towards the foot end	Late
M3142	3A	1.9	M (45±)	Jade gui tablet, pig mandibles (12)	Right side - towards the foot end	?
M3306	3A	1.5	F (50±)	Jade bi disc, headdress (2), pig mandible	Right side	?

M3372	3A	4.7	M (50–55)	Jade yue axe (3), bi disc, headdress, unidentifiable wooden objects (2), pig mandible	One mandible in the right head corner	?
M1364	3A	2.44	M (35±)	Jade yue axe, bi discs (2), comb, pig mandible	Head-end niche	?
M1411	3A	2.6	M (35-40)	Jade yue axe, bi disc, pig mandible	Head end, tomb chamber	?
M2169	3B	2.75	M (30–34)	Jade headdress, small turquoise pieces (3), teeth pendant, pig mandible.	Head right corner, tomb chamber	?
M3404	5	1.5	M (25-30)	Pig mandibles (14)	Foot end, tomb chamber	?
M1360	5	1.97	M (40–45)	Pig mandible	Head-end niche	?
M3318	5	0.9	M (30±)	Pig mandibles	Foot end, tomb chamber	?
M2230	5	1.6	M (30–35)	Pig mandibles (6)	On the foot-end, towards the left side	?
M2425	5	0.9	M (40–45)	Pig mandibles (8)	Pig mandibles surrounding the body, from the tibia area to the foot-end of the tomb.	?
M3162	?	0.9	M (45-50)	Stone dao knife, pig mandibles (7)	All funerary objects, including the pig mandibles are on the foot end	?
M1461	?	0.5	?	Pig mandible (10)	Foot end, tomb chamber	?

Pig mandibles represent a different use of pigs. In this case, the pigs were consumed a long time before the burial and the mandibles were accumulated over time during the lifetime of the deceased or received as gifts from the mourners (Xia and Gao 2022).

Compared to other forms of pig offerings, pig mandibles were more often placed on the earthen ledges or in the niches, rather than in the tomb chambers with the feasting vessels. As such, I qualify pig mandibles as primarily of ceremonial value.

Although quantified measurements of grave goods may not fully capture all aspects of graves that were meaningful to those who created them, they can serve as useful tools for comparing different burials. Referring to the formula developed by Lars Jørgensen for determining the rank of the deceased: [type value of an object = (total number of graves) / (frequency of type)]. Each burial good is assigned a type value, and the overall grave value is the sum of all the type values associated with it. At Taosi, the presence of two distinct contexts of deposition allows us to differentiate between two grave values for each tomb. One, termed the *deceased value*, is calculated based on the objects found in the chamber and reflects the social status of the deceased. The other, the *ceremony value*, is derived from objects placed in the niche and fill, providing an indication of the level of elaboration of the funeral rituals.

In addition to burial goods, Flad (2001: 40) also suggests considering grave attributes, which can help reveal the existence of different social identities and social actions. Grave attributes include a range of variables, such as location, the orientation of the body, corpse preparation and treatment, and receptacle type, shape, and size (O'Shea 1984: 39). At Taosi, the size of tombs, the construction of niches, and use of cinnabar are considered. Other attributes, such as type of coffins, may also have been attributed to status difference, but as they are not well preserved, they are not considered here. As Taosi tombs are heavily interrupted by the making of modern terrace fields, the size of tombs is based on the area of

the tomb bottom. They are grouped into three categories based on the natural breakage in the distribution of size: larger than 5 m^2, 1.5–5 m^2, and smaller than 1.5 m^2. In addition, cinnabar covering the deceased person's body is commonly found in the Taosi cemetery (type value 26.8), which adds towards the deceased grave value. The construction of niches, type value 66.3, on the other hand, adds to the ceremony grave value.

Lastly, it needs to be clarified that I only assessed the tombs in the cemetery. A small number of human burials also appear in the residential areas irregularly but given the partial publication and complicated nature of these burials, there are not counted here. At Taosi, the cemetery is divided into three Excavation Areas numbered I, II, and III. Excavators dug 434 tombs in Area I, 403 in Area II, and 472 in Area III. In addition, within the inner city dating to the Middle Phase, another smaller cemetery was found. According to published material (Wang and Yan 2006; Zhongguo, Shanxisheng and Linfenshi 2003), only an area of 67 m^2 was excavated, and 22 tombs dating to Middle and Late Phases were found there. Not all excavated tombs are published, but seven of them are published in preliminary reports, which yields a total number of 1259 graves.

It should also be noted that only one third of tombs can be assigned to a specific phase based on stratigraphic and typological information. Among them, 71 are dated to the Early Phase, seven to the Middle Phase, and 336 to the Late Phase (Zhongguo and Shanxisheng 2015: 833-898). These 414 dateable tombs will serve as the basis for the discussion of diachronic change of elite funerary tradition.

5.2 Type Values and Grave Values

Table 13 provides a summary of the burial goods that contributed to grave value and their type value, which is the base to calculate the grave value of each tomb. To identify patterns in burial elaboration at Taosi, Figure 62 plots the ceremony grave value (y-axis) and the deceased grave value (x-axis) of each grave. If grave goods and attributes directly and uniformly reflected the social rank of the deceased, all variables would be expected to correlate with one another. In that case, there would be a strong correlation between deceased grave values and ceremony grave values and the slope of the regression line should be approaching 1. Figure 62, however, reveals no such correlation. Some burials with high deceased grave values have minimal ceremony grave values, while others with elaborate niche assemblages contain few objects in the chamber. This suggests there are two distinct manners of value construction influencing the distribution of grave values. To understand the contribution of these two manners better, I group graves by time period to see if there are any discernable patterns.

Table 13. A summary of type value at the Taosi cemetery

Type	Number of graves	Type value	Count towards
Tomb size (>5m²)	17	74.1	Deceased value
Tomb size (1.5-5m²)	338	3.7	Deceased value
Tomb size (<1. 5m²)	904	1.4	Deceased value
Niche	19	66.3	Ceremony value
Cinnabar	47	26.8	Ceremony value
Painted pottery	40	31.5	Deceased and ceremony value (Depending on the place of display)
Unpainted pottery	32	39.3	
Cleaver	17	74.1	Deceased value
Axes and knifes	85	14.8	Deceased and ceremony value
Bangles	86	14.6	Deceased and ceremony value
Turquoise armband	8	157.4	Deceased value

Arrowhead	26	48.4	Deceased value
Chimestone	4	314.8	Sumptuary item
Pottery drum	5	251.8	Sumptuary item
Alligator drum	5	251.8	Sumptuary item
Dragon charger	4	314.8	Sumptuary item
Human retainer	31	40.6	Ceremony value
Animal retainer	4	314.8	Ceremony value
Pig offering (>20)	7	179.9	Deceased and ceremony value (Depending on the place of display)
Pig offering (5-20)	11	114.5	
Pig offering (<5)	24	52.5	

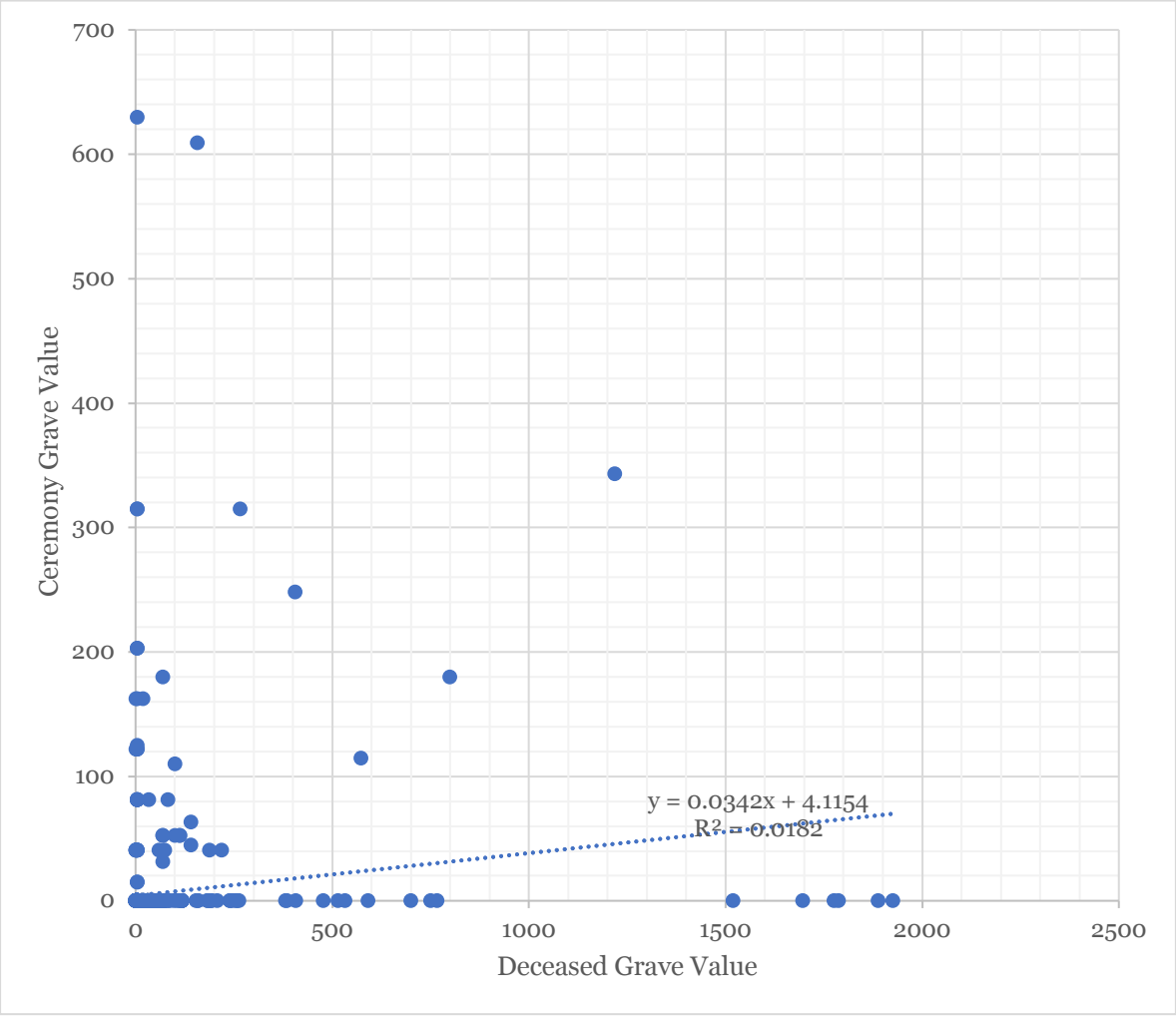


Figure 62. Regression plot of deceased and ceremony grave values of each tomb at the Taosi cemetery

The regression plots depicted in the following fitures capture the changes from Early, Middle, to Late Taosi. Comparison of the three regression plots shows that the primary contribution to grave value shifted from being derived more heavily from the deceased value

to relying more on the ceremony value. Among dateable tombs, those with the highest deceased grave values date to the early period, while the burials with the highest ceremony values date to the Late Phase. Although the patterns are not entirely clear—partly due to heavy disturbance and the limited sample size of Middle Phase tombs—they indicate more than a simple move from elaborating the chamber containing the corpse to elaborating burials through the placement of objects in niches or fills. I suggest this reflects a broader shift in strategic behavior within the Taosi Culture: a change occurred from a focus on elaborating the identity of the deceased during the Early Phase, to the elaboration on both processes in the Middle Phase, and finally to the elaboration of the strategic ceremonial stage of the ritual process in the Late Phase.

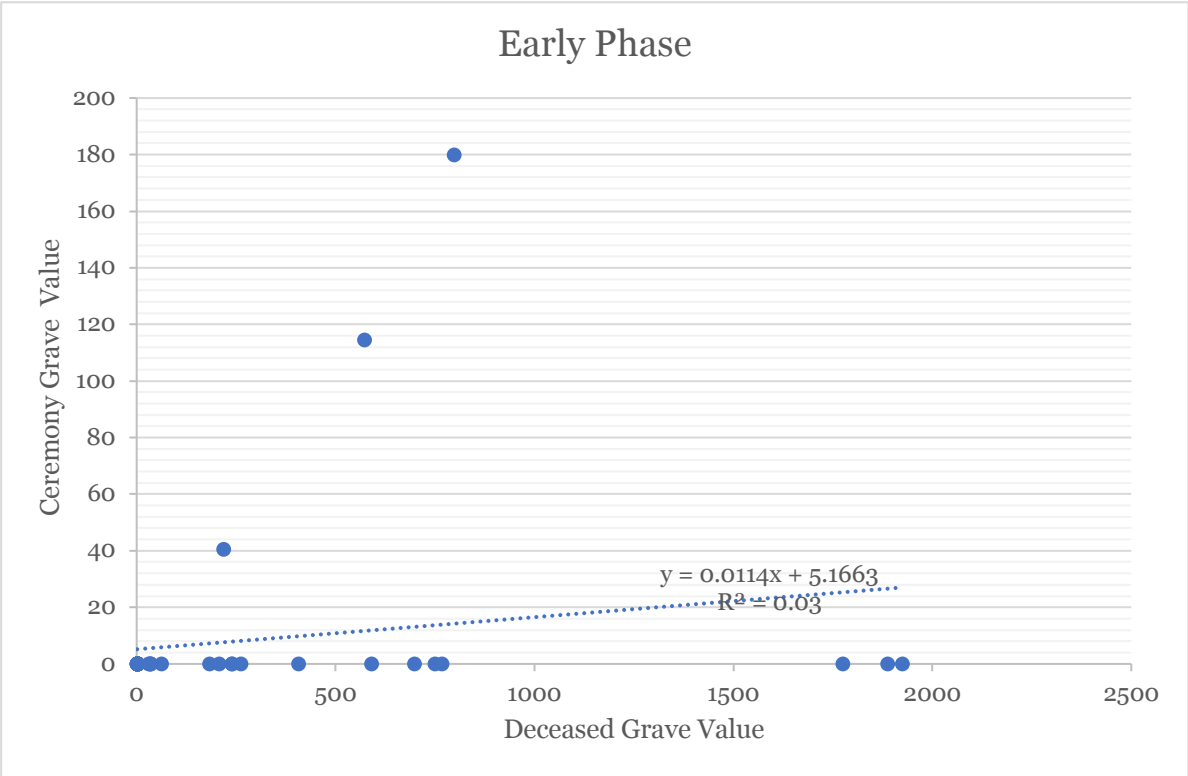


Figure 63. The regression plot of deceased grave value and ceremony grave value in Early Taosi.

During the Early Phase (Figure 63), likely influenced by their Dawenkou counterparts, Taosi had already developed a well-defined power strategy. Funerary practices in this system primarily emphasized reinforcing the social status of the deceased. The large size of tombs and the lavish display of feasting apparatus, musical instruments, and abundant meat contributed substantially to grave value. Graves with high grave values tend to be spatially clustered, indicating that high-status individuals likely attained their positions through kinship ties or associations with influential figures, it has been argued that the spatial arrangement of burials reflects kinship relationships (Dai 2019).

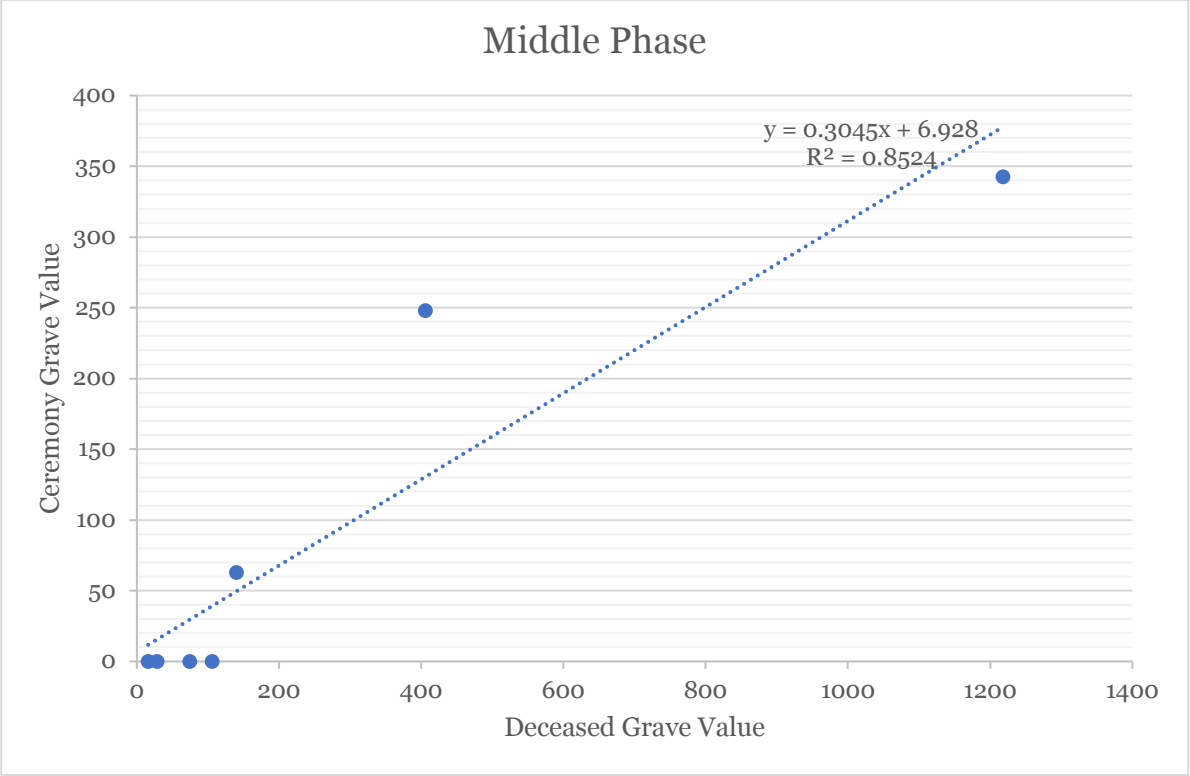


Figure 64. Regression plot of deceased grave value and ceremony grave value in Middle Taosi

During the Middle Phase, although the sample is limited, the ceremony and deceased grave values began to correlate, with the R^2 approaching one (Figure 64). This correlation is not particularly strong, but it indicates that during the peak of Taosi, high-status individual not only held prominence during their lifetime, but their death also provided important stage

for the community to gather and consolidate through elaborate ceremonies. During this phase, different sources of social power began to converge to the same group of political actors.

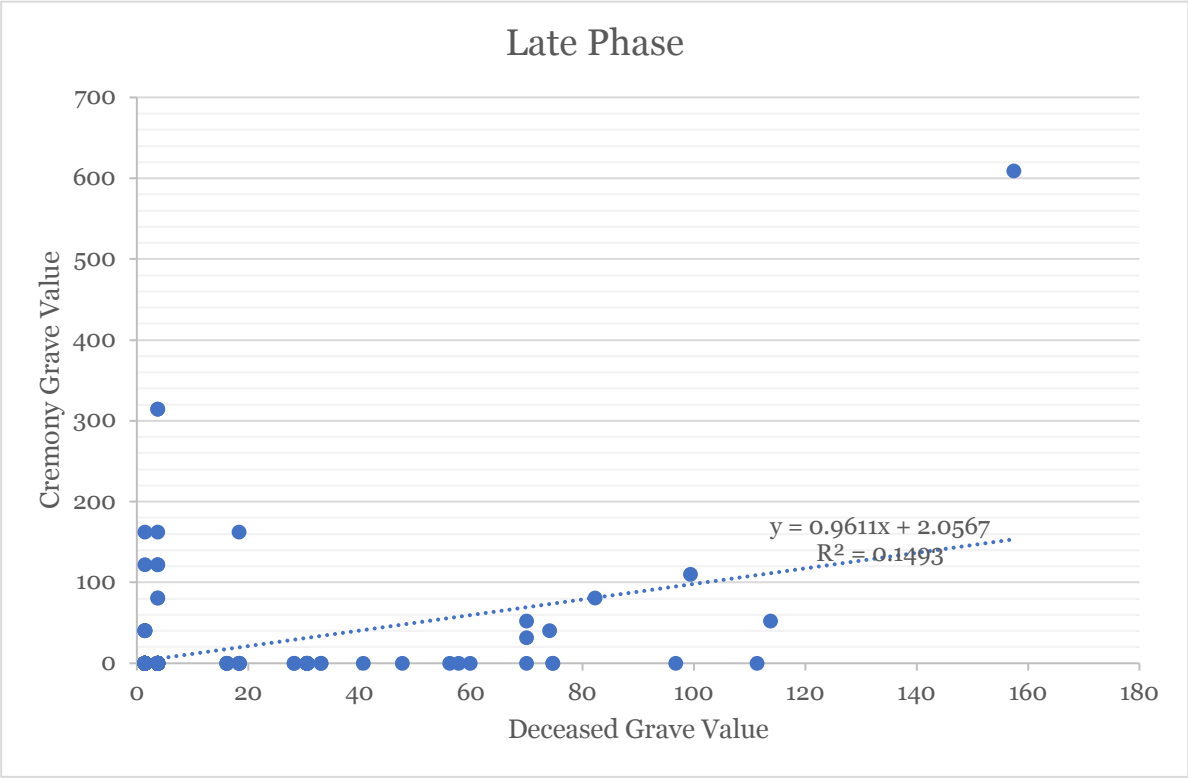


Figure 65. Regression plot of deceased grave value and ceremony grave value in Late Taosi

By the Late Phase, two notable changes emerged. First, the correlation between ceremony and deceased values dissolved. The regression line still leans toward the deceased value (Figure 65), largely due to the significant contribution of personal ornaments worn by the deceased and ritual weapons placed on the body. Compared to the Early Phase (Figure 63), however, the regression line shifted toward the axis of ceremony values, signaling the growing importance of funerary ceremonies in the construction of grave value.

The rising importance of ceremony value stems from the increased use of niches and the growing frequency of animal and human retainers. While pigs remained the most common sacrificial animal throughout Taosi, deer and sheep began to appear in tombs such as

M2336, M2373, M2430, M3166, and M3343. Only in one case (M3166) was a sheep placed at the bottom of the tomb and buried simultaneously with the corpse, symbolizing the deceased's personal wealth; I therefore count it toward deceased value. In all other cases, animals or humans were deposited in the fill and are better understood as elements of funerary ritual.

Human retainers became especially prevalent in the Late Phase: 31 tombs yielded 76 individuals, though many were represented only by partial remains (e.g., skulls or disarticulated limbs), so the minimum number of individuals (MNI) is used in counts. Taken together, these patterns suggest that high-value burials in the Late Phase were associated with individuals whose deaths became occasions for collective ceremonies and social negotiation, marking a departure from the static wealth-display strategies characteristic of the Early and Middle Phases.

Human retainers are also frequently found in the tombs of the Shimao Culture (e.g., Shaanxi Sheng *et al.* 2024; 2016; 2015) and Zhukaigou Culture (Neimenggu and E'erduosi 2000). In these contexts, human sacrifices—typically teenagers or young females with their hands tied—are consistently placed outside the coffin or on the *ercengtai* earthen ledges. Their skeletons are generally complete and undisturbed, suggesting a routinized and regulated practice among the northern Highland communities. At Taosi, by contrast, human sacrifices appear irregularly, suggesting that the practice was experimental or still in its early stages. The emergence of customs such as animal and human retainers or the placement of offerings in niches reflects both a search for new strategies of value construction and the instability of a sociopolitical environment where authority required constant negotiation.

When the Taosi inhabitants searched for new strategies, they likely drew significant inspiration from their peers in the northern Highland communities.

This instability is also visible in the spatial arrangement of high-value tombs. As mentioned above, in the Early Phase, such graves often aligned within orderly rows, and the clustering of high-value graves signal the hereditary power of ruling lineages. In the Late Phase, however, high-value tombs became dispersed and irregularly positioned. This spatial disorganization implies the erosion of kinship-based hierarchies: status was no longer determined by lineage affiliation but was increasingly fluid, contingent on the scale and performance of individual funerary events rather than inherited prestige.

