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Research Article

Intermarriage and ancient polity alliances: isotopic evidence of cross-regional female exogamy during the Longshan period (2500–1900 BC)

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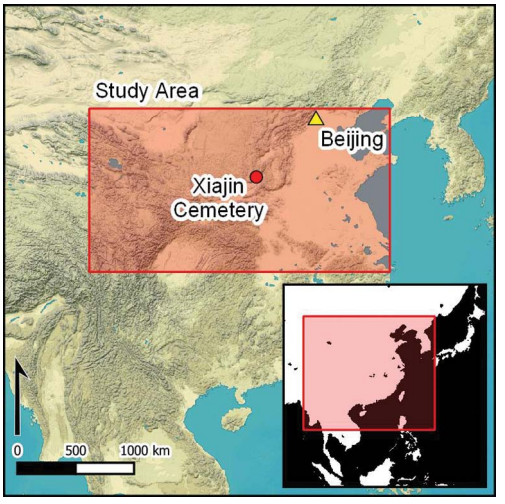

The late third-millennium BC Longshan period was a crucial time for state formation in central China. During these centuries, long-distance networks expanded and shared material culture and then cultural practices spread across wider areas precipitating social and ideological developments that presaged the rise of states and cities on the Central Plain. In this research, the authors use multiple (strontium, oxygen and carbon) isotope analyses from the dental enamel of 67 individuals buried at the Xiajin cemetery, Shanxi Province. The results indicate significant long-distance migration among females during the Longshan period, which the authors interpret as evidence of exogamous marriage for political alliance-building—a phenomenon found more widely across Eurasia at the start of the Bronze Age.

Keywords: central China, Neolithic, Bronze Age, Taosi culture, burial, isotopic analysis, migration, exogamy

Introduction

The Longshan period (*c.* 2500–1900 BC) was a crucial time for state formation in central China. During this period, inter-regional networks developed rapidly, transmitting shared material forms and cultural practices across wider areas and contributing to changes in social organisation and ideology that foreshadowed the rise of states and cities at the end of the third millennium BC (Yan 1981; Chang 1989; Zhao 2000; Li 2017). Human mobility is likely to have played an important role in these processes; however, our knowledge of the scale and

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type of movement is limited. In this article, we use isotopic analysis of individuals from a Longshan-period cemetery to identify and characterise the nature of human mobility and its significance in relation to the intensification of inter-regional networks during the late third millennium BC.

The Taosi culture (*c.* 2300–1900 BC), located in the area of present-day southern Shanxi Province, was the first group in the middle Yellow River Valley to establish cities of a royal character and it became the most complex society of the Longshan period (He 2013, 2018). The site of Taosi, extending across an area of more than 300ha, is one of the largest settlements in Neolithic China, featuring a palace enclosure, astronomical 'observatory' and royal tombs with many ritual vessels symbolising royal power as well as extensive areas of hierarchically organised settlement activity (He 2011). Approximately 25km north of the Taosi site area is the Xiajin cemetery, which features the largest number of Taosi-culture burials excavated to date. The organisation of the cemetery demonstrates clear hierarchical differentiation and social inequality, with high-status (noble) males accounting for more than 90 per cent of the social wealth attested by the size of tombs (Gao *et al.* 1983; Linfen & Shanxi 1999; Shanxi & Shanxi 2022). The Taosi culture appears to have been a patriarchal society, with males controlling property through succession; marriage was likely the only way for females to obtain wealth and higher social status (Li 1985).

The Taosi culture was located in *Jizhou* (*冀州*), one of the regions of the *Jiuzhou* (*九州*) or Nine Provinces recorded in the *Yugong* (*禹贡*), or 'Tribute of Yu', a chapter in the *Shangshu* (*尚书*) or 'Book of Documents'. It is possible that the Taosi site was the capital city of *Yao* (*尧*) (Li 1985; Zhang 2010; He 2015). Archaeological discoveries in this region reveal the incorporation of numerous foreign cultural elements, including the use of jade and copper, alligator drum (wooden frames covered with alligator skin), painted pottery and various funeral customs (Xu 2014; Wu 2018; Qin 2020). The network that brought these elements to the region extended from the highlands to the west to the coast of the Shandong more than 700km to the east, and from the Yangtze River Valley in the south to the steppe in the north. Over a period of five centuries during the late third and early second millennia BC, encompassing the transition between the Taosi (*c.* 2300–1900 BC) to Erlitou (*c.* 1900–1500 BC) cultures, the middle reaches of the Yellow River rapidly developed from a series of chiefdoms into a single territorial state (Liu & Chen 2012).