The second major change in Late Taosi is the overall decline in grave values compared to the Early and Middle Phases. In the Early Phase, the highest grave value approached 2000, and in the Middle Phase it exceeded 1200 (Figure 64), but in the Late Phase it quickly dropped to around 700 (Figure 65). This reduction aligns with the broader decline in prestige goods during the transition from Middle to Late Taosi. Early elite tombs were richly furnished with large numbers of cooking and serving vessels, jade and turquoise ornaments, ritual weapons, musical instruments, and abundant meat offerings. By contrast, in the Late Phase, cooking and serving vessels appear in only two tombs, musical instruments vanish entirely, and pig offerings, while still present, decline sharply in quantity. Tomb sizes also become much smaller. Together, these changes account for the significant decrease in overall grave values during the Late Phase.

Nonetheless, the overall decrease in grave values does not necessarily indicate a decline in social differentiation. Figure 66 compares the histograms of grave values from the Early

and Late Taosi Phases. Owing to the limited sample size of the Middle Phase, it is set aside here. Comparison between Early and Late Phase grave value distribution suggests that although grave values in the Late Phase was lowered, their distribution assumes a more pyramidal shape than in the Early Phase. This suggests a contrasting trend that the overall reduction in wealth was accompanied by an intensification of social differentiation. That means, what appears as the disappearance of prestige goods is better understood as a reconfiguration in the ways social distinctions were expressed, instead of social degradation.

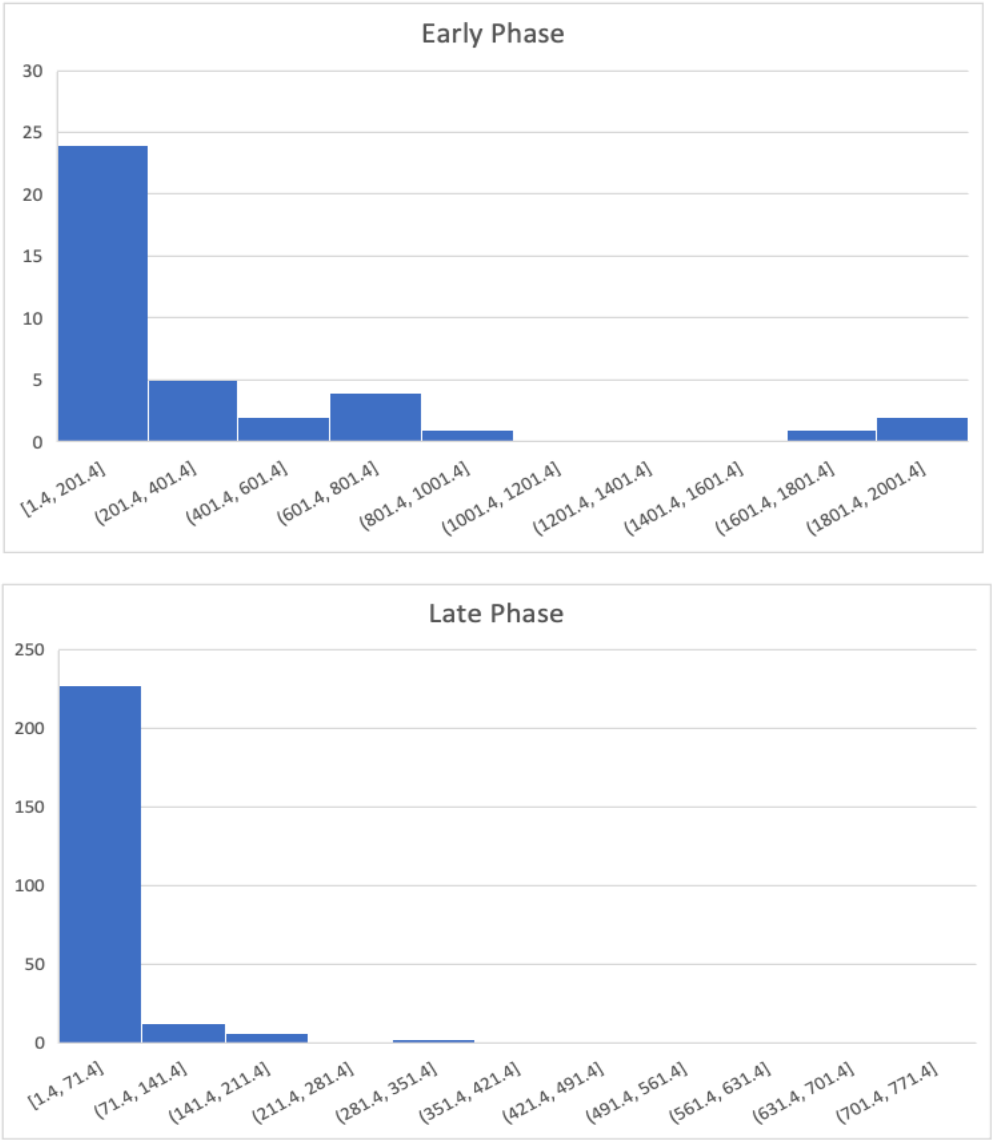


Figure 66. Distribution of grave values in Early and Late Taosi

Alternation between more lavish and more restrained expressions of social status appears to be a cross-cultural phenomenon during social "collapse" and an integral aspect of social transformation. Below, I will introduce another three cases that demonstrate this point. By highlighting this pattern, I hope to underscore that the fluctuation of grave values should not be viewed linearly as signs of a social development or decline, but as different responses to challenges and social needs. These strategies are not mutually exclusive; their coexistence in multiple post-collapse contexts reflects a broader pattern of reconfiguring power in response to social crisis.

5.3 Discussion: the "disappearance" of elite culture in cross-cultural context

The first comparative example is the case of Post-palatial Greece, where shifting mortuary practices illustrate how communities renegotiated authority after the collapse of the palatial system. Post-palatial Greece lacked the stable, institutionalized elites of the palace era. As Oliver Dickson (2006: 120) observed, burials of the Postpalatial and Iron Age periods show few signs of enduring aristocracy. Some graves contained rich offerings, but these were not segregated into elite cemeteries. Instead, mortuary practice suggests the rejection of palace-centered ideology. As Guy Middleton (2010: 92) notes, Mycenaeans deliberately abandoned elements such as Linear B writing or megaron layouts. The title *wanax* (supreme ruler of a palace-centered polity) gave way to *basileus* (roughly equivalent to a local leader of community during Early Iron Age), stripped of earlier grandeur, and leaders after 1200 BCE drew on new, more modest bases of authority. Ian Morris (2006: 76-77) adds that while burials appear homogeneous, subtle distinctions persisted, with wealthier farmers monopolizing visible rituals and restricting access to worship. This

contributed to what he terms a “middling ideology,” curbing aristocratic power and emphasizing collective norms.

Comparable dynamics can be observed in the Maya world. Chase and Chase (2006) argue that the transition from the Classic to the Postclassic period marked a shift toward symbolic egalitarianism, but such egalitarianism was only symbolic. The Terminal Classic was characterized by polarized inequality and an intensified focus on dynastic rulers, which was accompanied by rapid site abandonment, unfinished buildings, burning, and altered mortuary practices—signs of social upheaval (Aimers 2007; Demarest 2013). By the Postclassic, however, political organization moved toward shared governance rather than dynastic kingship. Household groups share similar caches and ritual practices, reinforcing communal integration (Chase and Chase 2006). Yet isotope analyses reveal clear dietary distinctions between elites and commoners, indicating that the egalitarianism of the Postclassic Maya was symbolic rather than substantive (Chase *et al.* 2001: 111, 113).

The gradual decline and eventual disappearance of fine pottery vessels from burial contexts in Norway during the Migration Period serves as the third comparative case. Initially part of everyday domestic use, these vessels increasingly became associated with funerary rituals in the later Migration Period. Rødsrud (2017) examines argues that the weakening of the warrior aristocracy in many regions led to a reorientation of ritual practices and a sharp decline in pottery production. As the social demand for clay vessels diminished, production in Norway ceased entirely by the late 6th century. This case study demonstrates that such “disappearance” should not be understood as simple loss, but rather as a

transformation closely tied to broader processes of social change and a shift in power strategy.

These comparative cases highlight that the absence of monuments or elite culture should not be equated with political decentralization or social degradation. Instead, such shifts may represent new strategies of power negotiation. This perspective sheds light on Late Taosi society, where the decline in grave values does not necessarily signal the disappearance of the elite class. Rather, it marks a transformation from a "network strategy"—in which leaders emphasized personal charisma, prestige goods exchange, and external connections, fostering individualized and competitive power—to a "corporate strategy" that prioritized collective institutions and communal rituals (Blanton *et al.* 1996).

This framework resonates with Alderfer's (2011) distinction between "overbounded" and "underbounded" systems. The former is characterized by rigid boundaries, formalized rules and hierarchy, and strong central leadership, but they often prove inflexible in the face of change. Underbounded systems, by contrast, feature weak boundaries, diffuse authority, and limited control, making them prone to fragmentation and conflict. Neither extreme is sustainable; resilience is found somewhere in between. Viewing Late Taosi as transitioning between these power strategies allows us to see it not linearly as a society in rise or decline, but as one reconfiguring authority—shifting from static wealth display to dynamic communal interaction in response to the drastic upheaval during the Middle-Late Taosi transition.

6. **The Aftermath**

After the abandonment of Taosi, the Dongxiafeng site emerged as a regional center in Jinnan. It yields ceramics closely resemble those of the Erlitou Culture (for a recent review

on the relationship between Dongxiafeng and Erlitou ceramics, see Chang 2022), representing a discontinuous break from the Taosi tradition. With the demise of Taosi, many elite traditions also declined in Jinnan during the Erlitou period, though some reemerged later in Bronze and Iron Age China, both in the Central Plains and beyond.

The musical tradition, for instance, was preserved among Central Plains elites. In the Late Shang and Early Western Zhou periods, the combination of alligator-skin drums and chimestones appears in elite tombs at Yinxu (Henan) (Liang and Gao 1968: 24-25) and Qianzhangda 前掌大 (Shandong) (Zhongguo 1992; 2000). Beyond the Central Plains, other traditions endured among Highland communities. For example, painted pottery disappeared in the Linfen Basin during the Erlitou Era, consistent with the broader decline of painted ceramics across most Central Plains cultures after Longshan. In the Highlands, however, painted pottery remained significant in contexts such as the Qijia Culture (2300–1500 BCE) and the Lower Xiajiadian Culture (2000–1300 BCE; 14C dates cited from [Tang *et al.* 2022]). An exception within the Lowlands is the Yueshi Culture, which briefly revived painted pottery (e.g., Yinjiacheng [Shandong 1990: 206]), likely due to influence from the Lower Xiajiadian Culture (Li 1992; Ogawa 1982; Zhang 1989).

Pig offerings in mortuary contexts provide another case of continuity and divergence. This practice can be traced to the Peiligang 裴李岗 horizon (c. 6000 – 5000 BCE) and by the third millennium BCE had spread widely across the middle and lower Yellow River regions. During the Longshan period, northern Highland communities also adopted the custom of placing pig mandibles in tombs (Pei 2022). Also in the Longshan Era, cattle and sheep sacrifices rose in prominence, eventually surpassing pigs during the Western Zhou (c. 1046–

771 BCE) (Okamura 2005: 188-198). Yet, in several so-called “peripheral” communities along the Crescent Belt—such as the Dadianzi cemetery in Inner Mongolia (Zhongguo 1998) and the Aofengshan 鳌凤山 cemetery in Yunnan (Yunnansheng 1990)—pig offerings remained important well into the Bronze Age and even the Early Iron Age. This is another case where the peripheral communities preserved the Longshan traditions that were suppressed in the Central Plains.

7. **Summary**

This chapter examined the changes in pottery style, elite burial customs, and some of the prestige goods at Taosi. The following trends have been observed. First, Early Taosi ceramic tradition was built upon the local tradition with painted pottery learned from the Dawenkou Culture in the east, but in the Middle and Late Phases, the pottery style became increasingly Highland-styled. Second, in the Early and Middle Phases, the elite burials served as a stage to build elite status through two strategies: one, situating the deceased in a lavish feast, and two, reconstructing the interregional network of interaction that was exclusive to the elites. During the Late Phase, in response to the crisis during the Middle–Late transition, both of these strategies were abandoned and replaced by a new strategy in which status differentiation was expressed in a subtler manner. The shifting status construction strategies went hand in hand with the multiple efforts to restore the Middle Phase palace and sacrificial altars mentioned in the last chapter. The changes reflected by mortuary data and settlement data collectively indicated that Late Taosi was characterized by constant power negotiation, experimentation, and instability. This enduring disorder likely contributed to the final abandonment of the site.

One of the recurring themes in discussions of Taosi is the extensive network in which it engaged. Increasing connectivity was, in fact, a defining feature of the Longshan world. To underscore this, Zhang Chi (2017) situated the Longshan world within the framework of Bronze Age world systems, drawing on the concepts of Barry Gills and Andre Gunder Frank's (1996) edited volume *The World System: Five Hundred Years or Five Thousand?* While I remain skeptical that current evidence supports the existence of world systems in the Longshan world—defined by unequal labor divisions and core-periphery power relations—I believe that its small-world-ness had a transformative impact on social change. Small-world networks are characterized by dense local clustering combined with easy connection between clusters (a concept I define more fully in the next chapter). This property, inherent in the world systems, also describes the Longshan network. Chapter 5 will expand on this point by reconstructing the Longshan networks, tracing their diachronic changes, and assessing how network dynamics shaped the trajectories of individual communities.

Chapter 5. The Longshan Network and Its Collapse

1. Introduction

The previous chapter, through an examination of various categories of prestige objects, revealed the dynamic history of Taosi. The analysis also uncovered a vast and complex interaction network, through which selective and diverse processes of transmission, reception, and localization actively shaped not only the individual societies participating in the network but also the broader interregional relationships within the Longshan sphere. By using the interregional interaction network of Taosi as a lens, this chapter explores the characteristics and transformations of the Longshan network, simulating how disruptions at major sites could destabilize the entire system. This provides an alternative interpretative framework for understanding the scale and intensity of the Longshan Transformation.

The chapter begins with an archaeological account of the interconnectedness of the Longshan world. It then introduces the methodology of Social Network Analysis (SNA) employed in this research, along with the archaeological indicators used to contextualize key SNA concepts for reconstructing Taosi social network. This is followed by an examination of the reconstructed network's properties, including various measures of centrality, the simulated fragmentation process, and assessments of whether the network exhibits scale-free or small-world characteristics.

The results indicate that Taosi's networks became increasingly interconnected while also developing a multi-centered structure. By the end of the Longshan Era, this configuration offered both resilience and risk: on the one hand, multiple centers allowed the network to absorb localized disturbances; on the other, the high degree of connectivity meant that

regional disruptions—whether invasions, floods, or environmental degradation—were rapidly amplified across the system. This dual dynamic helps explain how local crises could cascade into broader instability, contributing to the Longshan Transformation.

2. Longshan Interregional Interaction Network

Interregional interaction played an important role in shaping Longshan material culture, and evidence of such interaction has become increasingly clear since the fourth millennium BCE. K. C. Chang (1986: 237–242) observed that by approximately 4000 BCE, distinct archaeological cultures across northern and southern China began to show clear signs of growing connectivity. Regional societies engaged in direct contact and cultural exchange, leaving behind substantial and expanding material traces of long-term interaction. Although such exchanges likely began much earlier, it was around 4000 BCE that their impact became markedly evident in the archaeological record, with archaeological cultures — understood as the material remains left behind by communities of people who shared broadly similar ways of making things, living, and identifying themselves, but who were not necessarily homogeneous or bounded groups—increasingly linked through a transregional interaction sphere.

Since then, although the exact numerical dates continue to be refined, ongoing archaeological discoveries have made the patterns of interaction identified by K.C. Chang even more evident (for a recent summary, see C. Zhang 2021). Li Xinwei (2015), for example, uncovers the existence of an upper-elite interaction network connecting the Hongshan, Dawenkou, Miaodigou, Xuejiagang, Lingjiatan and Songze Cultures. He argues that this network emerged through long-distance travel undertaken by elites, during which not only

prestige goods but also knowledge was exchanged. To support his argument for direct contact, Li highlights the striking similarities in shape between Hongshan and Lingjiatan jades. The act of long-distance travel itself, Li suggests, serves as a means for elites to elevate their status within their own communities, providing experiences they could boast about and distinguish themselves from the rest of their community.

On a smaller geographical scale, several studies have noted that communities in western Henan, the Middle Huai River, and Middle Yangzi River were associated with Dawenkou-style pottery and customs—such as tooth removal and intentional cranial modification of the occipital bone—and they argue this as the evidence for the westward and southward movement of the Dawenkou population (Du 1992; Wu *et al.* 2024; Zhao *et al.* 2019). In the Middle Yellow River Basin, the emergence of various forms of hollow-legged vessels that characterized Miaodigou II Culture also demonstrates the growing ceramic similarities (Dai 2022). The growing similarity in ceramic assemblages should be understood within the broader context of intensified interactions whose forms include not limited to trade, exchange, technological diffusion, marriage alliances, ritual gatherings, warfare, emulation, shared resource use, and information exchange, which fostered shared pottery-making techniques, cooking practices, and aesthetic preferences.

The interactions became even more intensive during the Longshan Era and likely became the foundation of the historical period interaction network. For example, through an analysis of burial offerings from Longshan Era tombs, Liu Li (1996) identifies the exchange of prestige items—such as jades, alligator drums, and turtle shells—across different regions during this period. Further, building on Shao Wangping's (1989) proposal that the tributary

system described in the Zhou historical text *Yugong* 禹贡 reflected the situation in the Xia dynasty, Liu Li argues that this network predates the Xia Dynasty in the EB.

Li Min (2018) further expanded the conceptual scope of the Longshan network by outlining the interactive circles on the Eurasian continent. He discusses the meeting of three major cultural and exchange zones during the late third millennium BCE, which, he argues, profoundly shaped the Longshan world and early Chinese state formation. These three spheres are the East Asian Interaction Sphere, focused on early agrarian societies in China, the North Asian Interaction Sphere, where agropastoralists lived alongside hunter-gatherer groups in the Eurasian steppes and the Siberian taiga, and the Middle Asian Interaction Sphere—including Bronze Age urban societies in Central Asia and regions extending to the Persian Gulf and Indus Valley. Li suggests the interactions among the three spheres fostered extensive technological, economic, and ideological exchanges evidenced by the discovery of new crop species (wheat and barley), stockbreeding (cattle and sheep), metalworking, cowrie shells, and divination with animal scapulae.

The research discussed above demonstrates that extensive and complex networks for the interregional exchange of prestige goods and the transmission of regional styles were present throughout the Longshan world and even before. How did such interregional interaction shape local communities within the Longshan world? As demonstrated in Chapter 4, exotic elements—from the Dawenkou, Shimao, Xiaojiawuji, and Qijia Cultures—remained a defining feature of elite culture at Taosi. During the Late Taosi phase, however, as participation in interregional networks declined, Taosi's elite culture underwent significant reconfiguration: exotic goods ceased to be an institutionalized part of burial assemblages,

and mortuary practices shifted their focus toward funeral rites. This evolving relationship between local Taosi elite culture and the broader Longshan network underscores the crucial role that interregional interactions played in shaping local social structures.

With this understanding, I propose shifting our focus from analyzing the collapse, fragmentation, or abandonment of individual Longshan sites to exploring how the collapse of the network as a whole might have affected the broader Longshan world. Using social network analysis, I simulate what would happen to the larger network were central nodes such as Taosi to collapse.

3. **A Brief Introduction to Social Network Analysis**

3.1 Nodes, Links, and Geographical Position

Brandes *et al.* (2013: 2) describe network science as the discipline concerned with the collection, management, analysis, interpretation, and visualization of relational data. A network itself is defined as "a formal system of interdependent pairwise relationships among a set of entities (or actors)" (Brughmans and Peeples 2023: 4). Social Network Analysis (SNA) offers a robust methodology for investigating the connections and interactions that link social entities. Instead of treating archaeological sites or artifacts as isolated units, SNA highlights the relationships among them, fostering a relational perspective that reveals the organization and behavior of past social systems. Central to SNA are two key elements: nodes and links. In archaeology, nodes can represent sites, settlements, tombs, or individuals, depending on the specific research focus, while links signify the relationships between these entities, such as exchange, communication, or shared cultural practices. These relationships may be binary (indicating whether a connection exists) or weighted (measuring

the strength or frequency of interaction) (for more detailed introduction to SNA, please see Chapter 1 in Brughmans and Peeples 2023). In this chapter, nodes correspond to archaeological sites and links reflect the direct or indirect contact between sites, assessed through shared cultural features or material exchanges (as detailed below). In this chapter, nodes that are central and highly connected to others are referred to as "hubs."

I also integrate geographical coordinates into the network graphs to enable spatial visualization of the networks. When these coordinates are incorporated, the resulting diagrams are referred to as *geographical* social network graphs. By positioning nodes according to their actual longitude and latitude and representing links as connections scaled or colored by their weight, I situate the relational data within their geographical context. This spatial integration offers insight into how distance and regional factors influenced patterns of interaction, revealing, for instance, whether central sites were geographically clustered or dispersed. It is important to clarify that in the geographical social network graphs presented in this chapter, core and peripheral sites, as well as centrality measures, are evaluated based on their connectedness within the network, not their physical locations.

3.2 Measures of Centrality

To examine the structure of the Longshan interaction networks, I employ several analytical methods central to SNA. A key approach involves calculating centrality measures, which assess the importance or influence of individual nodes within the network. Degree centrality, to begin with, measures the number of direct connections a node has, reflecting its immediate level of interaction. In cases where the strength of connections varies, I use weighted degree centrality, which accounts for the intensity of these ties and provides a more

nuanced understanding of a site's significance. For instance, if two sites share not only painted pottery but also ornamental jades and small bronze objects, the link between them carries greater weight than that between sites sharing only a single cultural element.

Betweenness centrality, as it is called, measures the extent to which a node functions as a bridge within a network, sitting on the shortest paths between other nodes (Freeman 1977). A node with high betweenness centrality often plays a crucial role in facilitating communication or exchange across different parts of the network, acting as a conduit that connects otherwise distant or disconnected groups. In archaeological networks, a site with high betweenness centrality may have served as an intermediary or broker between distinct social or regional clusters, exercising influence not through the sheer number of its connections but through its strategic position in the overall structure.

Eigenvector centrality takes into account not just the number of connections a node has, but also the importance of the nodes it connects to (Bonacich 1972). A node with high eigenvector centrality is connected to other well-connected nodes, amplifying its influence through its association with central actors. In an archaeological context, eigenvector centrality helps to identify not only prominent sites but also those that are integrated into the densest and most influential parts of the social or exchange network.

3.3 Fragmentation

Another important aspect of my analysis involves fragmentation, which assesses the resilience or vulnerability of a network when nodes are systematically removed. By simulating the removal of nodes in the order of their weighted degree centrality scores—from the least connected to the most connected—I generated fragmentation curves that illustrate

how the connectedness of the network was sustained. The remaining connectedness is evaluated by size of the largest connected component of the network. Fragmentation investigates how many modes can be removed before the network disintegrates into isolated components (Graham 2006). This method allows me to evaluate the robustness of the network structure, revealing whether it remained cohesive or quickly disintegrated as key nodes were removed. Networks that maintain their integrity despite node removal suggest decentralized, resilient systems, while those that fragment rapidly point to centralized structures reliant on a few critical hubs.

In addition to the overall vulnerability or resilience of the network, by observing which nodes may cause the most significant impact on the connectedness of the network, the fragmentation function also inversely reflects the centrality of the nodes. Namely, the more significantly the fragmentation index changes when a node is removed, the more central this node is in the network.

Additionally, I explore the clustering properties of the networks, particularly after the removal of central nodes. Clustering examines the tendency of nodes to form tightly connected groups or communities within the broader network. By applying community detection algorithms, I observe how the network reorganized itself after key hubs were removed, revealing emergent substructures or regional clusters that may have been obscured by dominant nodes. This analysis therefore highlights more localized patterns of interaction, offering a finer-grained view of social organization within the broader network.