In this article, we focus on the Xiajin cemetery of the Taosi culture (Figure 1), utilising multi-isotope analyses to trace the geographical origins of some of the individuals buried at the site in order to assess the patterns of human mobility during the late Longshan period in southern Shanxi and evaluate the inter-regional social networks that underpinned wider cultural and political developments.

Xiajin cemetery

Xiajin cemetery (36°1′12″N, 111°26′24″E) is approximately 10km south-west of the present-day city of Linfen and 25km north of the Taosi site (Figure 1). The site is situated on a well-developed river terrace at 450m above sea level. Excavations in 1999 identified 533 burials across an area of 2000m^2 (Linfen & Shanxi 1999; Shanxi & Shanxi 2022; Figure 2). The original extent of the cemetery is estimated at nearly 6000m^2, with potentially more than

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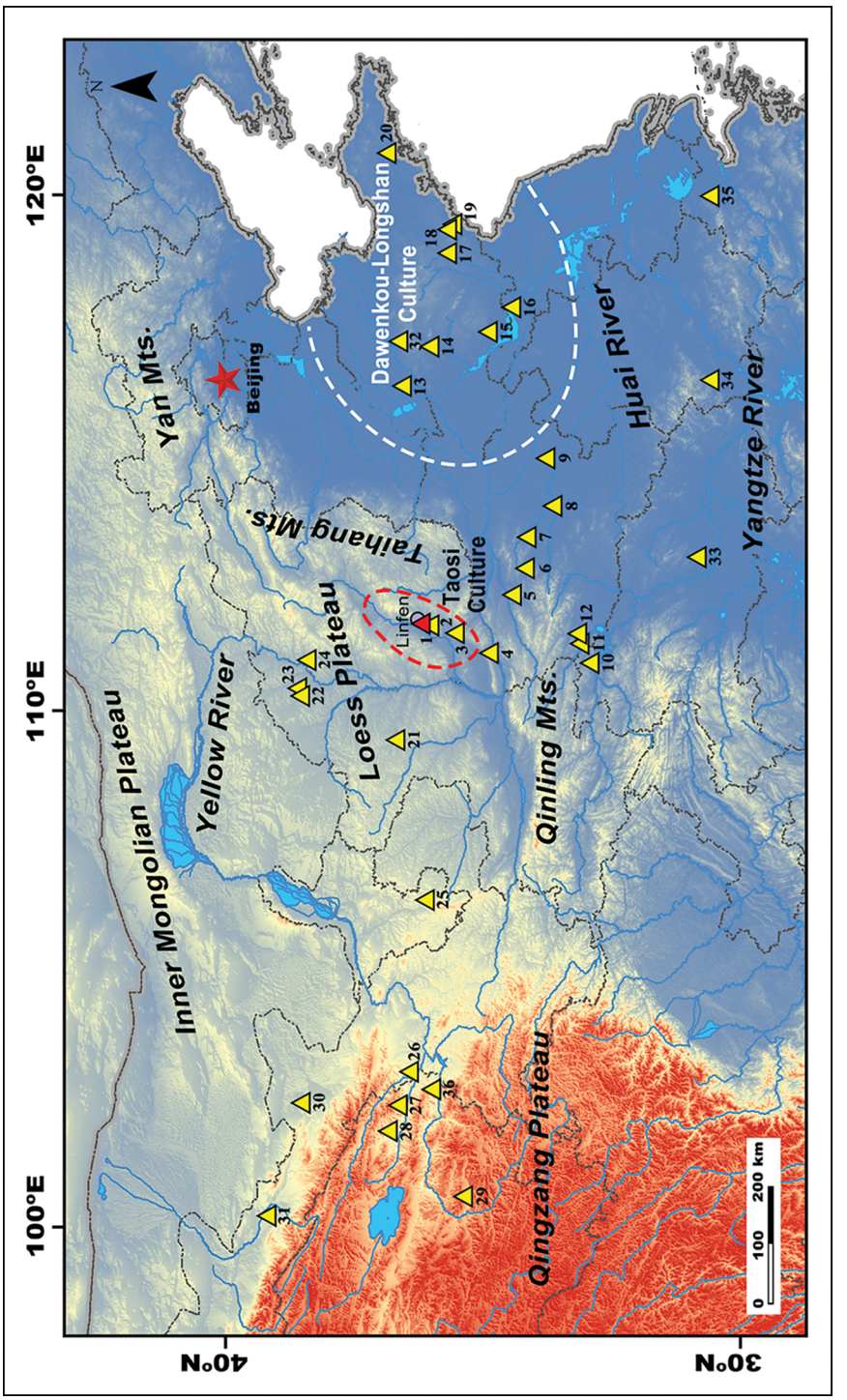