3.4 Scale-free network

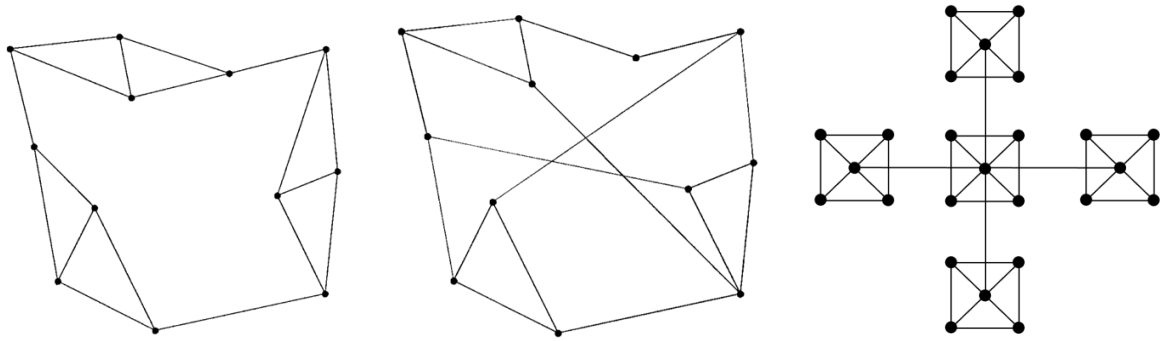
Barabási and Albert (1999) introduced the concept of the scale-free network, often described metaphorically as “the rich getting richer.” Unlike random networks, where connections are distributed more evenly, scale-free networks follow a power-law distribution: a few nodes accumulate an exceptionally large number of links, while most nodes remain sparsely connected (Brughmans and Peeples 2023: 109). The term “scale-free” reflects the absence of any typical degree of connectivity, since nodes vary widely in the number of their ties (Frommer and Pundoor 2003: 177). Growth in such networks is shaped by preferential attachment, meaning newcomers tend to link with already well-connected nodes. This feedback process consolidates the dominance of hubs and perpetuates the “rich get richer” dynamic.

In essence, the scale-free property reflects a network's tendency toward centralization: the more scale-free a network is, the more centralized its structure becomes. This centralization can accelerate the development of key hubs, which may come to control or monopolize resources and information. For instance, the rapid growth observed during Middle Taosi may, in part, be explained by the high level of centralization in the Early Taosi social network, which allowed Taosi to centralize population, resources, or information. However, this centralization also introduces vulnerability. Since scale-free networks rely heavily on a few highly connected hubs, the disturbance at these hubs can cause major disruptions or even the collapse of the entire network. In the analysis in Section 5.5 of this chapter, I examine whether the Longshan network exhibits scale-free characteristics and

whether such a structure could explain its collapse. As will be demonstrated, the results suggest otherwise.

3.5 Small-World Network

Small-world networks are characterized by dense local clustering combined with short path lengths between clusters (Figure 67: b). The concept of a small-world network is widely recognized through the idea of "six degrees of separation"—the notion that any two people are connected by no more than six intermediaries. This idea emerged from studies examining how many links it takes to connect two randomly chosen individuals with no prior acquaintance (Milgram 1967). While these findings offer valuable insights into patterns of social interaction, they were based on modern, densely populated, and technologically connected societies—conditions quite different from those typically found in archaeological contexts.



a b c

a. Clustered network (Frommer and Pundoor 2003 figs. 3); b. clustered network with shortcuts (Frommer and Pundoor 2003 fig. 4); world-system diagram (by author).

Figure 67. Clustered network, small-world network, and world-system network

Nevertheless, subsequent research revealed that a wide variety of networks—not just social ones—exhibit small-world properties. The core principle is that adding even a few random connections to an otherwise structured network can drastically reduce the average

distance between nodes. Watts and Strogatz (1998) demonstrated that many network types share two key features: a short average path length between nodes and a high clustering coefficient relative to a random network (Figure 67b). These mathematical properties define a small-world network and explain how seemingly distant or isolated entities can remain tightly interconnected within broader systems.

In archaeological research, it has been well established that societies in the Late Bronze Age (Knodell 2021) and Roman (Graham 2006) Mediterranean formed small-world networks characterized by a high level of connectivity. Such connectivity can, on the one hand, facilitate regional integration and the movement of goods, people, and ideas, while on the other hand, it can also accelerate and amplify the spread of disease, bad news, or other crises. As the following analysis demonstrates, this property may have played a role in the transformation of the Longshan world.

Beyond the case of the Longshan world, the long-term history of world-systems and core-periphery structures has long drawn scholarly attention (e.g., Gills and Frank 1993). Gills and Frank argue that cyclical rhythms of capital accumulation, crisis, and hegemonic shifts have characterized the world system for at least 5,000 years, not merely the last 500. Within such systems, expansionary “A-phases” (marked by integration, growth, and infrastructural investment) alternate with contractionary “B-phases” (defined by crisis, disintegration, and reduced trade). These cycles are systemic rather than local coincidences.

The conceptual model of a core-periphery system (Figure 67c) illustrates that such a network essentially functions as a small-world network: peripheral entities are strongly clustered internally yet remain connected to the core through shortcuts. From a network

perspective, the synchronization of systemic cycles can thus be explained by the small-world properties of world-systems. By the same logic, one may expect systemic changes to occur in other inter-polity organizational structures that exhibit small-world-ness, whether or not they can properly be termed "world-systems." This implication of the small-world networks may shed important light on the social transformation within the Longshan network.

By integrating centrality analysis, fragmentation modeling, geographical visualization, clustering detection, and the examination of scale-free and small-world properties, I develop a comprehensive understanding of the social and spatial dynamics that shaped the interaction networks in which Taosi was enmeshed. These methods enable me to evaluate both the structural organization and the geographic dimensions of ancient social systems, offering insights into how communities connected, maintained cohesion, and responded to potential disruptions.

As with any interdisciplinary framework applied to archaeological case studies, it is essential to identify key archaeological indicators that translate these concepts into material terms. In the following section, I discuss the archaeological indices adopted to define the nodes and links within the network.

4. **Defining Nodes and Edges of the Longshan Network**

Interactions occurred on multiple levels and across various domains, but in this chapter, I focus specifically on the interregional exchange of prestige goods and aim to reconstruct the upper-elite social networks in which Taosi participated. I propose that the presence of exotic prestige goods at Taosi—such as painted pottery, jade weapons, and turquoise ornaments—serves as footprints of its engagement in interregional interactions. By linking other sites

that contain similar artifacts, it becomes possible to map a network reflecting different forms of long-distance exchange.

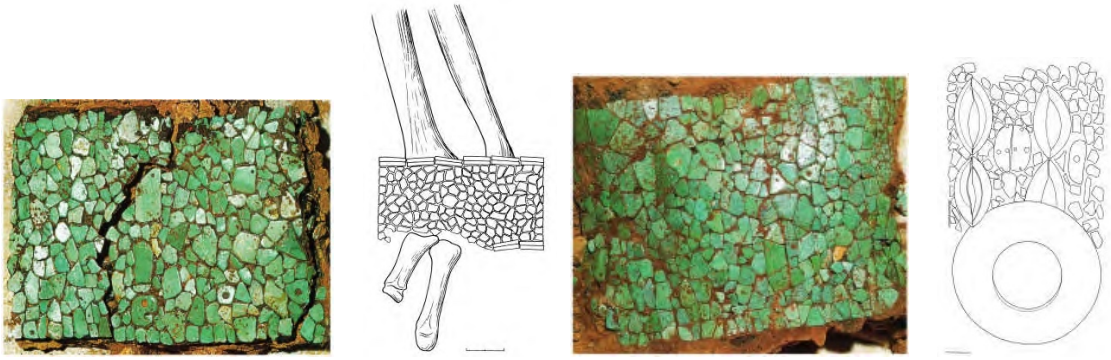
In this network, sites that yield prestige goods similar to those found at Taosi serve as nodes, while the discovery of shared cultural objects or common practices associated with elite identity provides the archaeological indicators of interaction—that is, the links—between communities at different locations. A more detailed discussion of these prestige goods follows below.

4.1 Painted Pottery in Mortuary Context

Interring painted pottery in tombs was a defining feature of Taosi elite culture. Within this framework, a meaningful link is recognized when painted pottery appears in the funerary assemblages of elite burials. What matters is not the vessels themselves but their use in mortuary rituals. This stricter criterion is necessary because, although painted pottery was declining during the Longshan Era, it remained widespread during the Late Dawenkou and Early Taosi phases; counting all instances would produce an overly dense network that obscures significant patterns. By narrowing the focus to mortuary contexts, the resulting links more accurately reflect deliberate choices and significant interactions. When comparing Taosi painted pottery with that of the Qijia Culture, for example, firing techniques and decorative styles differed regionally, but the shared preference for placing painted pottery in burials reveals a common mortuary practice that can be treated as a form of linkage within the Longshan network.

4.2 Turquoise Mosaic Ornaments

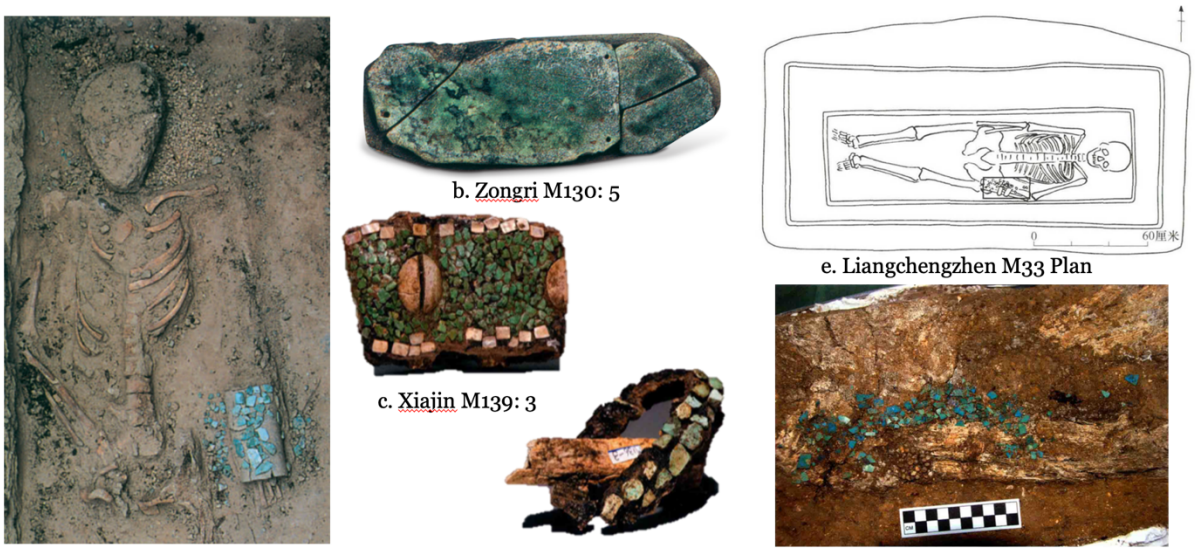
Turquoise armbands were discovered in Early and Late Taosi elite tombs (Figure 72). The widespread presence of turquoise mosaic armbands at sites such as Taosi, Xiajin, Zongri, and Liangchengzhen stands well testifies the long-distance interaction during the Longshan Era (Figure 68). These discoveries of mosaic turquoise armbands varied in dates significantly and thus cannot all be considered as links. The earliest examples are from the Zongri cemetery. The cemetery lasted from the Zongri period (3600–2100 BCE) to Qijia period (2300–1500 BCE) and some remains may even have entered the Kayue period (2000–1500 BCE). The turquoise armband from M322 (Figure 68a) is dated to the earliest phase of the Zongri Culture, predating the Longshan Era, and thus cannot be used to construct the Longshan network. Another turquoise ornament, made with perforated turquoise pieces stick to a stone slab (Figure 7b), is dated to the Qijia period of the cemetery, around 2000 BC, but the form and the manufacturing technique is quite different from other small-plate turquoise ornaments, as such, it is excluded from the network analysis as well.



a b. c. d.

a. M2001: 3 (Zhongguo and Shanxisheng 2015: pl. 54: 1); b. M2023: 4 (*ibid* fig. 4-191) c. M2010: 4 (*ibid* pl. 54: 2); d. M3168: 6 (*ibid* fig. 4-192)

Figure 68. Turquoise mosaic bands found at Taosi

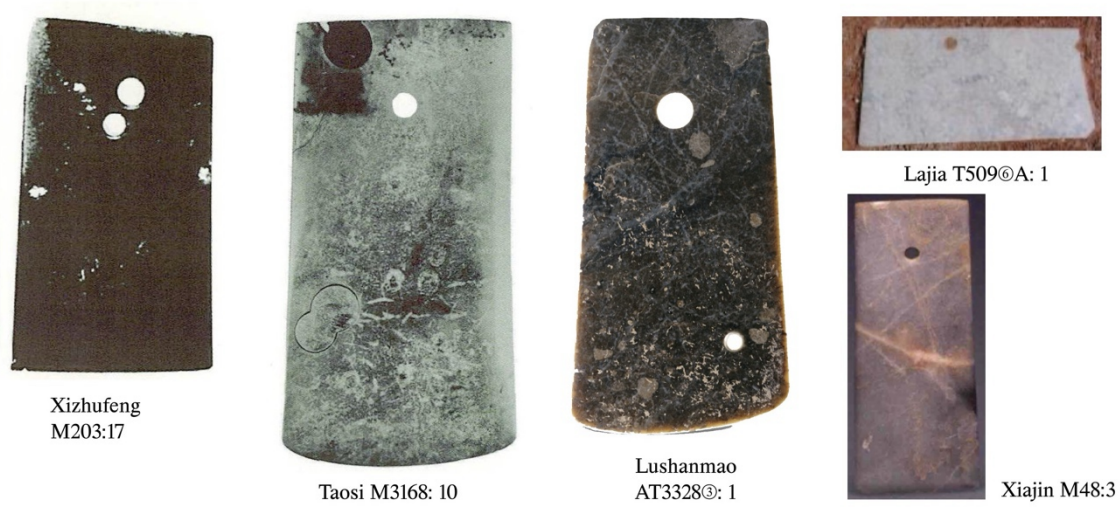


a. Zongri M322: 4 (Qinghaisheng and Hainan 2022: 63); b. Zongri M130: 5 (ibid 185); c. Xiajin M139: 3 (Shanxisheng and Shanxi 2022: pl.226: 2); d. Xiajin 136: 3 (ibid pl. 226: 1); e. Liangchengzhen M33 plan (Zhongmei lianhe kaogudui 2016: fig. 2-328); Liangchengzhen M33: 38 (ibid pl. 106: 1).

Figure 69. Mosaic turquoise ornaments found in other Longshan Era sites

4.3 Jade Axes and Knifes

During the Longshan Era, *yue* axes were generally thin, often less than 1 cm in thickness, with edges that tended to be straight. Most axes were shaped as elongated rectangles or trapezoids, typically with lengths twice their width, although examples with more balanced proportions occasionally appear. A single hole, usually drilled from one side, was placed near the shorter end of the axe for hafting. In some cases, axes featured two perforations aligned along the central axis of the blade. Across cultures such as Dawenkou, Shandong Longshan, Taosi, Shimao, and Qijia, the formal similarities of *yue* axes—particularly their thin profiles and straight edges—are notable despite regional variation (Figure 70).



a. Xizhufeng M203: 17 (Zhongguo *et al.* 2018: pl. 46: 1); b. Taosi M3168: 10 (Zhongguo and Shanxisheng 2015: pl. 41: 1); c. Lushanmao AT3328③: 1 (Shaanxisheng *et al.* 2019: fig. 45); d. Lajia T509⑥A: 1 (Zhongguo and Qinghaisheng 2004: fig. 5); e. Xiajin M48: 3 (Shanxisheng Kaogu Yanjiusuo and Shanxi bowuyuan 2022: pl. 210: 1).

Figure 70. A selection of *Yue* axes of the Longshan Era

However, while the form of jade axes remained similar across the Longshan world, the meanings and practices associated with them varied significantly between east and west, with Jinnan serving as a cultural crossroads where these traditions converged. In the Dawenkou and Shandong Longshan Cultures, *yue* axes likely served as personal weaponry and symbolized warrior identity, as suggested by their placement atop or near the deceased in burials. In contrast, within the Qijia and Shimao Cultures similar jade objects were often buried in ritual contexts, such as in the foundation of houses (e.g., Lushanmao), between the building stones of the city walls and gates (e.g., Shimao), or in a sacrificial pit (e.g., Xinhua K1), possibly associated with landscape worship (Shaanxisheng, Xibei daxue, and Yananshi 2019; Shaanxisheng and Yulinshi 2005; Sun, Shao, and Di 2020). At Taosi, both traditions coexisted: *yue* axes have been found in mortuary contexts placed on the body (Zhongguo and

Shanxisheng 2015), as well as buried beneath the road leading to the feature that is proposed to be an “observatory” by the excavators (He 2020).

The chronology of jade axes also differs regionally. They appear earlier in the east (prior to the Taosi cultural period) and later in the west (mainly during the horizon of Middle and Late Taosi Phases). This east-west division represents a general trend rather than a strict boundary, as evidence of jade burials in mountainous areas—likely associated with landscape rituals—also occured in Shandong (e.g., Dafanzhuang 大范庄 and Shangwanjiagou 上万家沟) (Luan 2020). What is important to recognize is that objects of similar form may carry different symbolic meanings. In other words, *yue* axes connect Taosi with western sites through shared ideas of landscape worship, while linking Taosi to eastern sites through the recognition of warrior identity.

4.4 Jade cylinders

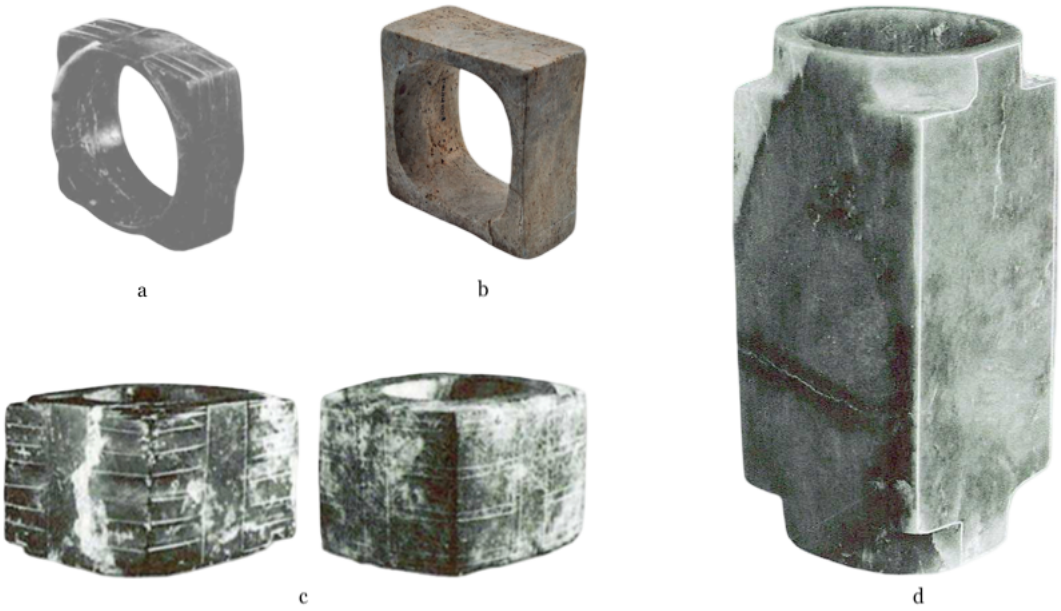
Cong cylinders, believed to facilitate communication between the earth and heaven, are among the most representative jade artifacts of the Liangzhu Culture (3300–2300 BCE). Central to this function is the depiction of sacred insignia that symbolized this connection. Toward the end of the Liangzhu period, however, these motifs became increasingly simplified and the craftsmanship declined. For example, on a *cong* cylinder from a Late Liangzhu burial (M40) in the Fuquanshan 福泉山 cemetery, Shanghai (Shanghai Shi 2000), the horizontal bridge between the deity’s eyes—representing a feathered headdress—is absent, a feature never omitted even in the most abstract earlier forms (Figure 71). This trend continued into the Longshan Era, where *cong* cylinders retained their basic form—a square exterior with a circular perforation—but often omitted or altered finer details.



(Shanghai Shi 2000: pl. 17)

Figure 71. *Cong* cylinder Fuquanshan M40:91

During the Late Dawenkou and Longshan Era, the form of *cong* cylinders varied regionally, becoming more simplified the farther they were from the Lower Yangzi region. In the area that used to be Liangzhu heartland, projecting collars became shorter or nearly absent, and shallow lines marked the horizontal sections and vertical divisions at the corners (Figure 72c). In Jinnan, *cong* cylinders retained narrow projecting collars at both ends, with fine lines along the corners imitating section divisions, while the convex body separated the corners from one another (Figure 72a). In the Ganqing region, *cong* cylinders preserved the central perforation, but the collars were formed simply by trimming the eight corners of the square prism, leaving the surfaces plain and without horizontal lines (Figure 72d).



a. Taosi M3168:7 (Zhongguo and Shanxisheng 2015: pl. 317); b. Stray find from Houliugou 后柳沟, Jingnin 静宁 (Gansu) (Qin 2022: fig. 4); c. Guangfulin (Guangfulin 2011: fig. 4); d. Taosi M3174:2 (Zhongguo 2022: 156).

Figure 72. Four variations of the *cong* cylinders discovered during the Late Dawenkou-Longshan period

These styles were not strictly bounded to specific regions but were transmitted across different regions; the Ganqing and Jinnan variations, for instance, intersected at Qingliangsi in southern Shanxi. The Potou 坡头 site is the settlement associated with the Qingliangsi cemetery. Qijia-style cylinders were found at the Potou settlement (Deng 2018) and the Jinnan-style cylinders in the cemetery (Shanxisheng *et al.* 2016). The transmission of *cong* cylinders was bidirectional, with Qijia-style cong moving eastward and simplified eastern styles spreading westward.

At Taosi, however, *cong* cylinders were only found in mortuary contexts and only used as body ornaments, whereas in the Qijia Culture they were buried in ritual contexts. Since Qijia-styled *cong* cylinders are absent at Taosi and none appear in ritual settings, this

suggests that Taosi did not participate in the transmission of Qijia *cong*. Therefore, in my analysis, *cong* cylinders at Taosi are considered links only when they serve as bangles rather than as ritual items.

4.5 Stone cleavers

The origin of stone cleavers remains uncertain. Although the Liangzhu Culture produced similar artifacts—referred to as stone plows rather than cleavers (Yang 1999), the significant spatial gap between the Liangzhu and Taosi cultures raises questions about whether Taosi directly adopted such objects from Liangzhu. Additionally, since most stone cleavers are dated to the Songze (4000–3300 BCE) and Liangzhu (3300–2300 BCE) cultural periods and are stray finds (Shanghai Shi 1985; Mou and Song 1981), it is difficult to establish their precise temporal relationship with the stone cleavers found at Taosi. Due to these uncertainties, I exclud Liangzhu stone cleavers (plows) from the reconstruction of Taosi's interaction network.

For finds with better chronological control, stone cleavers have been discovered at Lushanmao in Shaanxi and Qingshi 青石, Dingxiang 定襄 in Shanxi (Figure 73). Among these sites, Taosi has produced the largest and earliest assemblage of stone cleavers examples found on the Loess Plateau. This suggests that Taosi was likely the origin point for the transmission of stone cleavers in the region, and their presence at Lushanmao and Qingshi may reflect the spread of Taosi's elite culinary culture.



Left: Lushanmao AT3226④:1 (Shaanxisheng *et al.* 2019: fig. 38); Right: Qingshi H22:30 (Shanxisheng and Xinzhoushi 2012: pl. 7)

Figure 73. Stone cleavers

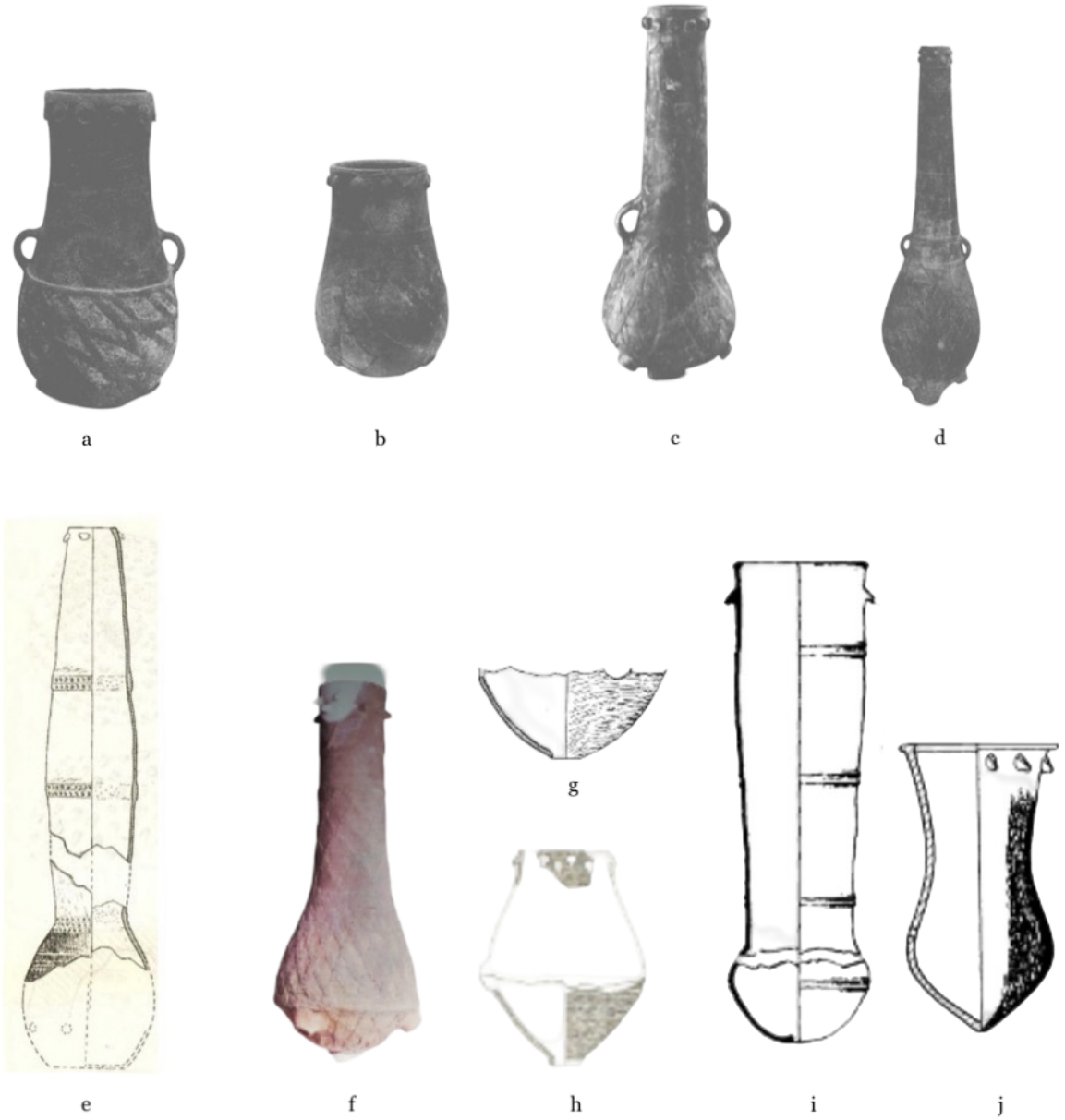
4.6 Alligator-skin drums

Alligator-skin drums have been extensively examined by scholars (Gao 2020; Z. Xu 2021), who have analyzed the spatial distribution of alligator osteoderm discoveries across northern China. Gao (2020) highlights that variations in the quantity and archaeological contexts of these remains suggest different uses of alligators, including meat consumption, placing alligator skins beneath the deceased, and crafting drums. He further argues that both the Taosi Culture and the Shandong Longshan Culture utilized alligators primarily for drum-making. These alligator-skin drums may therefore signify Taosi's connection with eastern communities.[15]

[15] While the Shimao site yielded one piece of alligator osteoderm, it was found in a secondary deposit within a house, offering little evidence for the presence of alligator skin drums at the site. Aside from Shimao, all other potential discoveries of alligator-skin drums come from either the Jinnan region or from sites associated with the Late Dawenkou and Shandong Longshan cultures. This distribution suggests that the use of alligator-skin drums represents an eastern tradition.

4.7 Pottery drums

In prehistoric China, various ceramic objects are believed to have functioned as pottery drums (e.g., Gao 1991; Fei 2009; Zhongguo and Shanxi Sheng 2015: 1342-1343). In this chapter, I focus on the type discovered at Taosi, which is characterized by elongated necks and rounded bodies. These drums feature perforations on the body to amplify sound and a single ring of small knobs attached to the neck (Figure 74). Based on formal similarities, it appears that Taosi artisans learned the shape of these pottery drums from the Yangshao Culture in eastern Henan. However, during the Yangshao period, such drums were not yet associated with elite consumption; it was only during the Taosi cultural period that these objects began to be linked with elite status.



a. Taosi M3072: 11; b. Taosi M3016: 33; c. Taosi M3002: 53; d. Taosi M3032: 1 (all images of Taosi pottery drums from Zhongguo and Shanxisheng 2015: pl 279, 280); e. Dugou T103H10: 2(Shanxisheng and Qingxuxian 2006: fig. 30: 7); f. Yugega stray finds (Shao 2020: fig. 3); g. Xuxizhuang T5③(Zhongguo 1988: fig. 50: 14); h. Mujiazui H23①: 9(Shanxisheng 2012: fig. 19: 2); i. Houzhuangwang M234: 1 (Henansheng 1988: fig. 20: 2); j. Dahecun W1: 1 (Zhengzhoushi 1979: fig. 36: 1)

Figure 74. Pottery drums

As these drums spread northward, they were no longer associated with elite contexts.

Similar pottery drums were found at sites such as Yuangeda 圆疙瘩 and Dugou 都沟, which

date slightly later than Early Taosi. This shift demonstrates that the status of so-called prestige goods can change as they move across regions: ordinary objects may be elevated to prestige status, while prestige goods can lose their elite associations over time and space.

4.8 Xiaojiawuji-style jades

Xiaojiawuji-style jades include anthropomorphic faces, diadems, deity faces, tigers, eagles, cicadas, and *huang*-arcs (Qin 2022). These jade objects were excavated from Tianmen 天门 Luojiabailing 罗家柏岭 (Hubeisheng and Zhongguo 1994), Zhongxiang Liuhe 钟祥六合 (Jingzhou and Zhongxiangxian 1987), Xiaojiawuji (Hubeisheng, Hubeisheng, and Beijing daxue 1999), Sunjijagang 孙家岗 (Hunansheng and Lixian 2018; Hunansheng and Lixian 2000; 2020), Zaolingang 枣林岗 (Hubeisheng 1999), and Tanjialing 谭家岭 (Hubeisheng, Beijing daxue, and Tianmenshi 2017).

These jades, with their distinct iconography, were widespread and well-received across various Longshan cultures. In the Shandong Longshan Culture, similar openwork designs appear in the elite tomb M202 at Xizhufeng 西朱封 (Zhongguo, Shandongsheng, and Shandong 2018), and a *gui* tablet found at Liangchengzhen (a stray find) bears incised depictions of the sacred mask and headdress motifs. In Henan, sites such as Wadian 瓦店 and Pingliangtai 平粮台 have also yielded similar examples (Zhang 2021). Further north, Shimao has produced small zoomorphic jades—including tiger heads and eagles—as well as headdress ornaments. The appearance of Xiaojiawuji-style jades at Taosi during the Middle Phase is yet another example of the broader Longshan elite exchange network and illustrates the active engagement by Taosi in this network.

At Taosi, only three types of these jades—crowns, cicadas, and *huang*-arcs—have been recovered (Figure 75a, b, c). However, I consider the transmission of all Xiaojiawuji-style jade types as evidence of a shared set of beliefs. As such, all Xiaojiawuji-style jades all together are treated as indicators of a jade-centered interaction network in which Taosi participated.



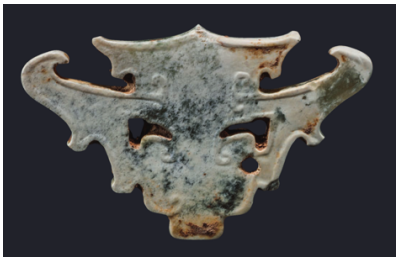
a. Taosi II M22: 135



b. Taosi II M22: 131



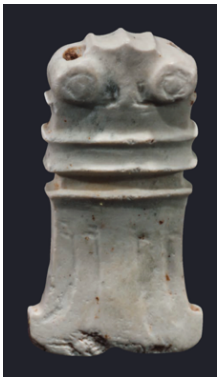
c. Taosi M1449: 5



d. Tanjialing W8: 11



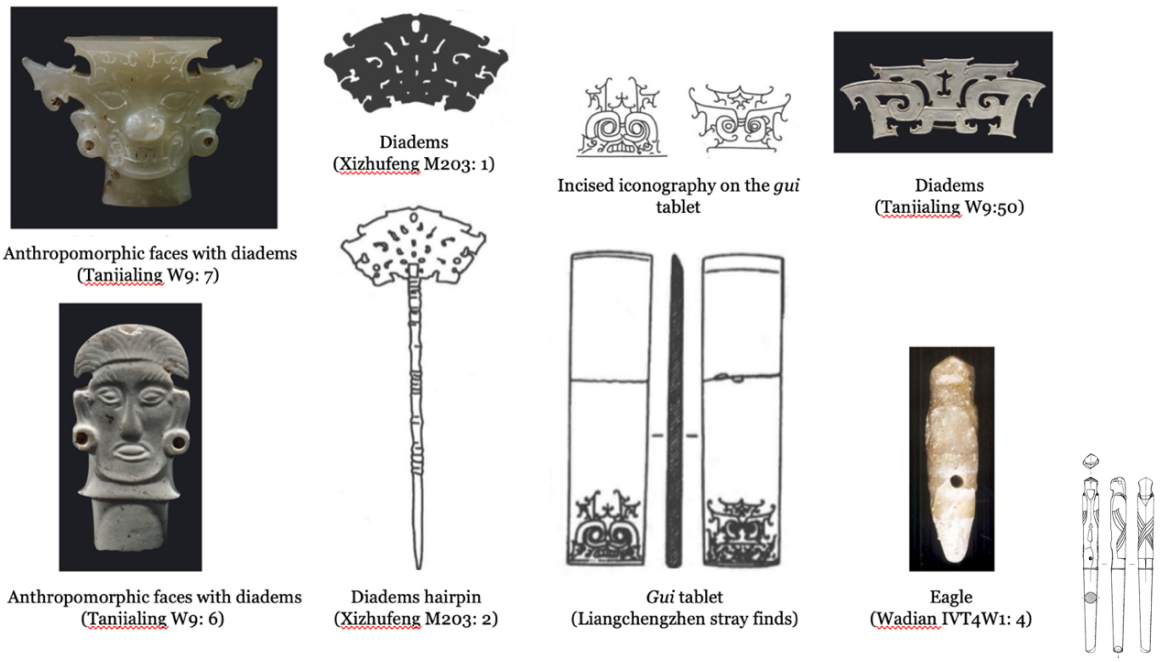
e. Tanjialing W8: 28



f. Tanjialing W9:12

a. Taosi IIM22: 135 (Zhongguo 2022: 159); b. Taosi IIM22: 131 (Zhongguo 2022: 158); c. Taosi M1449: 5 (Zhongguo and Shanxisheng 2015: fig.4-197: 4); d. Tanjialing W8: 11 (Hubeisheng *et al.* 2019: 44); e. Tanjialing W8: 28 (Hubeisheng 2019: 140) f. Tanjialing W9: 12 (Hubeisheng *et al.* 2019: 70).

Figure 75. Xiaojiawuji-styled jade objects found in Taosi Culture and Xiaojiawuji Culture

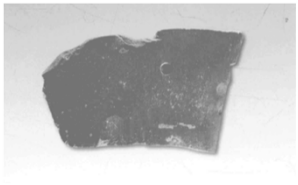


a. Tanjialing W9: 7 (Hubeisheng *et al.* 2019: 1); b. Tanjialing W9: 6 (Hubeisheng *et al.* 2019: 10); c. Xizhufeng M202: 1, 2 (Yang *et al.* 2015: fig. 7: 17); d. Liangchengzhen stray finds (Yang *et al.* 2015: fig. 4: 9); e. Tanjialing W9: 50 (Hubeisheng *et al.* 2019: 122); f. Wadian IVT4W1: 4 (Henansheng 2003: pl. 8: 2); g. Xiaojiawuji 012 (Hubeisheng *et al.* 1999: fig. 260: 1).

Figure 76. Xiaojiawuji-style jades transmitted in the Longshan world

4.9 Chimestones

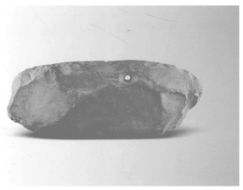
Chimestones, as argued in the previous chapter, were likely a Taosi invention. As such, their presence at other sites—including Wutai Yangbai 五台阳白 (Shanxi Daxue, Xinzhou, and Wutaixian 1997: 54), Yulin Lijiamiao 榆林李家庙 (Shao 2020), Yuzhou Yanzhai 禹州阎寨 (Kuang and Jiang 1984), and Ledu Liuwan 乐都柳湾 (Qinghai Sheng and Zhongguo 1984: 192)—may reflect the spread of Taosi music into other regions.



a. Taosi M3072: 10



b. Taosi M3002: 6



c. Taosi M3015: 17



d. Taosi M3016: 39



e. Lijiamiao stray finds



f. Yangbai H111: 1



g. Liuwan M1103: 35



h. Yanzhai T11M4

a. Taosi M3072: 10 (Zhongguo and Shanxisheng 2015: pl. 300: 2); b. Taosi M3002: 6 (Zhongguo 2022: 83); c. Taosi M3015: 17 (Zhongguo and Shanxisheng 2015: pl. 299); d. Taosi M3016: 39 (Zhongguo and Shanxisheng 2015: pl. 300: 1); e. Lijiamiao stray finds (Shao 2020: fig. 4); f. Yangbai H111: 1(Shanxi daxue *et al.* 1997: fig. 13: 6); g. Liuwan M1103: 35 (Qinghaisheng and Zhongguo 1984: fig. 141: 5); h. Yanzhai T11M4 (Liu 2023: fig.).

Figure 77. Chimestones of the Longshan Era

4.10 Copper-based metal objects

Bronze metallurgy was introduced into the Longshan world through the steppes and the Hexi Corridor and experience significant localization (e.g., Chen *et al.* 2022; Chen 2017). During the Longshan Era, the number of sites yielding bronze artifacts and evidence of copper smelting had increased. To date, bronzes have been discovered in the middle and lower reaches of the Yellow River, including in the provinces of Gansu, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong (Table 14). Most of these bronzes are relatively small in size and the craftsmanship is generally not highly developed. However, the discovery of bronzeworking remains across multiple locations indicates that bronze metallurgy had

already spread throughout the middle and lower Yellow River region during the Longshan Era.

Table 14 Discovery of copper-based metal objects during the Longshan Era

Sites	Reference
Shimao	Shaanxisheng, Yulinshi, and Shenmushi 2020
Bicun 碧村	Shanxisheng *et al.* 2022
Zhoujiazhuang	Zhongguo, Shanxisheng, and Yunchengshi 2011
Meishan 煤山	Zhongguo 1982
Wangchenggang 王城岗	Henansheng and Zhongguo 1983
Xinzhai 新砦	Beijing daxue and Zhengzhoushi 2008
Luantai 栾台	Henansheng 1989
Pingliangtai 平粮台	Henansheng and Zhoukou 1983
Yangjiaquan 杨家圈	Shandongsheng and Beijing daxue 1984
Dafanzhuan 大范庄	Shandongsheng 1999
Huangniangniangtai 皇娘娘台	Gansusheng 1978
Qinweijia 秦魏家	Zhongguo 1975
Dahezhuang 大何庄	Zhongguo 1974
Xinzhuangping 新庄坪	Gansu 1996
Qijiaping 齐家坪	Sun and Han 1997
Xichengyi 西城驿	Chen 2017
Changning 长宁	Qinghaisheng 2013

Bronzes discovered at Taosi including one bronze ring, one gear-shaped ring, one open work disk, a bronze bell, a frog-shaped bronze plaque, and a fragment of a bronze vessel. It remains unclear whether bronzes at Taosi were associated with status differentiation. However, they provide important evidence that even during the Late Taosi Phase, Taosi continued to engage in long-distance interaction with other regions. As such, I include them as a category for establishing links in the network to reflect the channels through which metallurgy techniques and bronze products were spread.

5. **The Longshan Geographical Social Network**

5.1 The Nature of the Constructed Network

Before diving into the visual examination of Taosi's geographical social network**,** some clarification is necessary. First, what is this network? It is a Taosi-centered complex interaction network. This complex network is the result of the overlay of many simple, non-centered networks and each of the simple network is linked by one category of objects discussed above. For example, in the network formed by the presence of jade *yue* axes, there is no central node; each site connects equally to othersThat said, because the links used to construct the network are derived from the inventory of prestige goods from Taosi, overlaying these non-centered individual networks naturally positions Taosi as the hub where all sub-networks converge. I designed the network in this way because, based on empirical observations from the archaeological record, Taosi functioned as an *axis mundus* during the Longshan Era (He 2013; Li 2018: 130). Thus, this design is not an artificial imposition but a faithful reflection of the real-world situation.

This raises the question: if Taosi is intentionally designed as the central node, is it still meaningful to evaluate network centrality? The answer is yes. While Taosi serves as the hub across all three phases of the Taosi Culture, its relative importance shifted over time, from being the sole center to becoming one among multiple centers. As multiple centers are established, the network redundancy increased, and the network grew more resilient. Thus, even though Taosi remains a central node by design, assessing properties such as connectivity, centralization, resilience, and fragmentation remains meaningful, since these

metrics capture how the structure of the broader network evolved and how the role of Taosi within it changed.

Another important question concerns the relationship between the Taosi interaction network and the broader Longshan interaction network. The former represents a subset of the latter and serves as a lens through which the properties of the wider system can be observed. This sampled network could be significantly expanded by incorporating additional indicators of interaction—for example, the transmission of *yazhang* toothed scepters, bone jaw harps, and stone-relief iconographies (which would allow Shimao-centered networks to be overlaid onto the Taosi-centered one), as well as the spread of li tripods, cowrie shells, and oracle bone divination practices (which would represent the broader Highland networks). In this sense, the network discussed in this chapter is not exhaustive but rather a manageable sample that helps illuminate the broader dynamics of the Longshan interaction network.

The last question concerns what was transmitted, exchanged, or communicated through the network. The Longshan interaction network was complex, and while the specifics remain unclear, several possibilities can be considered. One key aspect is the funerary customs that framed funerals as community-consolidating and status-affirming events. These customs, shared across the eastern part of the Early Taosi social network, involved the interment of painted pottery, jade *yue* axes, and alligator skin drums in elite burials, reinforcing elite identity across Taosi, Dawenkou, and Shandong Longshan Cultures. Additionally, burial customs, such as placing funerary offerings in niches, were shared between Taosi and Shimao. These burial customs were discussed in detail in Chapter 4, and for the purpose of

understanding the Longshan network, it is sufficient to state that this network served as a key channel for the transmission of funerary practices.

The Longshan network also facilitated the transmission of beliefs, as demonstrated by the widespread distribution of Xiaojiawuji-style jades. In their original context—the Xiaojiawuji Culture of eastern Hubei—these jades were found exclusively in adult urn burials, with the sole exception at Sunjiagang in the Liyang Plain (Hunan), where they appeared in shaft tombs. In other communities, such jades were likewise deposited primarily in mortuary contexts, though some were reduced to decorative elements, such as pendants for hairpins. This pattern suggests that their original symbolic meanings were at least partially preserved during transmission.

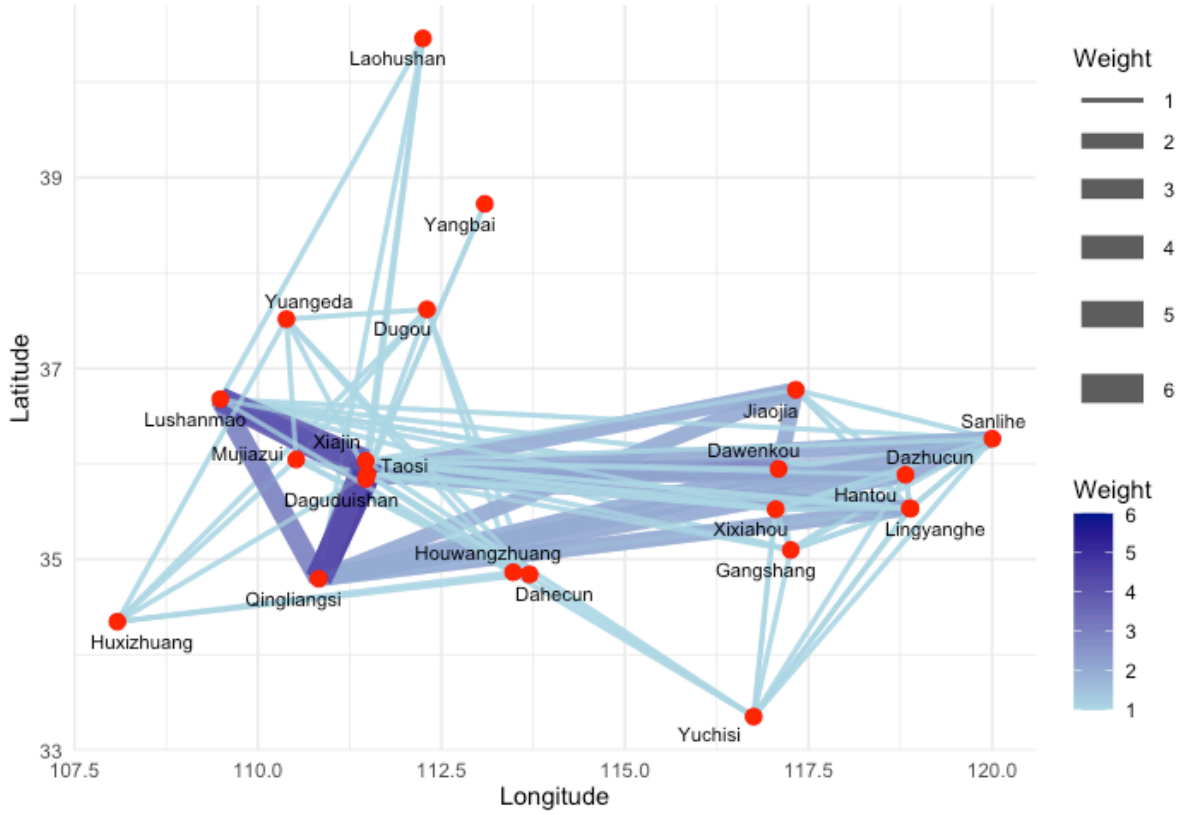
The network also enabled the spread of technology, most clearly seen in the dissemination of bronze objects. At Taosi, for example, bronze was used to imitate "pottery bells," indicating not only the acquisition of bronze artifacts but also the adoption of casting techniques, although no direct evidence of bronze production has yet been found on-site. Beyond bronzeworking, previous research also points to the transmission of wheat, cattle, and sheep, along with associated cultivation and breeding practices, through the Longshan interaction sphere (Li 2018; Zhang 2017).

In summary, the Longshan network should be viewed as a system transmitting customs, beliefs, and technologies. The network is not bounded by any given form of interaction—it may be travel by the elites, migration, trade, exchange, pilgrimage, or even marriage. Therefore, the Longshan network constructed in this chapter should be understood as a system for transmitting customs, beliefs, and technologies primarily associated with upper

elites. With the nature of this network clarified, I will now examine its centrality and the process of network fragmentation in the sections that follow. All figures and graphs are generated in R Studio using base R and the igraph package (Csárdi *et al.* 2025).