Figure 1. Location of Xiajin and related archaeological sites. 1) Xiajin (highlighted in red); 2) Taosi; 3) Zhoujiazhuang; 4) Qingliangsi; 5) Wanggedang; 6) Meishan; 7) Wadian; 8) Haojiatai; 9) Pingliangtai; 10) Qinglongquan; 11) Xiazhai; 12) Xiawanggang; 13) Shangzhuang; 14) Dawenkou; 15) Xigongqiao; 16) Liangwangcheng; 17) Lingyanghe; 18) Dantu; 19) Liangchengzhen; 20) Simatai; 21) Lushanmao; 22) Shengedaliang; 23) Shimao; 24) Bicun; 25) Dianbe; 26) Xiahaishi; 27) Shangsunjiazhai; 28) Liuwan; 29) Zongri; 30) Yuanyangchi; 31) Xichengyi; 32) Jiaojia; 33) Shijiabe; 34) Qujialing; 35) Liangzhu; 36) Lajia (figure by the authors).

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*Figure 2. Part plan of excavated area of the Xiajin cemetery; * indicates radiocarbon dating performed on a tooth from this tomb (figure by the authors and modified after Xiajin 1998; Linfen & Shanxi 1999; Shanxi & Shanxi 2022).*

1500 burials. The cemetery is thought to have served the 40ha settlement site at Dongdeng, located south of the cemetery in the Fenhe River valley. Large storage pits at Dongdeng, suggest it may have functioned as a land and water transportation hub on the route to the 'capital' at the Taosi site (He 2011).

The cemetery at Xiajin demonstrates an orderly layout, with clear hierarchical differences between individual burials expressed in terms of grave size and funerary goods (Figure 2). Despite the extensive robbing of graves, the surviving grave goods of high status, such as jade and stone objects, and the presence of coffins, are almost exclusively associated with the largest graves (Linfen & Shanxi 1999; Shanxi & Shanxi 2022). The mean size of graves containing male individuals is also significantly larger than those containing females (Figure 2). A similar arrangement is seen at the Taosi site, where all of the occupants of a large, royal grave are male with adjacent smaller graves of females, probably the rulers'

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wives (Gao *et al.* 1983). At the contemporaneous Qingliangsi cemetery 150km to the south of Taosi, sex-based inequality is even more pronounced: there, most of the large burials are of males, while females were typically buried alive in the same grave as sacrifices (Shanxi 2016). Thus, Taosi burial practices indicate that male-biased inequality, or the lower status of females, was the social norm during the Longshan period in southern Shanxi.

Based on AMS radiocarbon dating of six human teeth (Figure 2), the cemetery dates to 2464–2018 cal BC (Figure 3; online supplementary materials (OSM) Table S1). He (2006) divides the Taosi culture into three periods spanning *c.* 2300–1900 BC (previous studies had suggested earlier dates, *c.* 2600–2000 BC; Gao *et al.* 1983). The radiocarbon dates from Xiajin are therefore consistent with the new chronology with all six individuals corresponding to the early Taosi phase. Individual M521, the earliest of the group, dates to 2464–2290 cal BC (at 95.4% probability), a phase that overlaps with the late Dawenkou (2800–2400 BC) and late Liangzhu (2800–2300 BC) cultures to the east and south-east of the Taosi, respectively. The decline of the Liangzhu culture and expansion of the Dawenkou culture, *c.* 2300 BC, are major factors in early state formation on the Central Plain (Zhang 2021; Zhang & Zhao 2021).

Similar to the Taosi site, the Xiajin cemetery demonstrates evidence for some non-local funerary practices and grave goods, with the jade *yue* axe (玉钺) and the jade *bi*-disc (玉璧) as two prominent funerary objects. The jade *yue* was generally placed on an individual's body as a symbol of military power, whereas the jade *bi*-disc was worn on the wrist as a symbol of wealth and status (Figure 4), customs influenced by the Dawenkou culture (Figure 4). Several of the individuals at Xiajin (Shanxi & Shanxi 2022; Figure 4) and the Taosi cemeteries (CASS & Linfen 2015) were buried wearing turquoise-inlaid bracelets, a practice possibly originating in the Gansu-Qinghai region (Figure 4; see also OSM).

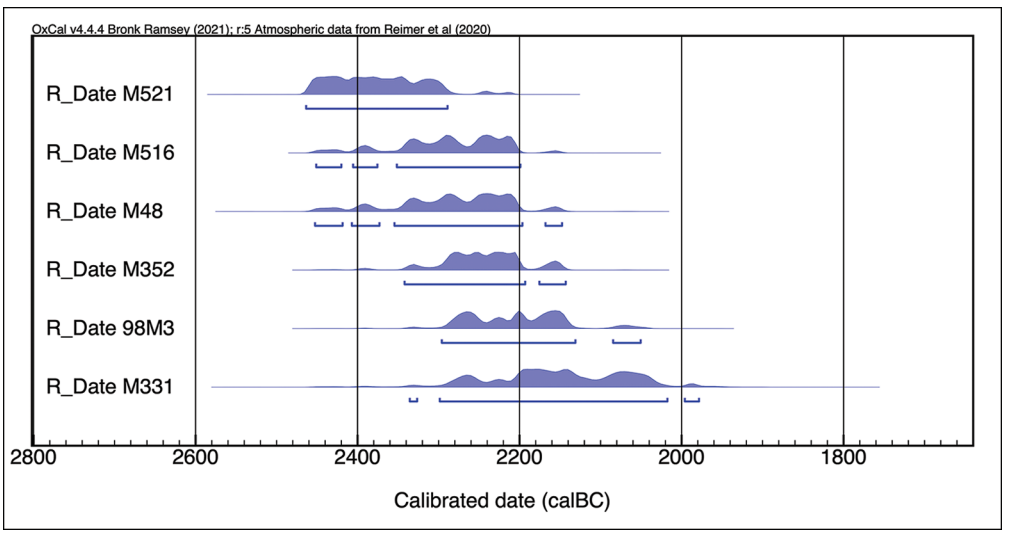

Figure 3. Calibrated radiocarbon dates for human teeth from Xiajin cemetery calibrated in OxCal v4.4.4, using the IntCal20 atmospheric curve (Bronk Ramsey 2021; Reimer et al. *2020) (figure by the authors).*

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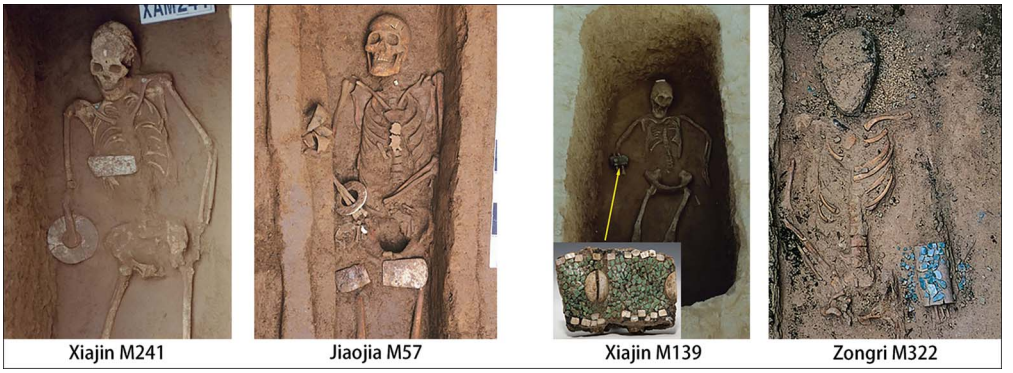

Figure 4. Burials of Xiajin site (Southern Shanxi Region), Jiaojia site (Haidai Region) and Zongri site (Gansu-Qinghai Region) (figure by the authors).