5.2 Geographical Shift of the Social Network

Figures 78-80 visualize the social networks of Early, Middle, and Late Taosi, respectively. The thickness and shade of the links reflect their weight—the darker and thicker the line, the stronger the connection. Over time, the geographical distribution of Taosi's social network undergoes visible shifts: it begins with a localized structure in the Early Phase, expands to broader regional connections in the Middle Phase, and concentrates northwestward in the Late Phase.



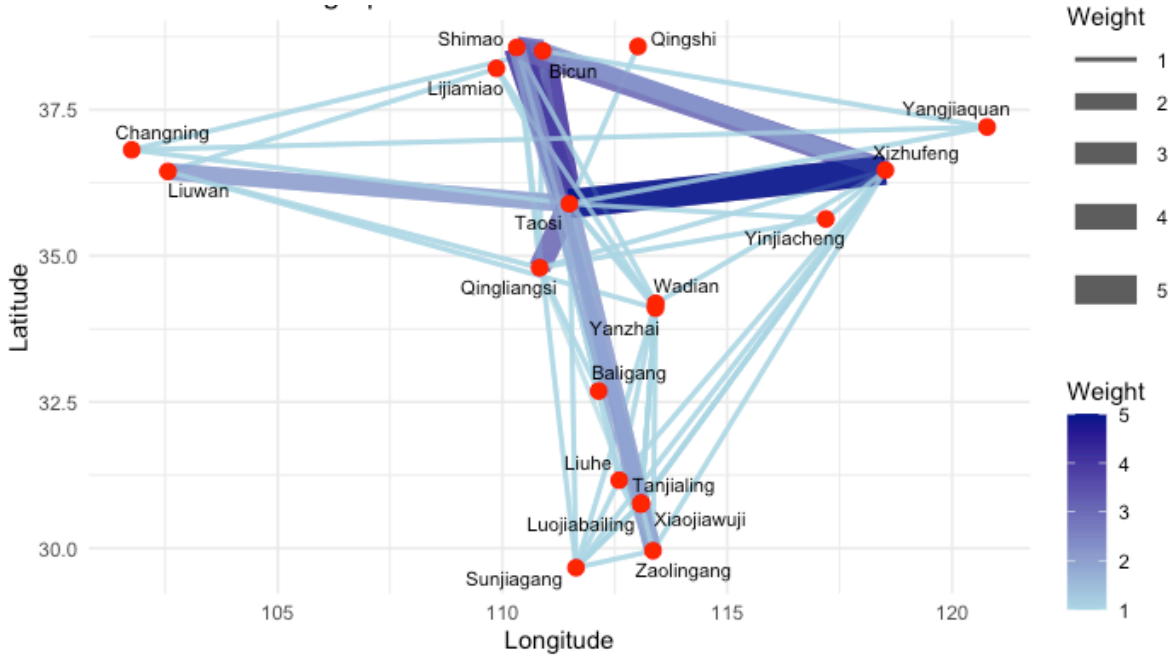
Plot by author

Figure 78. Early Taosi social network

During the Early Phase, the network remains densely clustered around the Central Plains, primarily within what is now southern Shanxi and western Shandong. Taosi holds a central position, closely connected to neighboring sites such as Qingliangsi, Xiajin, and Lushanmao—which form the strongest connections with Taosi. Sites associated with the Dawenkou Culture in Shandong exhibit the second-strongest connections. Nodes to the west of Taosi may connect indirectly to those in the east, but, for most of them, only by passing through Taosi. Overall, the network reflects a localized sphere of influence, forming a compact east-west corridor of interactions, with Taosi serving as the gatekeeper along this corridor.

As the network transitions into the Middle Phase, it expands significantly, reaching far beyond the Central Plains (Figure 79). Connections now extend northwestward to the Ganqing region and southward to sites such as Luojiabailing and Sunjiagang near the middle Yangtze River basin. While Taosi remains an important node, its centrality is now shared with northern hubs, including Shimao, Bicun, and Xizhufeng. Taosi forms its strongest connections with the Shimao Culture and Shandong Longshan Culture, while its ties with the Qijia Culture and Xiaojiawuji Culture are the second strongest. High-weight links are primarily concentrated in the area east of Ordos, with Shimao emerging as another key high-connectivity hub within Ordos. During the Middle Phase, nodes to the west of Taosi could communicate directly with nodes in the east, due to the rise Highland communities around this time. The Longshan Highlands formed an alternative west-east pathway that no longer depended on the corridor observed in the Early Taosi network. Overall, the Middle Taosi network is characterized by geographical expansion, with high-connectivity hubs distributed

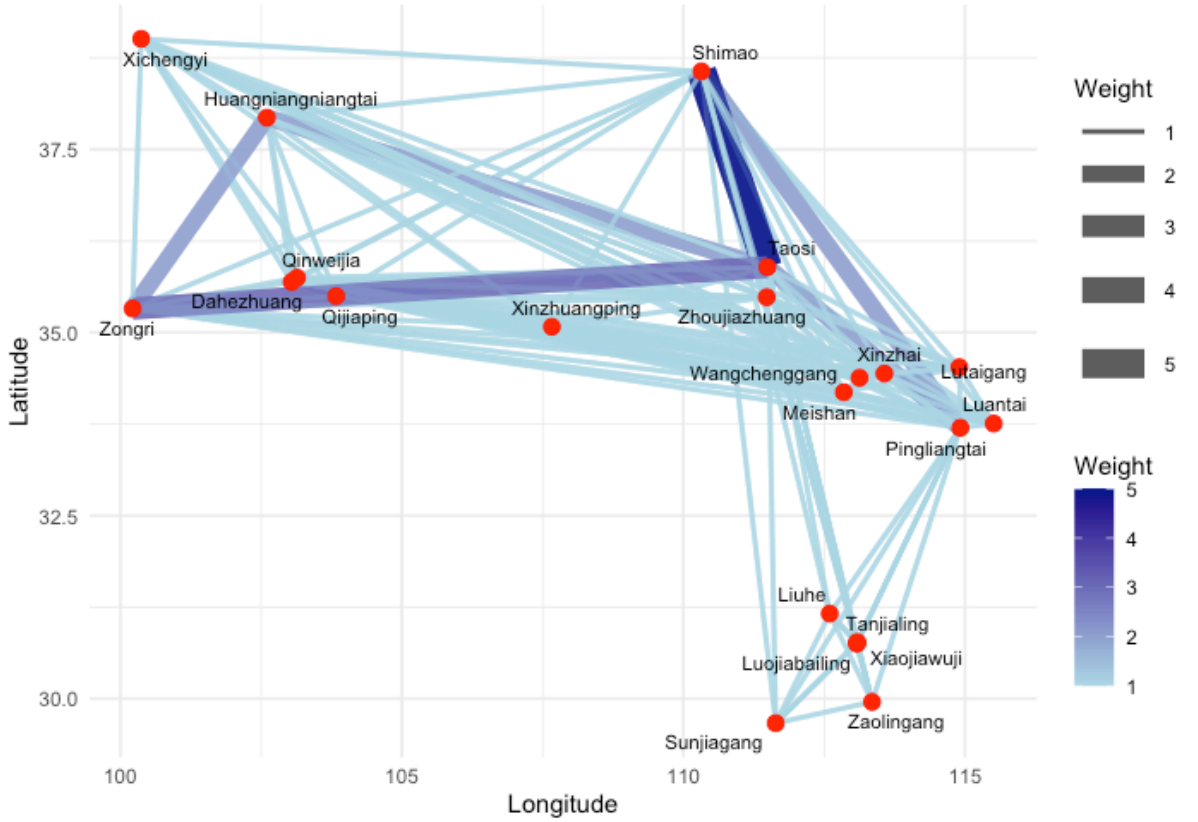
in a roughly balanced manner across the north, south, east, and west of Taosi, along with the emergence of new Highland east-west corridors.



Plot by author

Figure 79. Middle Taosi social network

In the Late Phase, the network contracts geographically but orients northwestward, shifting overall westward (Figure 80). Shimao remains a key hub, while nodes in eastern Henan, such as Pingliangtai, emerge as new centers of interaction. Although southern sites like Luojiabailing and Sunjiagang remain within the network, their connections weaken noticeably, indicating a decline in southern ties. This phase marks a clear shift in the political and economic center of gravity, consolidating power in the northwest and reducing the prominence of southern China.



Plot by author

Figure 80. Late Taosi social network

Throughout all three phases, Taosi consistently remained the most connected node in the network, yet its geographical position within that network shifted over time. In the Early Phase, Taosi was situated on the western margin, with most of its interactions oriented eastward. By the Middle Phase, Taosi occupied a more central position, maintaining relatively balanced connections with sites to both the east and the west. In the Late Phase, however, Taosi shifted to the eastern margin of the network, reflecting a westward reorientation of interaction, with most exchanges occurring west of Taosi.

Overall, the geographical distribution of the Taosi social network evolves from a compact, localized structure in the Early Phase to a widely dispersed, integrative, and balanced network in the Middle Phase, before contracting westwards in the Late Phase. These shifts likely reflect broader sociopolitical transformations during the Longshan period,

including the initial rise of Taosi as a regional center, the expansion of interregional interactions in the Middle Phase, and the eventual emergence of Shimao as a dominant power in the Highlands and the overall rise of the Highland communities. Meanwhile, western Henan in the Central Plains also emerged as a third center during the Late Taosi Phase, a precursor of the rise of the Central Plains in the Erlitou period.

5.3 Measuring Centrality

The degree centrality of Taosi within the network changes over time (Figure 81). During the Early Taosi phase, Taosi was highly central and the secondary central node—Xiajin—also belonged to the Taosi Culture, altogether indicating a high level of centralization. In the Middle Phase, Taosi remains central, now connecting robustly with more distant nodes such as Shimao and Xizhufeng. While Shimao and Xizhufeng function as secondary hubs within the Middle Taosi network, their centrality remains lower than that of Taosi. In the Late Phase, however, Taosi continues to hold a central position but now shares this centrality more equally with Shimao and Pingliangtai.

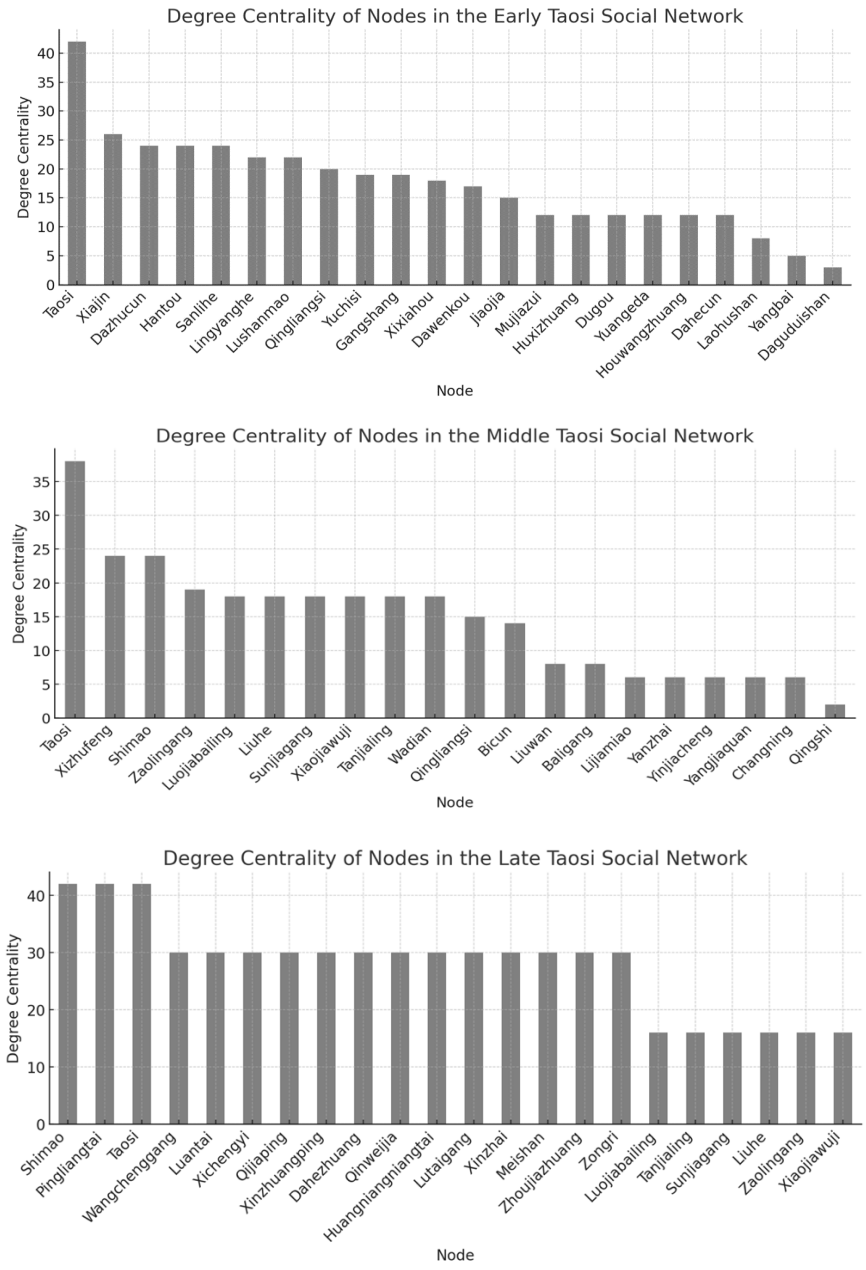


Figure 81. Degree centrality of the Taosi social network

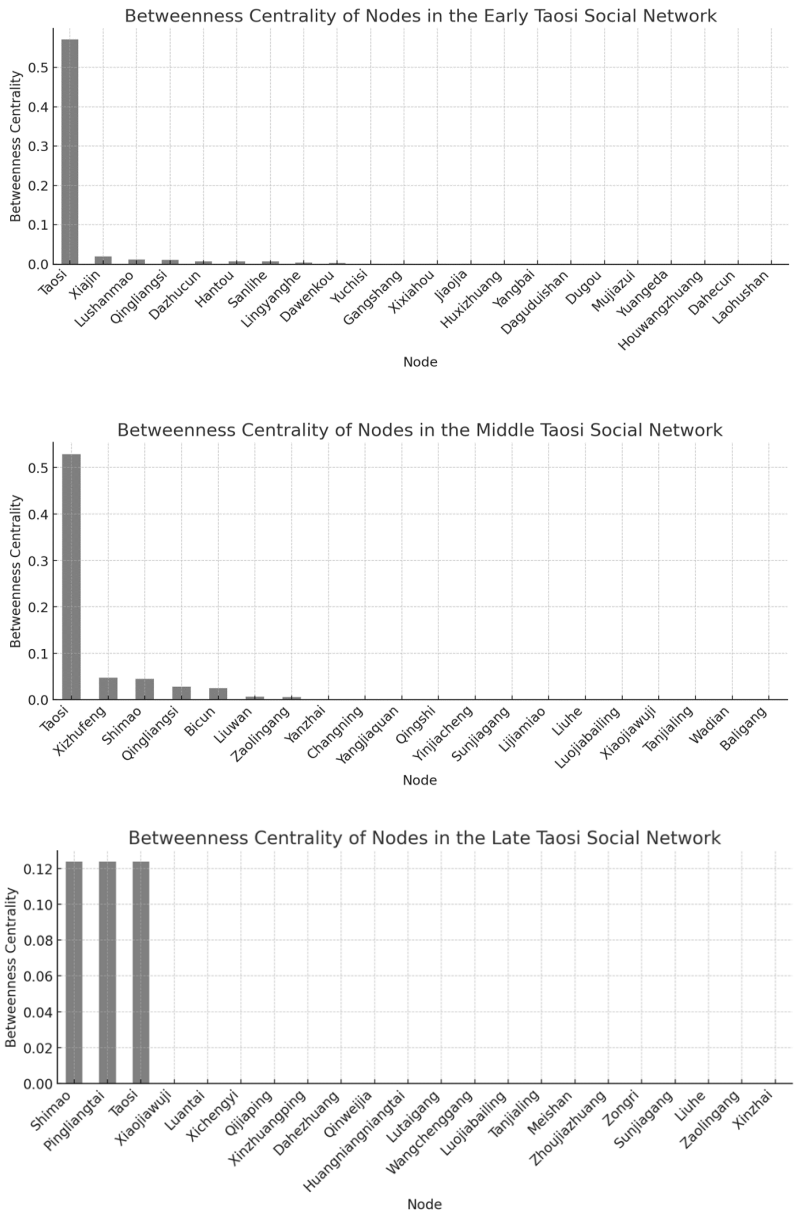


Figure 82. Betweenness centrality of the Taosi social network.

Turning to betweenness centrality, which measures how often a node lies on the shortest paths between other pairs of nodes; a node with zero betweenness does not lie on any of these shortest paths, meaning no information, resources, or interactions pass through it when considering the most efficient routes within the network. During the Early and Middle Phases, Taosi consistently exhibits the highest betweenness centrality as the central node

(Figure 82). However, several low-connectivity nodes also act as "middlemen", facilitating the flow of information, goods, and people.

In the Late Phase, this dynamic shifts; except for the three central nodes (Taosi, Shimao, and Pingliangtai), all other nodes exhibit zero betweenness. The rising average degree and closeness centrality (Figure 83) across all nodes suggest that this decline in average betweenness is not due to the fact that all connections must funnel through the three central hubs. Rather, it reflects that most connections could now be completed directly between nodes. Therefore, the decline in betweenness centrality indicates that, by the Late Phase, interactions became more direct, reducing the need for intermediaries within the network.

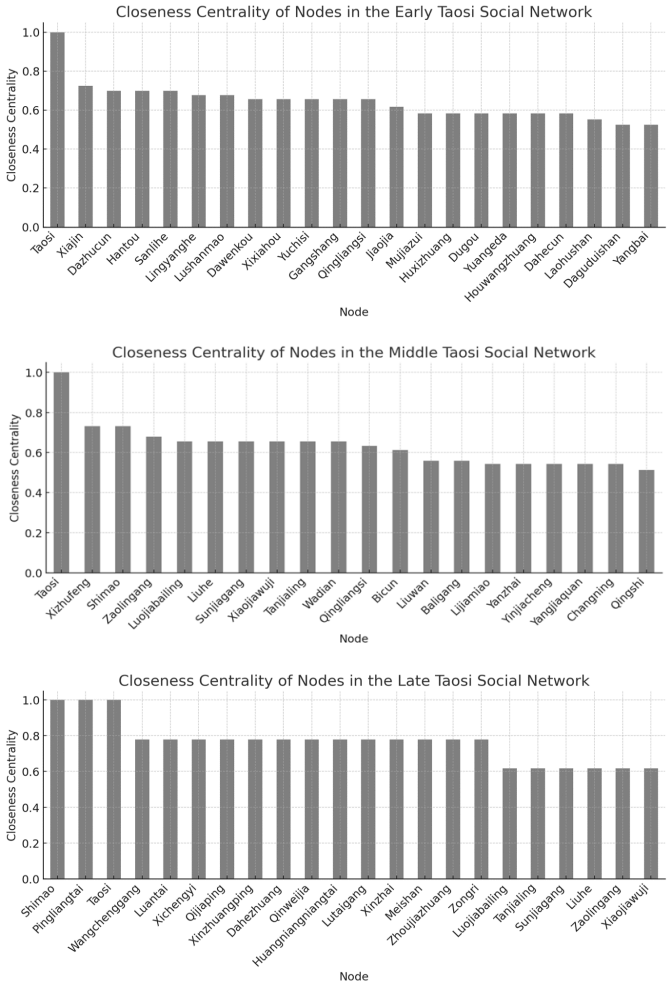
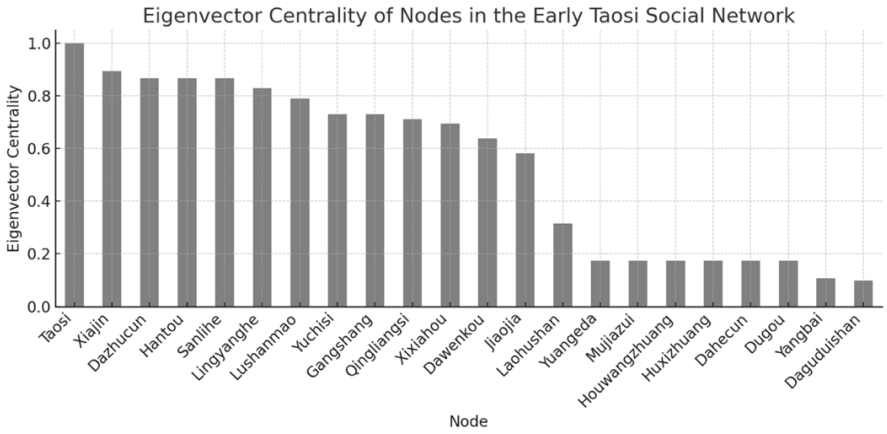
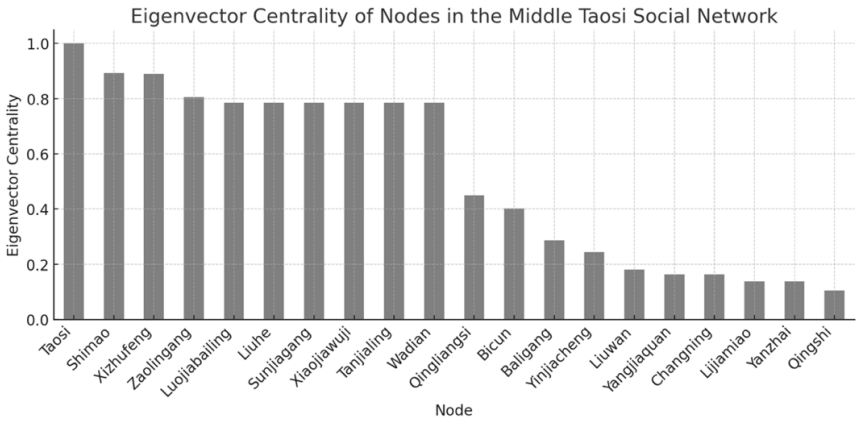


Figure 83. Closeness centrality of the Taosi social network

Examining eigenvector centrality, which measures how well-connected a node is to other highly central nodes, the average eigenvector centrality increases steadily across the three phases (Figure 84). This indicates that an increasing number of nodes became closely linked to central hubs, enhancing the overall connectivity of the network as well as the centrality of the hubs. Because eigenvector centrality recursively depends on the centrality of neighbors, once a node starts to become central, its influence can snowball. The increase over time may reflect cumulative advantage processes—like powerful actors reinforcing each other's status through repeated interactions. In archaeological terms, this means, the hubs such as Taosi, Shimao, and Pingliangtai, with rising eigenvector centrality may be becoming the prestige center, attracting long-distance ties, increasing ritual significance, or bringing in economic flows.





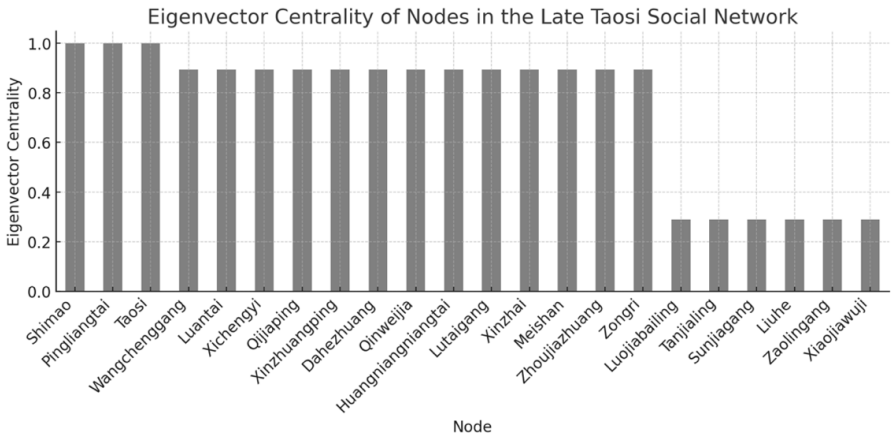


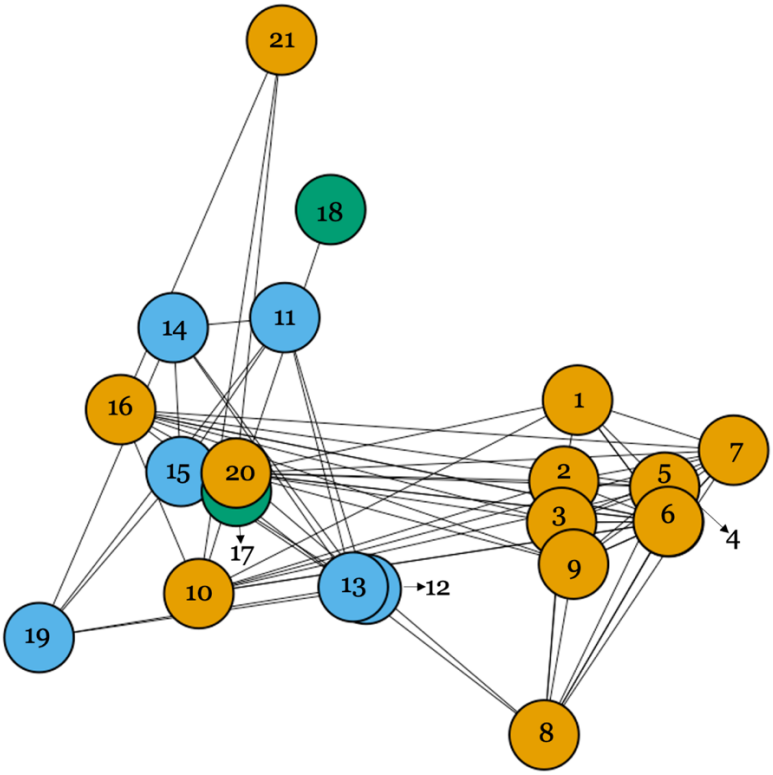
Figure 84. Eigenvector centrality of the Taosi social network

The various measures of centrality discussed above reveal three trends. First, overall centralization steadily increased across the three phases of the Longshan Era. Second, the hubs grew in importance, playing an increasingly critical role in forming, expanding, and strengthening the network. Third, however, this did not mean that hubs monopolized connections—some peripheral sites could still link directly without passing through them. In sum, the Longshan era produced a highly connected and centralized, yet still balanced, network. With this foundation, I now turn to a more dynamic perspective to examine how the collapse of central sites might reshape patterns of interaction.

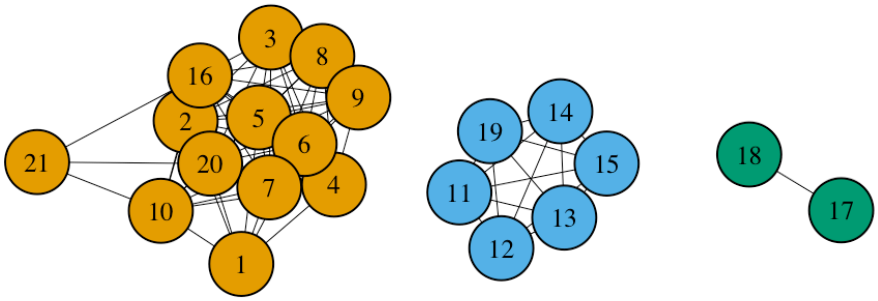
5.4 Evaluating the fragmentation of the networks

Early Taosi

To evaluate the impact of Taosi within its interaction network, I simulate a subgroup network by removing Taosi. In Figure 85a, nodes of different colors (blue, yellow, and green) represent distinct subgroups, each disconnected from the others. These three separate clusters geographically overlap with one another, indicating that the fragmentation of the network results not from geographical barriers, but from a relational breakage.



a. Remaining subsets (geographical location incorporated)



b. Remaining subsets (without geographical location)

1. Jiaojia; 2. Dawenkou; 3. Xixiahou; 4. Lingyanghe; 5. Dazhucun; 6. Hangtou; 7. Sanlihe; 8. Yuchisi; 9. Gangshang; 10. Qingliangsi; 11. Dugou; 12. Houzhuangwang; 13. Dahecun; 14. Yuangeda; 15. Mujiazui; 16. Lushanmao; 17. Daguduishan; 18. Yangbai; 19. Xuxizhuang; 20. Xiajin; 21. Laohushan.

Figure 85. Remaining subsets of the Early Taosi social network if Taosi is removed

This visualization offers a compelling view of the structural role played by Taosi within the Early Taosi social network by illustrating how the network fragments once Taosi is removed from its central position. After eliminating Taosi, the network splits into three distinct, disconnected clusters (Figure 85b), revealing its pivotal role as a bridge linking otherwise separate groups.

The blue group of Dahecun, Dugou, Mujiazui, Yuangeda, Houzhuangwang, remains connected internally but becomes entirely isolated from the other regions. The link is formed due the common discovery of pottery drums. This indicates that these sites' primary connection to the broader network was mediated through Taosi. Similarly, the green group of Yangbai and Daguodushan form a small, isolated component, suggesting that while they shared a direct tie with each other, their access to the broader network depended heavily on Taosi by the common discovery of stone chimes. In turn, this suggests that pottery drums and stone meat cleavers, while appearing as elite emblems at Taosi, were not part of the broader Longshan elite cultural package or a shared material lingua franca among elites. This is further supported by the fact that outside Taosi, such objects are not found in contexts associated with high status. The special connection between these items and elite identity at Taosi was perhaps not widely accepted by contemporary peers.

In contrast, the yellow group shows a larger cluster of sites, including Lushanmao, Laohushan, Xiajin, Qingliangsi, Dawenkou, Sanlihe, and Jiaojia, etc. This group retains internal cohesion, which suggests a densely connected sub-network that could sustain itself independently, though these sites had likely relied on Taosi to maintain external connections with other regions. This subgroup is linked by painted pottery, ritual jades, and turquoise. Its close internal connectivity suggests that these materials served as widely accepted markers of value and high-status association among Longshan elites.

Despite the uneven reception of different elements within the Taosi elite cultural package, the fragmentation of the network into these three disconnected components underscores the critical integrative role of Taosi. Its centrality was not limited to geography

or weighted degree alone but extended to maintaining the overall cohesion of the entire interaction sphere. The removal of Taosi severely disrupts interregional communication and connectivity, fracturing the network into smaller, localized groups. This result highlights Taosi as a keystone settlement or broker whose position enabled the flow of information, goods, or cultural practices between disparate regions.

I now move to remove all nodes one by one in order of their weighted degree centrality and to observe how this may affect the level of fragmentation of the network. Fragmentation ranges from zero to one. A fragmentation level of zero means that the whole network is entirely connected, and a fragmentation level of one means that the network is entirely disintegrated and no nodes are connected with any other nodes.

In the Early Taosi social network, the fragmentation curve shows a distinct pattern. After the removal of Taosi, the fragmentation immediately rises to 0.55. Compared to the Middle and Late networks (discussed below), this is a significant rise. Then, during the gradual increase phase when the second to the tenth nodes are removed, fragmentation rises steadily from approximately 0.55 to about 0.7. This phase reflects the gradual weakening of the network as the highest-degree nodes are removed early on. Despite this, the network managed to retain a certain level of cohesion, demonstrating moderate resilience to these initial removals.

Following this, the network enters a phase that could be characterized by a plateau and even a slight dip in fragmentation, occurring roughly between the removal of the 11th and 14th nodes (Yuchisi, Gangshang, and Xixiahou). This temporary stabilization suggests that although these nodes may have high degree centrality, they do not serve as key bridges

between clusters. Their removal did not immediately lead to further fragmentation; instead, remaining components reorganized into tighter sub-clusters, allowing the network to maintain a degree of integrity despite the ongoing node removals.

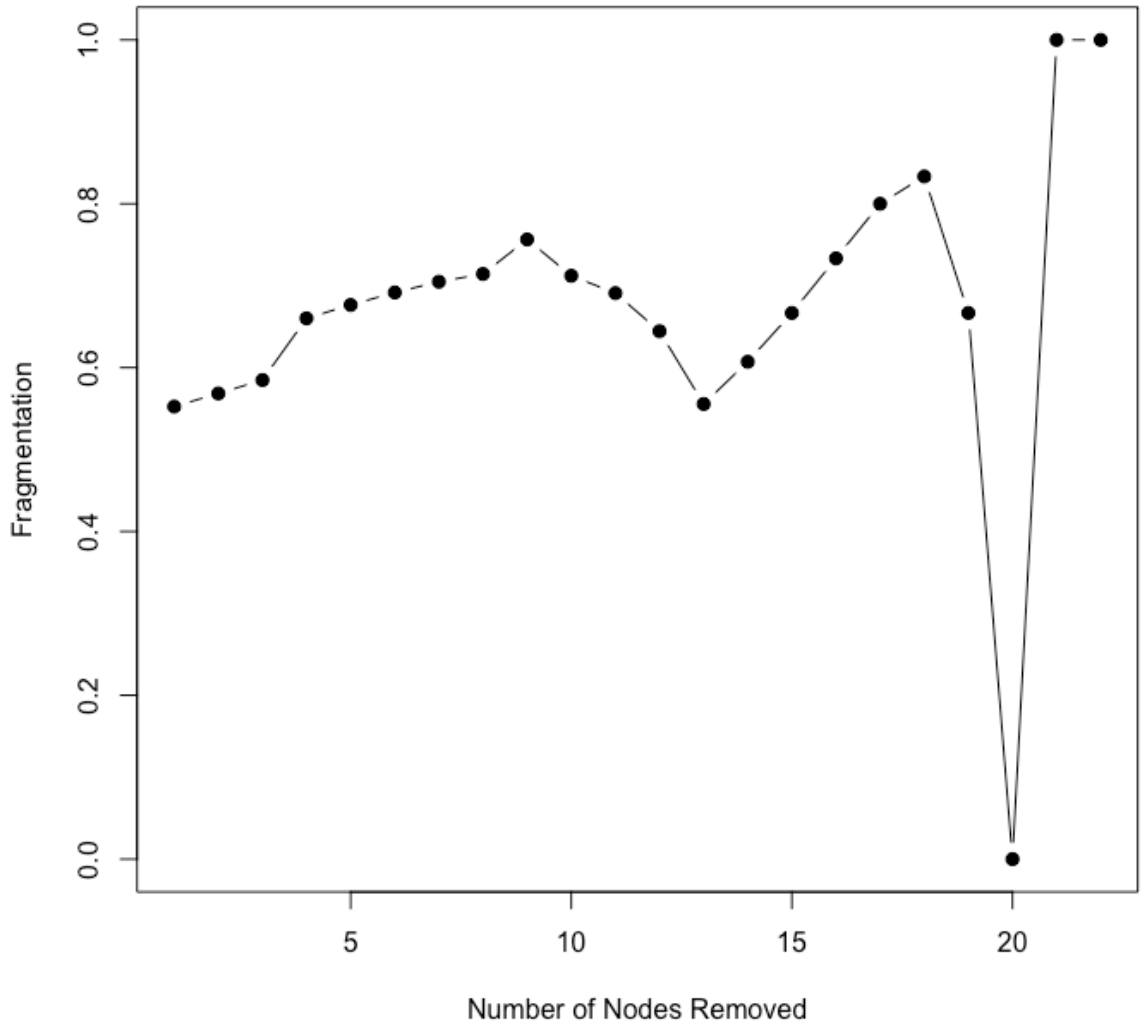


Figure 86. Fragmentation curve of the Early Taosi social network

Table 15. The sequence in which nodes are removed

Rank	**Node**	**Weighted Degree Centrality**
1	Taosi	78
2	Qingliangsi	48
3	Xiajin	48
4	Lushanmao	38

5	Dazhucun	32
6	Sanlihe	31
7	Dawenkou	28
8	Hangtou	28
9	Lingyanghe	22
10	Jiaojia	21
11	Yuchisi	19
12	Gangshang	19
13	Xixiahou	18
14	Dugou	12
15	Dahecun	12
16	Houzhuangwang	12
17	Yuangeda	12
18	Mujiazui	12
19	Xuxizhuang	12
20	Laohushan	8
21	Yangbai	5
22	Daguduishan	3

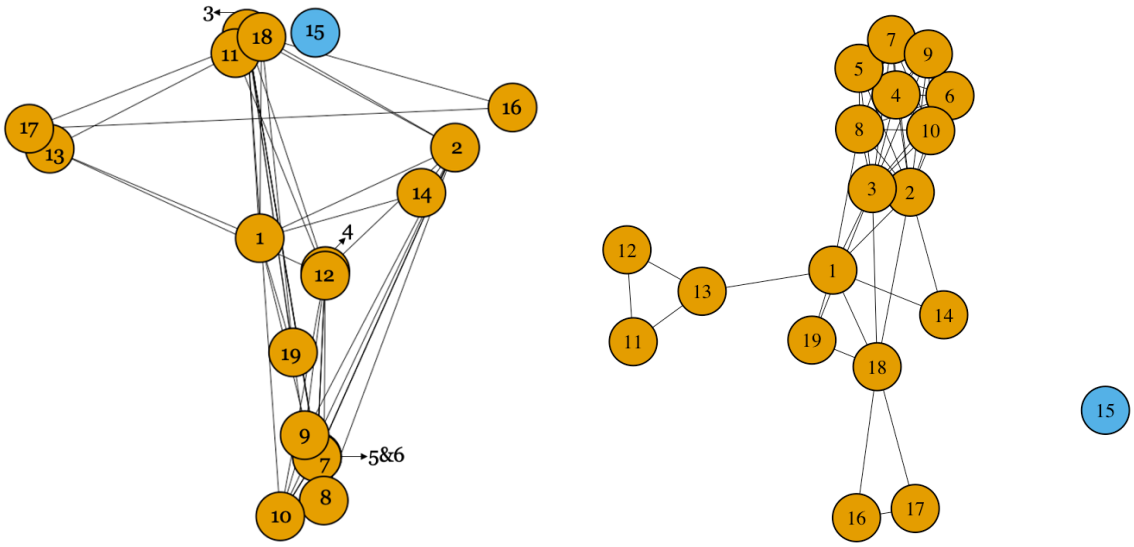
As the process enters the sharp-rise phase, the remaining subset of the network becomes simple in nature. The links consist primarily of musical instruments—pottery drums and chimestones. As noted earlier, during the Longshan era such objects were associated with elite contexts only at Taosi. Although similar forms were found at other sites, musical instruments were not widely established as part of the broader elite cultural package. Moreover, pottery drums and chimestones represent two distinct categories of links and do not coexist in the same site outside of Taosi. The steady increase in fragmentation between the 15th and 22nd node removals reflects this structural simplicity: each node is connected to others by a single element (either pottery drums or stone chimes) rather than by a complex package. Consequently, node removal produces an almost linear rise in fragmentation.

The sudden drop in fragmentation with the removal of the 20th node—falling close to zero—may appear unexpected, but it is explicable. In a subgroup defined by two distinct

categories of links, the complete removal of nodes associated with the first category leaves those of the second forming a fully connected sub-network. Although counterintuitive, at this late stage very few nodes remain, and these become directly connected. Thus, despite the near-total collapse of the overall network, the persistence of a single connected pair causes the fragmentation metric to drop to zero, reflecting the full connectivity of this minimal remnant.

Middle Taosi

The two figures below simulate the reorganization of the Middle Taosi social network after removing Taosi (Figure 87). The left figure has geographical coordinates incorporated and the right figure does not consider the geographical location of the nodes, but only their connectedness in the network. In both figures, the main network cluster remains largely intact despite Taosi's removal, which contrasts with the more severe fragmentation observed in the Early Taosi network. This persistence suggests that, by the Middle phase, the network had diversified its connectivity, reducing its dependence on Taosi as a sole central hub. This also means, an established package of prestige goods is being shared more widely. Several nodes, particularly Shimao, Xizhufeng, and Bicun, emerged as alternative centers, sharing similar ritual jades assemblage and iconography and maintaining the cohesion of the broader interaction network. These sites appear to function as secondary hubs, preventing the network from fully disintegrating. The density of connections among these nodes, especially in the central region of the network, indicates resilient inter-cluster ties, which helped sustain overall connectivity even when a major node like Taosi is removed.



a. geographical location incorporated b. without geographical location

1. Qingliangsi; 2. Xizhufeng; 3. Shimao; 4. Wadian; 5. Xiaojiawuji; 6. Luojiabailing; 7. Tanjialing; 8. Zaolingang; 9. Liuhe; 10. Sunjiagang; 11. Lijiamiao; 12. Yanzhai; 13. Liuwan; 14. Yinjiacheng; 15. Qingshi; 16. Yangjiaquan; 17. Changning; 18. Bicun; 19. Baligang.

Figure 87. Remaining clusters in the Middle Taosi social network after removing Taosi

However, the presence of Qingshi as an isolated node in both graphs highlights the vulnerability of peripheral sites. Qingshi was linked to Taosi through the shared presence of stone cleavers, and its isolation suggests that its primary connection to the broader network was mediated by Taosi. Once this link was removed, Qingshi became disconnected. This pattern reveals a subtle layer of network fragility, in which certain nodes depended on specific hubs for integration. Stone cleavers played a role similar to that of musical instruments: they were associated with elite status only at Taosi and did not form part of a stable assemblage elsewhere. This indicates, on the one hand, that Taosi's elite culture was not widely embraced by its Longshan peers, and on the other hand, that the collapse of Taosi could have caused the isolation of sites that had adopted Taosi's elite emblems.

As mentioned above, the geographical layout adds another dimension to the interpretation. The main cluster was geographically elongated, with northern, southern, and eastern extensions—reaching sites such as Changning, Yangjiaquan, and Liuwan. Despite their spatial spread, these geographically peripheral sites remained connected to the core network, suggesting that the maintenance of long-distance ties depends not on physical distance, but rather on the nature of the connection.

Overall, Figure 87 suggests that by the Middle phase, the Taosi social network had developed structural *redundancy*, allowing it to withstand the removal of Taosi without complete fragmentation. In network terms, redundancy refers to the extent to which a node's connections (or ties) overlap or duplicate one another, meaning they connect to the same nodes or serve similar functions within the network (Burt 2010). They provide the buffer to mediate risks. The emergence of other hubs like Shimao provided such redundancy. Yet, the isolation of nodes like Qingshi indicates that vulnerabilities persisted, particularly for sites on the periphery (in term of connectivity) of the network.

This fragmentation curve (Figure 88) provides insight into the structural resilience and vulnerabilities of the Middle Taosi social network and the role of specific sites as nodes are removed in the order of highest to lowest weighted degree. At the beginning, during the removal of the first three nodes (Taosi, Shimao, Xizhufeng), fragmentation remained quite low, hovering between approximately 0.1 and 0.15. This indicates that even though the nodes with the highest weighted degrees were being eliminated, the network exhibited initial robustness. This resilience reflects redundancy in the network's structure, where multiple pathways maintained overall connectivity despite the loss of these key nodes. In

archaeological terms, this means more competing power have emerged within the network and the prestige goods package used for SNA became increasingly widely shared.

That said, a sharp rise in fragmentation at when the removal of the fourth node—Bicun—the fragmentation value rises sharply from about 0.3 to over 0.7, the fragmentation reached a tipping point. It is not Bicun itself, but all four removed nodes collectively that caused this structural disturbance. Following this disruption, between the fifth and twelfth node removals, fragmentation continues to increase but at a more gradual pace, eventually leveling off between 0.8 and 0.9. During this period, while the network continued to degrade, redundant subclusters seem to persist internally.

Beyond the twelfth node removal, the curve plateaus at a high fragmentation level with only minor fluctuations. This suggests the network is now highly fragmented, consisting mainly of isolated clusters or small components, and that removing additional nodes causes limited further disruption to the overall network structure. The minor ups and downs reflect the removal of nodes that may slightly reshape the small remaining clusters without significantly affecting the overall level of fragmentation.

Toward the end, as the sixteenth to twentieth nodes are removed, fragmentation remains consistently high but briefly dips, likely due to the elimination of residual nodes within already fragmented sections of the network. The final sharp rise back to near-total fragmentation.

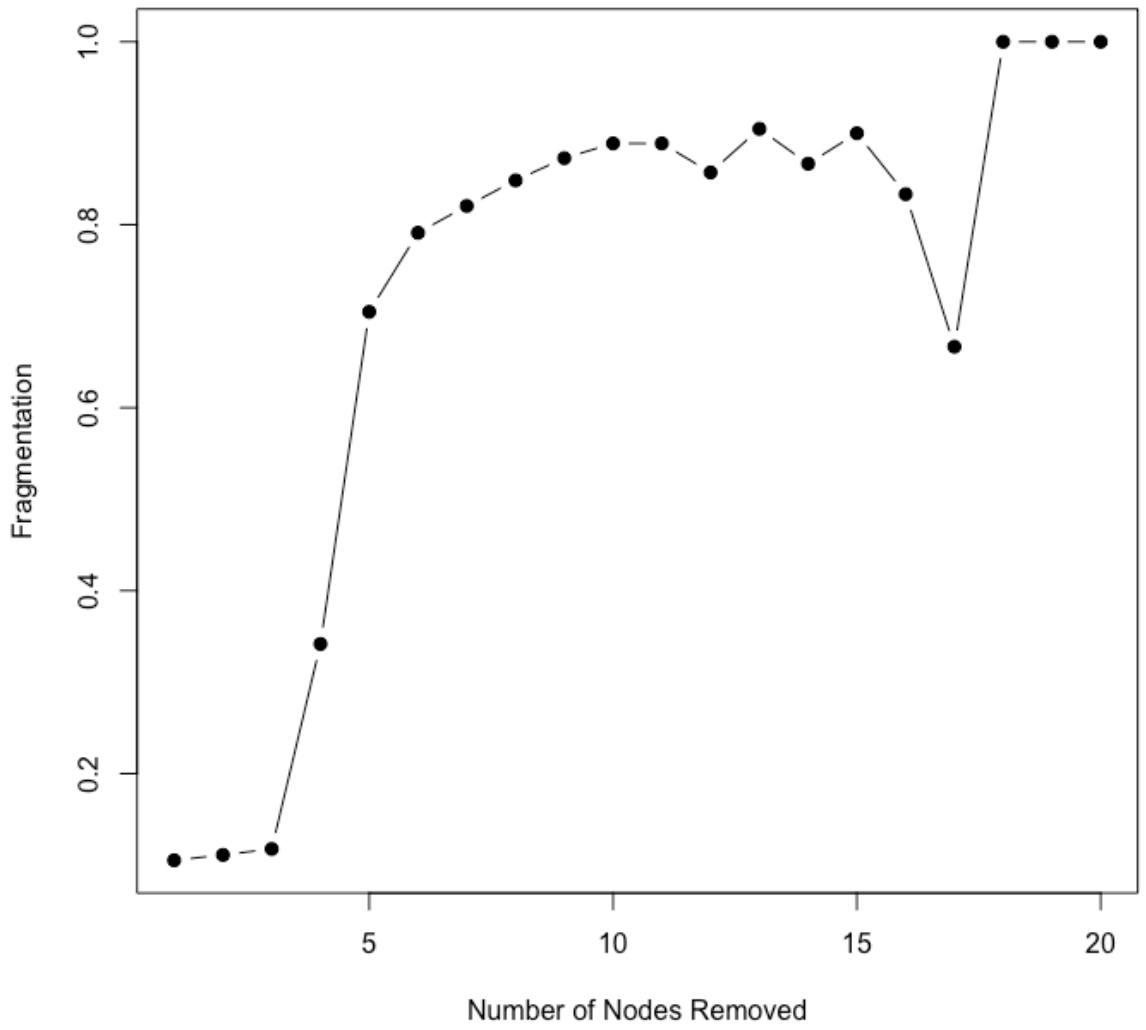


Figure 88. Fragmentation curve of the Middle Taosi social network

Table 16. Sequence removing nodes to create Middle Taosi fragmentation curve

Rank	**Node**	**Weighted_Degree_Centrality**
1	Taosi	66
2	Shimao	39
3	Xizhufeng	38
4	Bicun	26
5	Zaolingang	22
6	Qingliangsi	19
7	Wadian	18
8	Tanjialing	18
9	Xiaojiawuji	18
10	Luojiabailing	18
11	Liuhe	18
12	Sunjiagang	18
13	Liuwan	10

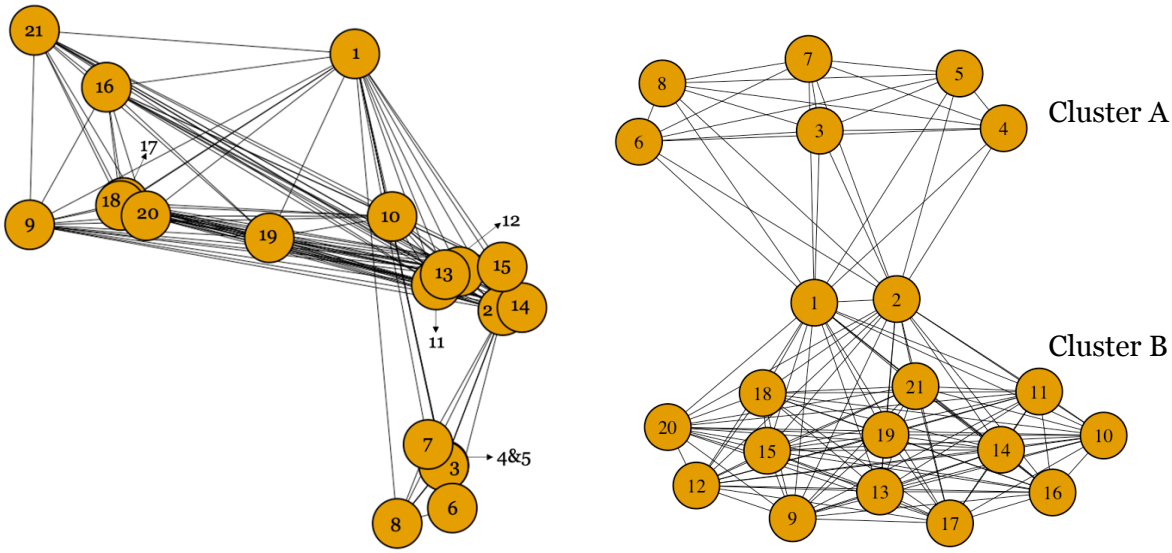
14	Baligang	8
15	Lijiamiao	6
16	Yanzhai	6
17	Yinjiacheng	6
18	Yangjiaquan	6
19	Changning	6
20	Qingshi	2

In summary, this curve shows that while the Middle Taosi network initially demonstrated resilience to the removal of high-degree nodes, certain key nodes—particularly those bridging major clusters, such as Shimao, Taosi, Xizhufeng, and Bicun—were critical for maintaining overall integrity. Once these nodes were removed, the network fragmented rapidly, highlighting its vulnerability to targeted disruptions, even though structural redundancy provided some temporary stability. Nevertheless, fragmentation levels remained relatively modest until the final few nodes were eliminated. Compared with the Early Taosi process, the Middle Phase network appears more resilient. The increase in network resilience persisted into the Late Phase.