Many of the grave goods from Xiajin cemetery reflect the influence of the Dawenkou and Longshan cultures in the Haidai (海岱) region of eastern China, such as jade *yues*, jade knives with double holes, *cong*-shaped jade bracelets, T-shaped jade bracelets and jade discs (Figure 5; see also OSM). Some of these objects are also found at Taosi, Qingliangsi and other sites in southern Shanxi during the Longshan period. The influence of Dawenkou, Liangzhu and Xuejiagang cultures on southern Shanxi through the transmission of jades, musical instruments and burial customs is widely attested (Zhao 2000; Song 2003; Luan

Figure 5. Comparison of burial objects from the Xiajin cemetery with those from the Dawenkou and Longshan culture in the Haidai region (non-uniform scale). Xiajin cemetery: 1 & 2) pottery bottles; 3) jade Yue*; 4) jade knife with double holes; 5) jade bracelet with repair; 6)* cong*-shaped jade bracelet; 7) T-shaped jade bracelet; 8) canine teeth of boar; Dawenkou and Longshan culture: 9 & 10) pottery bottles (Lingyanghe); 11) jade* Yue *(Liangchengzhen); 12) jade knife with double holes (Dantu); 13) jade bracelet with repair (Dawenkou); 14)* cong*-shaped jade bracelet (Shangzhuang); 15) T-shaped jade bracelet (Simatai); 16) canine teeth of boar (Dawenkou) (figure by the authors).*

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2010; Wu 2018, 2019; Xu 2021). Archaeologically, however, it has proven difficult to establish the role of human mobility in the spreading of these cultural influences and, specifically, the migration of individuals to the Taosi culture area. To help identify potential migrant populations and determine their geographical (and hence cultural) origins, we conducted multi-isotope analyses on 36 males and 31 females from the Xiajin cemetery (see OSM for detailed methods).

Results of multi-isotope analyses

The $^{87}Sr/^{86}Sr$ results

The results of strontium isotope analysis for Xiajin individuals are summarised in Table 1 (see Table S2 for detailed results). Geochemical studies have documented the $^{87}Sr/^{86}Sr$ ratio of soluble carbonate in the Quaternary loess of southern Shanxi Province as approximately 0.7110–0.7120 (Chen *et al.* 1997; Currell & Cartwright 2011). These soluble carbonates are taken up by plants and water in the region and, when consumed by humans and animals, incorporated into teeth and bone. The bioavailable $^{87}Sr/^{86}Sr$ range available through the consumption of plants and water in the loess region typically show little variation (Zhao *et al.* 2011; Zhao *et al.* 2016; Cao 2021).

The five local plant samples analysed demonstrate narrow $^{87}Sr/^{86}Sr$ ratio range of 0.711235–0.711356, with a mean of 0.711299 ± 0.000044 (1SD, $n = 5$). This result is close to the isotope signatures of a sample of archaeological pig tooth enamel (0.711311) and the soluble carbonate minerals in a sample of loess (0.711429). The mean $^{87}Sr/^{86}Sr$ ratio of these plant, faunal and mineral samples from Xiajin ($n = 7$) also closely matches that of a faunal sample from Taosi (0.711170 ± 0.00006, 1SD, $n = 9$, including 8 pig and 1 dog; Figure 6 & Table S3). Similarities in the age and underlying geology of the Xiajin cemetery and the Taosi site allow us to estimate a local bioavailable $^{87}Sr/^{86}Sr$ ratio range for the area within a 25km radius around Xiajin of 0.711042–0.711428 (2SD, $n = 16$; Figure 6).

Table 1 shows that Xiajin females have a greater range and variation in $^{87}Sr/^{86}Sr$ ratios than males. More specifically, the isotopic signatures of 23 of the individuals fall outside the local bioavailable $^{87}Sr/^{86}Sr$ range, including 16 females and seven males (Figure 6). More females than males may therefore be categorised as non-local, though most of these individuals still fall within the bioavailable $^{87}Sr/^{86}Sr$ ratio of the loess zone beyond the 25km radius area of Xiajin Cemetery. Exceptions are three adult females (M273, M308 & M521) who clearly stand out with $^{87}Sr/^{86}Sr$ values of 0.71070–0.71204 defined by Xiajin human individuals

Table 1. Results of strontium isotope analysis of human dental enamel from Xiajin cemetery.

	n	$^{87}Sr/^{86}Sr$ ratio range	Mean $^{87}Sr/^{86}Sr$ ratio	2 SD
Total	67	0.710496–0.713198	0.711368	0.000668
Male	36	0.711046–0.711901	0.711319	0.000412
Female	31	0.710496–0.713198	0.711424	0.000872

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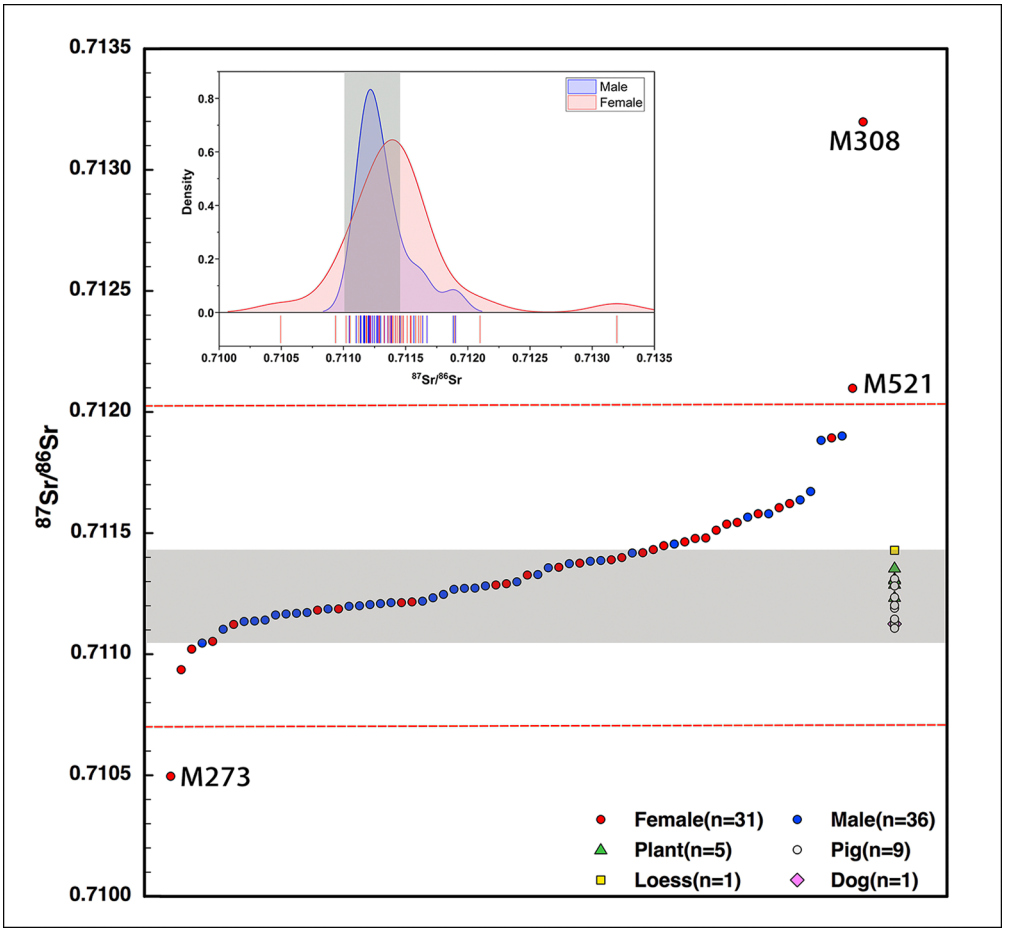

Figure 6. $^{87}Sr/^{86}Sr$ ratios of human enamel from the Xiajin cemetery. Grey bar shows the local bioavailable $^{87}Sr/^{86}Sr$ range of Xiajin site with a radius of 25km defined by 16 local non-human samples; red dotted line shows the range defined by Xiajin human samples (mean ± 2SD, n = 67) (figure by the authors).

(0.711368 ± 0.000668, 2SD, n = 67) (Figures 6 & 7; OSM Tables S2 & S3). We infer that at least three individuals buried at Xiajin cemetery came from beyond the Linfen Basin.