Late Taosi

The following two figures in Figure 89 present the remaining clusters in the Late Taosi social network after the removal of Taosi. The Late Taosi network was grouped into two connected clusters and the nodes of Pingliangtai and Shimao served as the bridges linking these two remaining clusters. We shall call the cluster on above the bridges Cluster A and the one below the bridges Cluster B. When putting the geographical positions into perspective, it shows that the nodes in Cluster A are distributed in the north and those in Cluster B in the south. One of the bridges—Shimao—is not geographically located between the two clusters, while the other bridge—Pingliangtai—is geographically located between the two clusters.

This might suggest that Pingtliangtai assumed the bridge role partially due to its geographical position, but Shimao's obtaining the bridging position had little to do with its geographical convenience and it might be its political authority, cultural attractiveness, or religious importance that made Shimao a central connecting point in the network.



a. geographical coordinates incorporated b. without geographical coordinates

1. Shimao; 2. Pingliangtai; 3. Xiaojiawuji; 4. Luojiabailing; 5. Tanjialing; 6. Zaolingang; 7. Liuhe; 8. Sunjiagang; 9. Zongri; 10. Zhoujiazhuang; 11. Meishan; 12. Xinzhai; 13. Wangchenggang; 14. Luantai; 15. Lutaigang; 16. Huangniangniangtai; 17. Dahezhuang; 18. Qinweijia; 19. Xinzhuangping; 20. Qijiaping; 21. Xichengyi.

Figure 89. Remaining clusters in the Late Taosi social network after removing Taosi.

The Late Taosi fragmentation curve (Figure 95) reveals several distinct phases in its structural response to node removal. During the initial robustness phase, which includes the first and second removal steps (the removal of Taosi and Shimao), fragmentation remains at zero, indicating that the network remained fully connected. Even after the removal of the highest-degree nodes, overall connectivity was not disrupted at this stage. However, at the third removal step (Pingliangtai), the network experienced a sudden spike in fragmentation to approximately 0.45, indicating that Taosi, Shimao, and Pingliangtai collectively provided redundancy and resilience for the network.

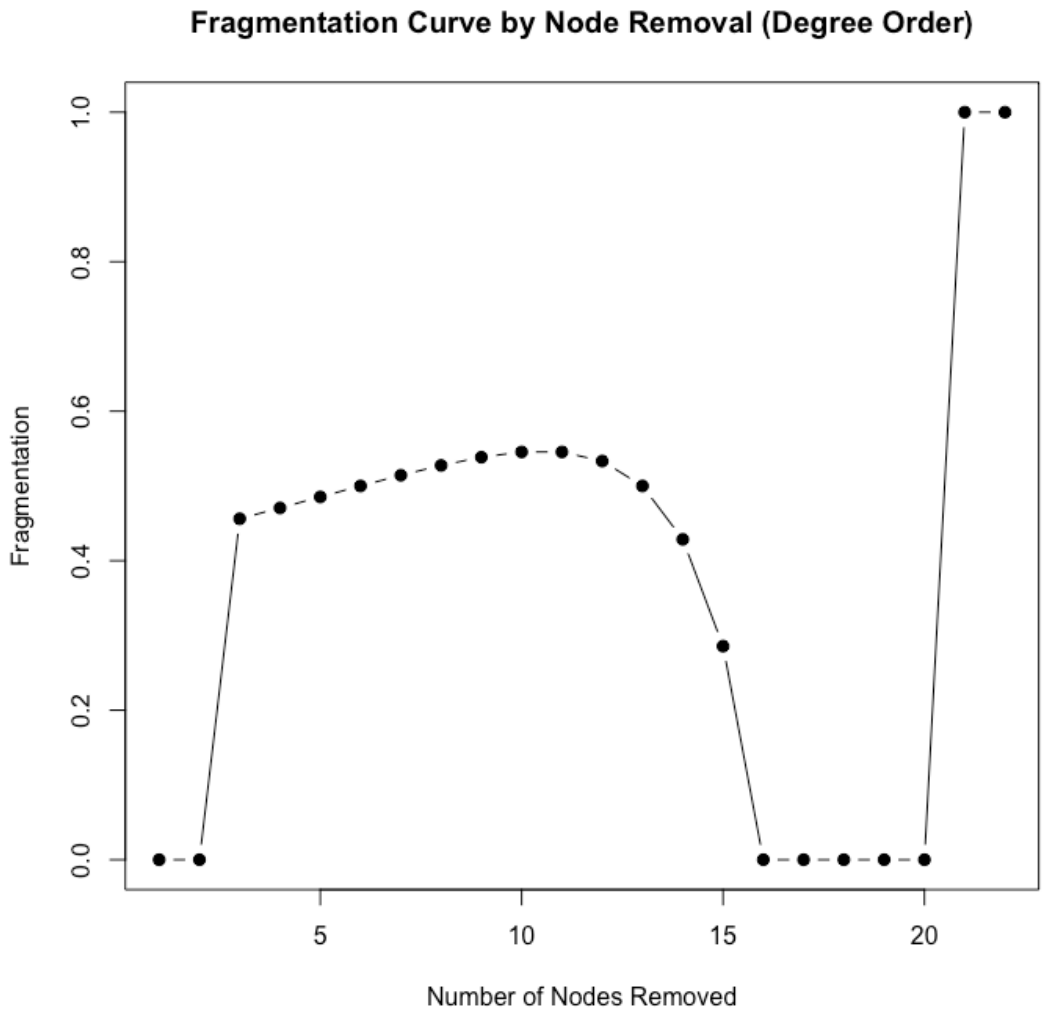


Figure 90. Fragmentation curve of the Late Taosi social network

Table 17. Sequence with nodes removed

Rank	**Node**	**Weighted_Degree_Centrality**
1	Taosi	58
2	Shimao	52
3	Pingliangtai	46
4	Zongri	36
5	Huangniangniangtai	34
6	Zhoujiazhuang	30
7	Meishan	30
8	Xinzhai	30
9	Wangchenggang	30

10	Luantai	30
11	Lutaigang	30
12	Qinweijia	30
13	Dahezhuang	30
14	Xinzhuangping	30
15	Qijiaping	30
16	Xichengyi	30
17	Tanjialing	16
18	Xiaojiawuji	16
19	Luojiabailing	16
20	Zaolingang	16
21	Liuhe	16
22	Sunjiagang	16

Following this disruption, the network entered a period of gradual increase and plateau between steps four and thirteen, where fragmentation slowly rises toward 0.55 before stabilizing. During this phase, the network broke into smaller components but retained some level of redundancy, preventing total collapse. From steps fourteen to seventeen, fragmentation declines to zero, indicating that the network had reduced to a small, fully connected cluster. The remaining nodes reconnected because these nodes—Tanjialing, Xiaojiawuji, Luojiabailing, Zaolingang, Liuhe, and Sunjiagang—were all connected through Xiaojiawuji-style jades. Finally, in the last phase of node removals, fragmentation spikes sharply to 1.0, signaling the total collapse of the network, where the remaining nodes became fully disconnected from one another.

It is important to note that in the Late Taosi network, Taosi, Shimao, and Pingliangtai mutually served as backup connection points for one another, significantly increasing the resilience of the network. This aligns with the fact that after the abandonment of Taosi around 1900 BCE, the Longshan network did not show clear signs of disruption until around 1800 BCE, when other major sites such as Shimao and Pingliangtai also declined. The

fragmentation curve thus offers an intriguing explanation for the time lag between the abandonment of Taosi and the wider disruption of the Longshan network.

5.5 Is the Taosi social network scale-free?

I now move to examine whether the Taosi network is scale-free. To reiterate, the scale-free properties reflect the level of centralization of a network.

Results

To evaluate whether the Early Taosi social network is scale-free (whether the distribution of degree fits the power-law), I use the following method. The power-law hypothesis was tested using the bootstrap goodness-of-fit test. In these tests: A p-value > 0.1 means the power-law is a plausible fit and a p-value < 0.1 would suggest the power-law is not a good fit.

The results show that the p-value of Early Taosi social network is 0.264, which is well above 0.1, meaning the power-law is a plausible model for your network's degree distribution. Therefore, the Early Taosi network has scale-free properties. This means that in this network a few hubs have many connections; most nodes have few connections.

With the same method, I tested the Middle and Late Taosi social networks, whose p-values are 0.002 and 0 respectively, which means that the Middle Taosi network is unlikely to have been scale-free and the Late network is definitely not scale-free. Overtime, the Taosi's interaction networks have evolved to be less and less centralized from the Early to the Late Phase.

Implications

Archaeological evidence from the Late Dawenkou Phase and the Late Miaodigou II Phase suggests that Taosi, along with its peers such as Dantu and Yaowangcheng, formed centralized networks within their respective regions (as argued in Chapter 3 based on settlement data). The social network analysis presented here allows us to move beyond the regional scale and examine the level of centralization on a transregional scale, spanning a landscape from Shandong in the east to Shanxi in the west, and from northern Shaanxi in the north to Anhui in the south. The results demonstrate that the Taosi network was transregionally centralized during the Early Phase. Combined with archaeological evidence, we can outline the following scenario.

Following steady growth in sociopolitical complexity during the Miaodigou II Era, Taosi rapidly emerged as both a proto-urban center and a regional hub. Elites at Taosi quickly leveraged long-distance exchange and possibly new administrative technologies to consolidate and expand their authority. This authority was reinforced both materially and institutionally, likely through the adoption of social consolidating institutions (such as elite-sponsored feasting) borrowed from their Dawenkou peers. This deliberate expansion of connections effectively kick-started a scale-free network, where unconnected sites would preferentially attach themselves to the most highly connected places, i.e., Taosi.

By the Middle Phase, however, Taosi's network remained highly integrated on a regional scale (for such argument based on settlement data, see Chapter 3), but it was no longer scale-free on the transregional level, indicating a shift toward decentralization. This observation is supported by both centrality measures and the fragmentation curve. Centrality data show

that multiple nodes, such as Shimao, Xizhufeng, and Pingliangtai, began to exhibit similar levels of centrality to Taosi during the Middle and Late Phases. The fragmentation curve further supports this, showing that fragmentation levels did not significantly increase until all major hubs were removed. This suggests that by the Middle Phase, the network had become more decentralized and resilient.

That said, the increasing decentralization does not imply that the Taosi network became less connected. On the contrary, as the following calculations suggest, it evolved into a small-world network—a structure characterized by high local clustering and short average path lengths. This configuration allowed nodes to remain tightly connected within clusters while still maintaining efficient connections across the entire network.

5.6 Did Taosi and its peers form a small world?

Results: Early Taosi

In R, a common method to determine whether a network exhibits small-world properties involves comparing the *clustering coefficient* and *average path length* of the observed network to those of a randomly generated network with the same number of nodes and edges. Using packages like *igraph*, the clustering coefficient measures how likely nodes are to form tightly knit groups, while the average path length indicates the typical distance between nodes across the network. The small-world coefficient (S) is then calculated by dividing the ratio of the real network's clustering coefficient to that of the random network by the ratio of their average path lengths. The formula is below:

$$S = \left(\frac{C_{\text{real}}}{C_{\text{random}}}\right) \div \left(\frac{L_{\text{real}}}{L_{\text{random}}}\right)$$

If S > 1, it suggests that the network has higher clustering than a random network but maintains similar path lengths, indicating the presence of small-world characteristics.

The clustering coefficient of the Early Taosi network has a value of 0.9050, which is more than double that of the random network at 0.4407. This indicates that the Early Taosi network has a much higher tendency for nodes to cluster together than a random network of the same size and density. High clustering is a key characteristic of small-world networks.

Next, I calculate the average path length. The Early Taosi network has an average path length of 1.5801, which is very close to the random network's path length of 1.5974. This suggests that despite the high clustering, the network maintains short global distances, similar to what's expected in a random network. This is the second hallmark of small-world networks.

Plugging in the numbers to the formula:

$$S = (\frac{0.9050}{0.4407}) \div (\frac{1.5801}{1.5974}) = 2.0762$$

Here, S = 2.0762. This suggests that the Early Taosi network exhibits clearer small-world properties.

Results: Middle Taosi

The same methods are applied to the Middle Taosi network. The clustering coefficient of the Middle Taosi network is approximately 0.858, which is significantly higher than the clustering coefficient of a comparable random network (0.404). At the same time, the average path length of the Middle Taosi network is 1.616, which is very close to that of the random network, measured at 1.653. This similarity implies that, despite its high clustering,

the Middle Taosi network maintained an efficient global structure where most nodes can reach each other through a small number of steps.

The Middle Taosi network yields an S value of approximately 2.17, which is well above the threshold of 1 typically used to identify small-world behavior. This value indicates that the network was not only highly clustered relative to a random graph but also retained short path lengths, allowing for efficient communication across the network.

Results: Late Taosi

The clustering coefficient of the Late Taosi network is 0.9494, which is considerably higher than the clustering coefficient of the random network (0.6641). For average path length, both the real network and the random network have the same value of 1.3377. This implies that, despite the high clustering in the Late Taosi network, information or interaction pathways remained just as short as they would be in a random network. The S value of the Late Taosi network turns out to be 1.441894, which is modest, indicating that the Late Taosi network does show small-world tendencies, but not strongly so. The clustering is higher than random, but the gain isn't as dramatic as in some classic small-world examples.

In sum, the Late Taosi social network likely exhibits weak small-world characteristics. The high clustering combined with short path lengths fits the small-world model, but the small-world coefficient suggests only a mild departure from randomness.

Implications

The changes of small-world coefficients across the Early, Middle, and Late Taosi networks reveals important insights into the changing structure of social relationships over

time. The Early Taosi network, with a small-world coefficient of 2.08, demonstrates strong small-world characteristics. The network retained both significant clustering and efficient pathways. This period likely represents a formative stage in the development of Taosi's sociopolitical landscape, where emerging elite groups were establishing ties across regions, gradually building the dense interconnections that would culminate in the Middle phase. The Early phase may reflect a period of political integration in progress, with social cohesion steadily increasing but not yet reaching its peak.

In the Middle Taosi phase, the small-world coefficient reaches its highest value of 2.17, suggesting that during this period the network exhibited the most optimal balance between high local clustering and short global path lengths. This configuration reflects a robustly interconnected social system, where tightly knit local communities remained embedded within a broader network of efficient long-distance connections. Such a network structure likely supported stable sociopolitical organization, facilitating the flow of information, resources, and influence across different regions within the Taosi sphere. This peak in network cohesion may correspond with the height of political centralization and effective control mechanisms that linked disparate social groups.

By the Late Taosi phase, the small-world coefficient declines to 1.44, indicating a weakening of the small-world structure that once characterized the network, but it was still a small-world network with high connectivity. Although the clustering coefficient remains relatively high, the global connectivity of the network appears to have diminished. This decline suggests that while local communities may have maintained internal cohesion, the broader connections between different groups became less efficient or began to fragment.

Such a pattern may reflect the onset of political decentralization on a transregional scale, the weakening of overarching authority structures, or the breakdown of interregional exchange and communication systems.

Taken together, the changing small-world-ness over time and the observation on the free-scale properties suggests that the interaction network that Taosi participated in remained interdependent and interconnected throughout the Longshan Era but became less and less centralized. The decline in small-world characteristics during the Late Phase may signal rising regional autonomy, which would explain the regional variety of the Longshan Transformation (for the description of regional variety, see Chapter 3).

6. **Comparing the Regional Settlement System and the Transregional Network**

Chapter 3 reconstructed the regional settlement system as a way to understand the regional political organization. By comparing the local political organization and the transregional network, I would argue for the most part—but especially for those sites that are well-excavated—regional centers also served as central hubs of the Longshan network. This is true for Shimao, Taosi, and Pingliangtai (for the function of Pingliangtai as the regional center, see Henansheng, Beijing daxue, Zhoukoushi, Huaiyangxian 2019).

That said, an interesting observation is that regional centers were not necessarily network hubs and network hubs are not necessarily the regional centers. For example, Tonglin, although the sole center in its region, shows no detectable connections to other sites currently included in the Longshan network. Conversely, some highly connected sites—such as Dazhucun and Xizhufeng in Haidai and Xiajin in Jinnan—are not identified as regional centers within their local settlement systems. I would argue that this discrepancy is largely

the result of biases created by the partial state of archaeological discovery. For instance, since the settlement associated with the Xiajin cemetery has not yet been identified, its role within the regional polity remains uncertain. Such partiality is an inherent limitation of network analyses based on archaeological materials and it is important to bare this in mind when evaluating networks of such type. Recognizing this limitation underscores the need to evaluate multiple categories of evidence when assessing social transformations, which is precisely why this dissertation integrates settlement, ceramic, and mortuary data to provide a more balanced perspective.

7. Collapse of network and its implication on the decline of individual sites in the network: revisiting Renfrew's theory of systems collapse

As discussed earlier, the Longshan networks, exemplified by the Taosi network, primarily served as channels for the transmission of technologies, beliefs, and customs; very little is known about the circulation of subsistence materials, such as grains and livestock.[16] Therefore, while we cannot completely rule out the possibility, it would be too speculative to suggest that the decline of hub sites directly interrupted the circulation of subsistence

[16] It is indeed that very little is known about the circulation of crops between proto-cities and its hinterlands but we might be able to suggest that sheep-keeping remained independent to the settlement of agropatoralists as the zooarchaeological evidence from multiple sites — including Xinzhai (Li Qian 2018), Taosi (Zhao et al. 2011), Zhoujiazhuang (the research by Brunson [2015: 62-64] indicates that no individual at age between 0-2 months died at Zhoujiazhuang. This is the age when death rate was very high and the lack of individuals at this age indicates the young individuals were raised elsewhere then imported to the site at older age. Same argument might apply to Zhaimaoliang), Zhaimaoliang (Owlett 2018) — indicates that the sheep at the site were imported from elsewhere.

resources. That being said, the disruption of the network may still have had a crucial impact on individual sites when viewed through the lens of systems collapse theory.

Renfrew (1984) outlined several key characteristics commonly observed during a system collapse, identifying them as: (1) the breakdown of centralized administrative structures; (2) the disappearance of the established elite class; (3) the collapse of a centralized economic system; and (4) shifts in settlement patterns accompanied by population decline. He suggested that the full process of collapse could unfold over the course of a century and emphasized that no single, clear-cut cause typically accounts for such an event. He further emphasized that "one of the first lessons which the discussion underlines is that the sudden collapse of an early state society is simply one of a number of possible rapid changes of state of relatively simple agrarian societies" (385-386).

In examining the Late Bronze Age collapse in the Mediterranean, Cline (2014) argued that individual disruptions—such as earthquakes, invasions, warfare, or agricultural crises—were likely insufficient on their own to bring down an entire civilization, l*et al*one multiple interconnected ones. Instead, he proposed that the cumulative effects of multiple stressors, what scholars have referred to as a "multiplier effect" (Liverani 1987; Drews 1995; Monroe 2009), amplified each other's impacts. A failure in one part of the system could trigger cascading failures elsewhere, creating a domino effect. Ultimately, this interconnected fragility led to the collapse of multiple societies, as the breakdown of long-distance trade networks and economic interdependence undermined the foundations of each civilization.

The network properties discussed in this chapter—high connectedness throughout the Longshan Era—made it possible for crises to spread from one site to another and from one

institution to another. Because the Longshan network was highly interconnected, perceptions of disturbance could travel rapidly across the network. In other words, the transformation witnessed at the end of the Longshan era occurred on an unprecedented scale precisely because the Longshan world was interconnected at an unprecedented level.

8. **Conclusion**

In this chapter, I reconstructed the social networks that Taosi participated in during its Early, Middle, and Late Phases, using the distribution of exotic prestige goods found at Taosi and other Longshan sites as indicators to direct or indirect interaction between sites. These reconstructed networks should be viewed as a sample representing the broader Longshan interaction network. Through these networks, we can both examine Taosi's role in interregional interactions and gain insights into the characteristics of the overall Longshan network.

By analyzing centrality measures, fragmentation curves, small-world properties, and scale-free features, I find that the Taosi network was highly centralized during the Early Phase but became increasingly decentralized through the Middle and Late Phases. At the same time, the interconnectedness of the network, although decreasing during the Late Phase, remained high. Taosi's relative importance in interregional interactions declined as other hubs, such as Shimao in the Middle Phase and both Shimao and Pingliangtai in the Late Phase, rose to prominence.

While previous research based on settlement and mortuary data has effectively demonstrated sociopolitical centralization and integration at the regional level, the application of network methods in this study reveals these dynamics on a transregional scale.

This approach allows us to view the Longshan world as a cohesive whole rather than as a series of disconnected archaeological cultures. The high degree of interconnectedness uncovered by the network analysis also provides a strong foundation for applying Renfrew's systems collapse theory to the Longshan Transformation. Given the level of integration observed, it is reasonable to interpret the Longshan world through a systems-theoretical perspective.

From this perspective, we should not expect to identify a single factor—or even a number of them—that caused the collapse of Longshan cultures. Instead, we must consider the amplifying effects generated by the network. This means that while many individual stressors may have contributed to the fragility and disruption of the Longshan world (e.g., Yoffee 2019), none alone would have been sufficient to explain why so many cultures, spread across such a broad landscape, declined or disappeared within roughly a century. However, when these factors were linked together by the interconnected system, they could have combined to produce catastrophic consequences. Although this interpretation cannot be conclusively proven, it is grounded in multiple lines of evidence and offers a fresh and plausible explanation for the collapse of the Longshan cultures and proto-state polities in the first quarter of the third millennium BCE.

In political science terms, the intensified interregional interactions of the Longshan world may be understood as a form of prehistoric "globalization." Although geographically limited and lacking the deep economic integration characteristic of modern systems—since economies at the time remained largely self-sufficient—it nonetheless offers a valuable lens for theoretical reflection. Political scientists have long recognized the "global-local dialectic"

of globalization, often describing it as fragmentation, a process of simultaneous integration and fragmentation (Rosenau 1997) or as "glocalization" (Robertson 1992: 173-174), in which "the universalisation of particularism and the particularisation of universalism" operate together (*ibid* 102). Cerny (1998: 41) further emphasized that globalization is constituted through the *interaction of differences*, that may challenge the existing form of governance and inter-polity relations and introduce *durable disorder*.

While the scope and nature of interaction in the Longshan world differ from globalization as defined by political scientists, the intensified and expanded encounters among diverse peoples, social institutions, and cultural traditions likely had comparable impacts on existing social orders. On the one hand, when communities faced similar challenges of consolidating power, social institutions could be borrowed and adapted in a Lamarckian fashion: effective strategies were retained and expanded, while ineffective ones were discarded. In this way, intensified interregional interaction—the very fabric of the Longshan network—likely accelerated both the growth of social complexity across regions and the simultaneous formation of localized identity markers. On the other hand, encounters also introduced heightened insecurity. Archaeological evidence suggests increased interpersonal violence: at Taosi, a sacrificial pit contained the skulls of young men and the body of a tortured woman (see Chapter 3), while at Shimao, the severed heads of young women were buried beneath the eastern city gate (Sun *et al.* 2018: 37-38). These examples do not imply that warfare or human sacrifice directly caused the collapse of the Longshan world. Rather, I suggest that violence functioned as a counteraction to perceived threats and insecurities. Over time, the accumulation of such insecurities—and the cyclical escalation of

action and counteraction—may have placed severe strain on the Longshan social order. Thus, when considering the driving forces behind the Longshan Transformation, the effects of this prehistoric form of "globalization" should be taken into consideration.

Conclusion

This dissertation reconceptualizes the Longshan Transformation by providing a comprehensive account of its pace, scale, processes, regional variations, and transregional connectedness. Rather than a singular, sudden collapse that marks the end of the prehistoric age, the Longshan Transformation is framed here as a medium-term conjuncture composed of a series of site-specific, short-term events within the broader, continuous, long-term trajectory toward state formation in the Early Bronze Age. Beginning around 2000 BCE, this transformation extended over two to three centuries, culminating in the rise of the Erlitou polity, which developed into the first state-level society in the Central Plains during Erlitou Phase II. While cultural change is often localized and unsynchronized, the Longshan Transformation stands out for its unusual breadth and relative simultaneity, warranting the sustained scholarly attention it has received.

1. Chapter Summary

The five principal chapters of this work collectively revise the current narrative of the Longshan Transformation. Given its multi-scalar nature, these revisions operate at different geographical scales. Chapters 1–3 adopt a transregional approach. Chapter 1 revises the previous oversimplified view of Longshan-era climate change and emphasizes that the north and southwest experienced increasing aridity while the south received greater precipitation, with climatic instability causing frequent floods in river valleys. These divergent conditions did not produce uniform cultural decline: aridification could foster sociopolitical development in the Highlands, while inundation posed severe challenges in the south, contributing to the collapse of Liangzhu and transformation of Late Shijiahe societies.

In addition to spatial differences, there is also a clear temporal gap in climate change. Stalagmite records reveal a “south-early, north-late” pattern of monsoon weakening, with southern societies collapsing earlier around 2300 BCE, while changes in the Yellow River valley occurred later, in the first quarter of the second millennium BCE. Climate shaped societies differently across regions, but the outcomes depended as much on human responses as on environmental stress.

Chapter 2 is closely related to Chapter 1. It turns to food security, a critical but often implicit assumption of the climate-driven collapse model. It tests whether the 4.2k event caused agricultural failure, dietary stress, and social breakdown. Drawing on osteological, zooarchaeological, and archaeobotanical evidence across Longshan sites, the analysis finds no consistent link between subsistence failure and sociopolitical decline. Either food insecurity was not a primary driver, or existing methods cannot detect it adequately. This challenges collapse models that reduce social change to agricultural stress, and instead calls for systematic, multi-proxy approaches to disentangle the interplay of environment, economy, and society.

Chapter 3 focuses on settlement data, long considered the strongest evidence for the Longshan “collapse.” While the previous narrative left an impression of sudden collapse, Chapter 3 demonstrated that this process was not sudden or uniform but unfolded in at least two waves of transformation, around 2000 BCE and 1800 BCE respectively. Each region followed its own trajectory: Liangchengzhen and Taosi experienced sharp decline, while Chengziya and the Hutuo River basin remained relatively stable or even flourished afterward. Settlement histories thus reveal the Longshan Transformation as a mosaic of

interconnected but regionally distinct processes, shaped by local vulnerabilities and responses.

Because of the regional variation in climate change and social change, and the inadequacy of pan-regional interpretations (as exemplified by the food insecurity hypothesis), a broad descriptive or interpretive framework is insufficient for fully understanding the Longshan Transformation. Therefore, the second part of the dissertation adopts a site-specific perspective. Chapters 4 and 5 focus on the Taosi site, which most representatively showcases the Longshan collapse.

Chapter 4 examines pottery and mortuary practices to reconstruct Taosi's cultural and social trajectory. Early Taosi painted pottery reflects Lowland traditions and the changes in the pottery assemblage emphasizes culinary elaboration, while Middle and Late Taosi assemblages show increasing "Highland-ization," signaling intensified cultural sharing across communities.

Mortuary practices likewise evolved. While the previous narrative emphasized the disappearance of the lavish burial customs, this chapter demonstrated a shift in power negotiation strategies. In the Early and Middle phases, elite status was displayed through lavish feasting paraphernalia and long-distance connections, epitomized by tombs like IIM22. By the Late phase, such displays vanished: funerary focus shifted from the wealth of the deceased to ritual ceremonies where the living negotiated power. These shifts reflect a reconfiguration—not disappearance—of sociopolitical power, weakening Taosi's integrative role and contributing to its eventual abandonment.

After reconstructing the transformation on a site-specific level, Chapter 5 returns to a transregional level. While Chapters 1 to 3 are also on the transregional level, they took a comparative perspective that Longshan polities as discrete units, emphasizing similarities and differences to classify, contrast, and explain patterns and variations. Chapter 5, instead, took a connective perspective, which aims to reconstruct networks of interaction, transmission, and transformation, showing how cultural phenomena are shaped by encounters and mobility. It examines the flows of people, objects, and ideas across boundaries, foregrounding networks and interactions.

Under a connective perspective, Chapter 5 reconnects Taosi to the wider Longshan network through Social Network Analysis. It reconstructs interaction networks across phases using exotic prestige goods. The connectivity of the network remained high throughout Longshan Era, but the level of centralization shifted overtime. Taosi dominated as the sole hub in the Early Phase. By the Middle Phase, Shimao became more important but still only a secondary hub, but by the Late Phase, centrality was shared among Taosi, Shimao, and Pingliangtai. In other words, the centralization of the network decreased during the Late Phase. Small-world coefficients also confirm that while the network remained highly interconnected, it became less centralized, signaling increasing regional autonomy and competition.

Drawing on Renfrew's systems-collapse theory, the chapter argues that high integration created systemic fragility: crises in key hubs cascaded across the network, producing macroregional disruption. The Longshan Transformation is therefore best understood not as

the product of a single cause, but as the cumulative outcome of multiple stressors amplified by interconnectivity.

2. Synchronized History: Individual Site and the Longshan Network

With the delineation of the history of Taosi and its social network, several synchronized changes become evident. Drawing from settlement, ceramic, mortuary, and network analyses, I synthesize the following parallel developments at Taosi and within the broader Longshan world. By presenting the parallel changes, I hope to demonstrate that the rise and fall of individual communities is highly connected to the fluctuation of the network they are involved with.

2.1 Early Taosi Phase (2450–2200 BCE)

During the Early Taosi Phase, the Linfen Basin experienced rapid growth in settlement size, density, and hierarchy. Rank-size analysis reveals a steep slope, indicating extreme primacy and high political integration already concentrated at Taosi. This centralization is further corroborated by the early construction of the city wall, which reflects administrative capacity from the outset of the site's development. By the second half of the Early Phase, funerary traditions emphasizing wealth differentiation and elite status were firmly established. Palatial construction, elite mortuary display, and imported ritual forms became markers of social stratification, testifying the primacy of Taosi in its immediate environs.

These local developments were inseparable from Taosi's broader role in transregional networks. Serving as the sole hub of east–west communication, Taosi occupied a position of maximum centrality. The Longshan network at this stage has a high small-world coefficient,

demonstrating both efficient communication and tightly clustered ties. Together, archaeological evidence and network metrics show how Taosi's network centrality and rapid local development mutually reinforced one another, enabling Taosi to emerge as a highly integrated, hierarchical polity.

The closely knit Longshan network promoted social stratification not only at Taosi but also across other regions of the Longshan world. Both Highland communities and the Central Plains began to show stronger evidence for social differentiation and the consolidation of sociopolitical power, where such evidence had previously been weak. I do not interpret the synchronicity between the rise of Taosi and stratification elsewhere as the result of diffusionism. Rather, Colin Renfrew's (1986) proposal is more compelling: interaction among autonomous but equal peer polities, through imitation, emulation, competition, warfare, and exchange, can generate greater social complexity and formal similarities.

From a systems-theory perspective, the multiplier effect of such a network meant that small changes in one polity—for example, the adoption of new prestige goods, ritual practices, or political strategies—could be copied, adapted, or competitively outdone by others, producing cumulative effects across the system. In this context, the prosperity and centrality of Taosi were both a local achievement and a regional multiplier: changes in one polity set off reactions in others, creating an overall acceleration of social transformation throughout the Longshan world. The high degree of centralization in the Early Longshan network suggests that its connectedness was sufficient for the multiplier effect to operate effectively.

2.2 Middle Taosi Phase (2200–2000 BCE)

By the Middle Phase, Taosi had expanded dramatically to 280 ha, its inner city was reorganized, and a three-tiered settlement hierarchy emerged. These changes point to a more centralized urban plan and settlement system. The expansion of the walled area and the construction of fortification also happened during this time, which corresponds to the rise of Shimao and other stone-walled sites on the northern Loess Plateau, such as Houchengzui 后城咀, Bicun, Zhaishan, Xiata 下塔, Zhaimao (for a recent review, see Pei 2023: 110–112). Elite mortuary practices combined strategies that highlighted individual status with those that facilitated power negotiation. Individual prestige was expressed through lavish feasting paraphernalia and long-distance connections. Both strategies have reached their peak during the Middle Phase.

The Longshan interaction network also underwent clear changes. Connectivity continued to rise, and the small-world coefficient peaked during this phase, reflecting an optimal balance between local clustering and global connectivity. Archaeological evidence from Taosi confirms this increasing connectedness. Highland ceramic styles and a greater reliance on sheep herding (Brunson 2015) began to appear in Middle Taosi. Isotopic and osteological evidence suggests the presence of non-local populations (Zhang *et al*. 2009; Zhao and He 2014), implying not only temporary movements or indirect exchange but also immigration from the Highlands. This deeper integration of Taosi into the macroregional network coincides with the broader rise in Longshan connectivity. Yet Taosi's centrality declined as other sites, such as Shimao in the Highlands, rose as secondary hubs. While this

redundancy of central hubs made the network more robust, it also meant that Taosi began losing the attraction that once brought it flows of goods, information, and people.

Growing connectivity brought not only opportunities for knowledge exchange but also new threats. Revisiting Cerny's discussion of globalization, he argues that globalization can produce "durable disorder" within and among states. In a similar way, the emergence of fortified centers during the later Early and Middle Longshan phases can be understood as a response to heightened connectivity. As Cerny (1996: 38) explains, the security dilemma arises when perceived external threats generate feelings of insecurity, prompting counteractive defensive measures that are themselves viewed as threatening by others, thus triggering cycles of action and reaction. This dynamic closely resembles the peer polity interaction model that is familiar to archaeologists, but the detailed description of the process offers a useful model to understand the rapid proliferation of fortifications during the Longshan Era and to understand how the tendency to system breakdown might be introduced to the Longshan world through the formation of network.

Evidence for what exactly occurred during the Middle Phase is limited, largely because of Late Phase destruction of the palace and the looting of Early and Middle elite tombs. Nevertheless, by the end of the Middle Phase, a major crisis is evident in the destruction of palatial structures and the looting of elite burials during the transition to the Late Phase. Whereas in the Early Phase the amplifier effect of the highly connected Longshan network promoted social complexity, by the Middle Phase crises at key hubs—such as Taosi, Liangchengzhen (the hinterland contracted in Late Longshan), and Yaowangcheng (site was abandoned in Late Longshan)—could destabilize the broader network. Crises did not need to

occur everywhere at once; disruptions at a few central nodes were sufficient to trigger widespread social upheaval across the Longshan world.

2.3 Late Taosi Phase (2000–1900 BCE)

The Late Phase was marked by crisis and fragmentation. Archaeological evidence indicates the destruction of palaces, the looting of elite tombs, and episodes of interpersonal violence. Although Taosi remained the largest site in the region, its political authority had disintegrated. Palatial and ritual landmarks were hastily rebuilt with poor construction, only to be abandoned again, signaling failed attempts to restore the Middle Phase social order. Mortuary practices also changed significantly: feasting paraphernalia and exotic goods disappeared, replaced by ceremonies and human sacrifices that emphasized political negotiation among the living rather than conspicuous display of the deceased.

Regionally, as medium-sized sites declined, the settlement hierarchy became simpler. This produced a steeper slope in rank-size distribution, but not because of stronger control by the central site. Instead, it reflected the disappearance of intermediate settlements and the polarization of sites into either very large or very small. If each settlement tier corresponded to an administrative level, then the erosion of the middle tier—while superficially suggesting greater centralization—actually led to fragmentation and weakened connections between the central site and its hinterland communities.

The Longshan network exhibited parallel changes. The small-world coefficient declined, reflecting the weakening of global connectivity even as local clusters persisted. This pattern mirrors the broader macroregional collapse, marked by the abandonment of major centers in the coastal region, the Jinnan region, and the northern Loess Plateau. Renfrew's systems-

collapse model helps explain this synchronicity: the very interconnectivity that had once sustained the Longshan world now amplified its vulnerabilities, allowing violence, disruption, and political decentralization to cascade across regions. Taosi's decline was thus not an isolated failure, but part of a systemic unraveling in which interdependence transformed fragility into macroregional collapse.

My analysis has shown that the changes at Taosi during its Early, Middle, and Late Phases corresponded with the changes of the Longshan network. This synchronization invites us to think deeper about the relationship between the history of individual sites and the development of the broader network.

As outlined in the introduction, this dissertation addresses two overarching questions: (1) How do individual societies change—through collapse, fragmentation, persistence, or transformation? and (2) Why did such changes occur in a roughly synchronized fashion across regions? I take Taosi as a case study to address the first question, and I adopt a connective perspective, together with Social Network Analysis, to propose an interpretive hypothesis for the second.

Drawing on Taosi's trajectory and its role within a transregional network, I argue that the scale and breadth of the Longshan Transformation were not the result of any single global event—such as climate change, flooding, or military campaign —capable of uniformly affecting the entire Longshan world. Instead, they emerged from the very intensification of interregional connectivity that defined this world. The same networks that fostered the development of complexity also transmitted crises, allowing disruptions to spread widely. Change was a constant across settlements, driven by local dynamics as well as responses to

broader shifts within the network, and these changes in turn reshaped the network itself. The intersection of local transformations and systemic reconfiguration thus produced the apparent synchronicity of change observed across regions.

With the shift of question from what would be broad enough to cause such a large-scale transformation to what network quality allowed transregional transformation, this dissertation has proposed a model that enables researchers to navigate between site-specific, regional, and transregional scales. This approach captures the interactions across scales and levels within a connected, dynamic system, offering a new lens for understanding not only the Longshan Transformation, but also social collapse and transformation more broadly.

3. **Viewing the Longshan Transformation from a Network Perspective**

While this new approach holds significant potential, it remains highly hypothetical. Before concluding this dissertation, I therefore turn to more empirical considerations in order to better understand the form and nature of Longshan interregional interactions and to outline future research directions.

3.1 The Significance of Interregional Contact in Pre-State Complex Societies

Long-distance contact has remained important throughout human history. During the Longshan Era, however, there is no evidence for state institutions, taxation, or a cross-regional core-periphery system in which a single center politically and economically dominated surrounding regions. That said, several possibilities and archaeological analogies are worth considering for understanding the potential forms of Longshan interregional interaction and their role in sustaining stability.

One possibility long discussed by scholars is the tributary system. Shao Wangping (1987) argued that the territories of the Nine Prefectures in the *Yugong* (Tribute of Yu) chapter of the *Shangshu* largely correspond to the distribution of archaeological cultures, noting that many of the items and customs described resemble late Neolithic and Shang-period finds. Liu Li (1996) further suggested that elite goods—such as jades, alligator drums, and turtle shells—were transported across regions during the Longshan Era. More recently, Li Min (2018) demonstrated that the Ji-Prefecture-centered geography in the Yugong corresponded to the Longshan cultural–political landscape, in which the Jinnan region held centrality. These arguments suggest that a tributary network resembling the one later recorded in the *Yugong* may already have existed in the Longshan Era. I am not suggesting that the Longshan social network was identical to the *Yugong* or that *Yugong* was written in the Longshan Era, but rather that the system in *Yugong* may preserve some deep structures formed in Longshan. If so, the Longshan network as a semi-tributary network may have functioned as a channel through which people affirmed inter-polity political order and maintained inter-polity stability.

Beyond inter-polity relations, travel itself may have served as a source of political–religious authority. Mary Helms (1988; 1992) argued that geographical distance was rarely neutral in traditional cosmologies: distant places were imbued with supernatural qualities, and elites who accessed them gained prestige, esoteric knowledge, and legitimacy. Exotic goods thus operated not only as economic resources but also as tangible proofs of cosmological engagement, linking rulers to extraordinary realms of power. Distance mattered in two ways: first, by providing an "other" against which societies defined

themselves; and second, by allowing elites to restrict and manipulate access to distant knowledge, thereby concentrating power.

Later, Timothy Earle (1997) argued that chiefs mobilized prestige goods and distant connections to consolidate power, while Ian Hodder (1982) emphasized that imported objects functioned as symbols in strategies of social differentiation and legitimation. Together, these scholars converge on the idea that interregional interaction was not merely economic but also symbolic, transforming foreignness into political capital and cosmological authority.

State-sponsored pilgrimage provides another useful analogy. Brian Bauer and Charles Stanish (2001) showed how the Inca transformed the Islands of the Sun and Moon on Lake Titicaca into pan-Andean pilgrimage centers, building upon earlier sacred traditions. Archaeological evidence reveals ritual activity on the islands as early as the Late Formative (500 BCE–AD 400), later incorporated by Tiwanaku, and reconfigured by the Inca through temples, plazas, storage, and hostels. From a Durkheimian perspective, Bauer and Stanish (2001) argue that pilgrimage was not counter-hegemonic but rather a state project to legitimate imperial authority. By appropriating local shrines and reframing them within Cuzco-centered cosmology, the Inca sanctified expansion and consolidated control. Pilgrims were fed, clothed, and housed by the state, incorporating imperial ideology into their personal worldview. In this way, the sacred and political became inseparable, and ideology was materialized through movement across a sacred landscape.

The Longshan network presents an interesting parallel. Most of the sites with the highest or secondary centrality were also regional settlement centers despite the bias

introduced by fragmentary archaeological discovery. These hubs present evidence of administrative projects, elites, and/or population aggregation. Their role as network hubs is confirmed by the coalescence of prestige goods of diverse origins. Because these hubs have the capacity to mobilize local resources, they could have accommodated long-distance travelers with feasting and ritual events. If so, the effect achieved by the Inca through state-sponsored pilgrimage might also have been realized at Longshan centers through such gatherings.

Intermarriage may have been another important form of interregional interaction. Recent isotope analysis shows that about 55 percent of the sampled women at the Xiajin cemetery were non-local, indicating the presence of female exogamy. Based on their foodways and burial practices, many of these women appear to have affiliation with the Haidai region. Furthermore, DNA studies by Xue *et al.* (2022) reveal that populations at sites of the Taosi Culture shared close genetic affinities with Shimao groups, also possibly resulted from intermarriage. Additional mitochondrial DNA research indicates that maternal lineages in the Haidai region were relatively simple before and during the Dawenkou period but became increasingly diverse from the Longshan period onward (Liu *et al.* 2021). Together, these patterns point to widespread interregional marriage during the Longshan period.

In sum, the cross-cultural and historical analogies outlined above help us to perceive possible forms of Longshan interregional interaction. Mobility—whether through tribute, travel, pilgrimage, or marriage—contributed both directly and indirectly to maintaining

political order. The next question, then, is how the disruption of individual sites might have contributed to the collapse of the entire network.

3.2 The Way of Perceiving the Distant

Knowledge of travel in the past was not conveyed in the "departure-arrival" mode of thinking, as in modern air travel, but in a "node-by-node" manner. To reach a distant destination, one had to pass through a series of intermediary points, each indispensable for accessing the final goal. For example, a medieval Tibetan manuscript from Dunhuang describing a Chinese monk's journey to India records (translation from Wen 2023: 114):

> Proceeding from Mount Wutai he arrived at the gold and turquoise halls of Hezhou; after that he arrived at the mountain of Dantig Shan; after that he arrived at the gold and turquoise halls of Tsongkha; after that he will arrive at the palace of Liangzhou; after that he will arrive at the castle of Ganzhou; after that he will arrive at Shazhou. After that he will certainly go to see the great teachers of Śrī Nālandā and the relics of Śākyamuni at the Vulture's Peak in India.

Here, the route from Mount Wutai to the Vulture' s Peak is described as a chain of cities and forts—Mount Wutai → Hezhou → Danting Shan → Tsongkha → Liangzhou → Ganzhou → Shazhou → Vulture' s Peak. The account emphasizes that each midpoint was indispensable: if any one node became inaccessible, the entire route was perceived as blocked. Other Dunhuang texts suggest that certain Silk Road segments had two or three alternatives, but the redundancy was limited.

This structural limitation is echoed in the Social Network Analysis of the Longshan world, where in the Early, Middle, and Late Phases only one to three hubs exhibit high

betweenness centrality. Such hubs acted as bottlenecks: connections between clusters depended on them, and without them cross-regional mobility was severely constrained. For travelers, mobility was experienced not as a net of many options but as a handful of linear routes. Thus, disruption at just one or two key nodes could make the entire system of travel routes appear inaccessible—not because every connection vanished, but because the remaining network no longer aligned with the experiential logic of node-to-node travel.

Because interregional interaction in the Longshan world likely played a vital role in sustaining local social orders, the breakdown of key routes could destabilize not just mobility but also political stability. In this sense, the Longshan network exemplifies Renfrew's "multiplier effect": local disruptions and network disturbances reinforced one another, producing instability at both the site and system levels, ultimately cascading into collapse.

Regardless of its precise form, Longshan interregional interaction undeniably mobilized creativity and enabled new pathways toward social complexity. The prehistoric "glocalization" on the one hand promotes the quick development of local social complexity, on the other hand, challenges the existing internl and interregional social orders. Contacts among Longshan communities and with the wider Eurasian continent provided opportunities for unprecedented political and institutional development. By situating the Longshan "collapse" not as the end of the prehistory but as a transformation within the continous trajectory toward Bronze Age state formation and an emerging World System, and by shifting from a comparative perspective to a connective one, this dissertation aims to contribute some new perspective to understanding the Longshan Transformation.

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