The $\delta^{13}C$ results

The $\delta^{13}C$ values of human tooth enamel from Xiajin range from –4.5 to –0.7‰, with a mean of –1.7 ± 0.65‰ (1SD, $n = 67$; Figure 8, Table S2). Assuming a dietary enrichment factor of 12–14‰ (Passey *et al.* 2005, Cerling *et al.* 2013), these results suggest that the local Xiajin people consumed a predominantly C_4 diet. This finding is consistent with archaeobotanical evidence for the predominance of millet in Taosi agriculture (Zhao & He 2006) and with the results of previous isotopic analyses of humans and pigs in southern Shanxi during the Longshan period (Zhang *et al.* 2007; Chen *et al.* 2012). Two individuals (M83 & M124), both female, demonstrate $\delta^{13}C$ values that are significantly lower than the range (−3.1 to

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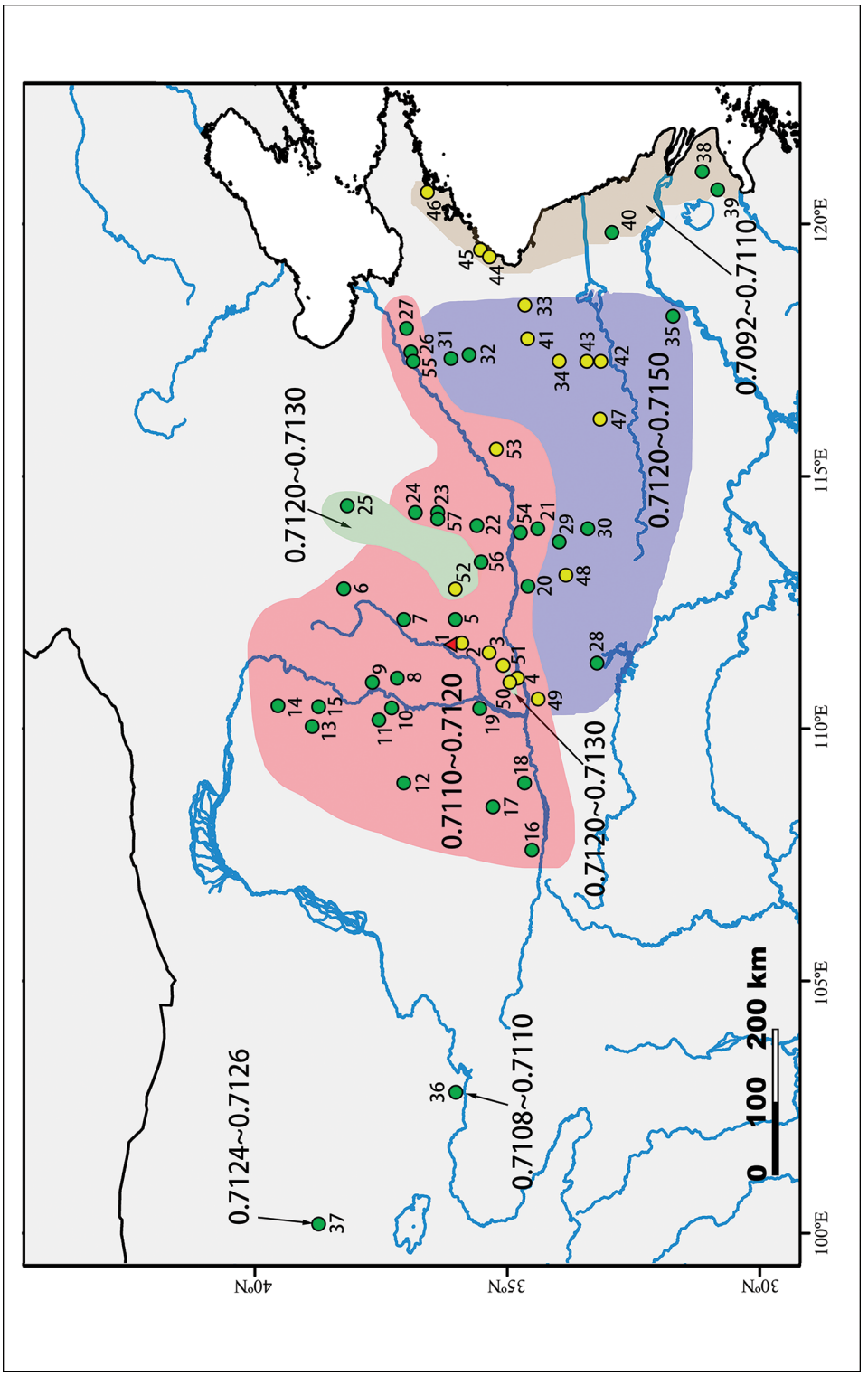

Figure 7. Bioavailable Sr isotope distribution in the Yellow River Valley and surrounding areas. Yellow circles represent data from this study, green circles represent published data, numbers indicate sites listed in Table S3 (figure by the authors).

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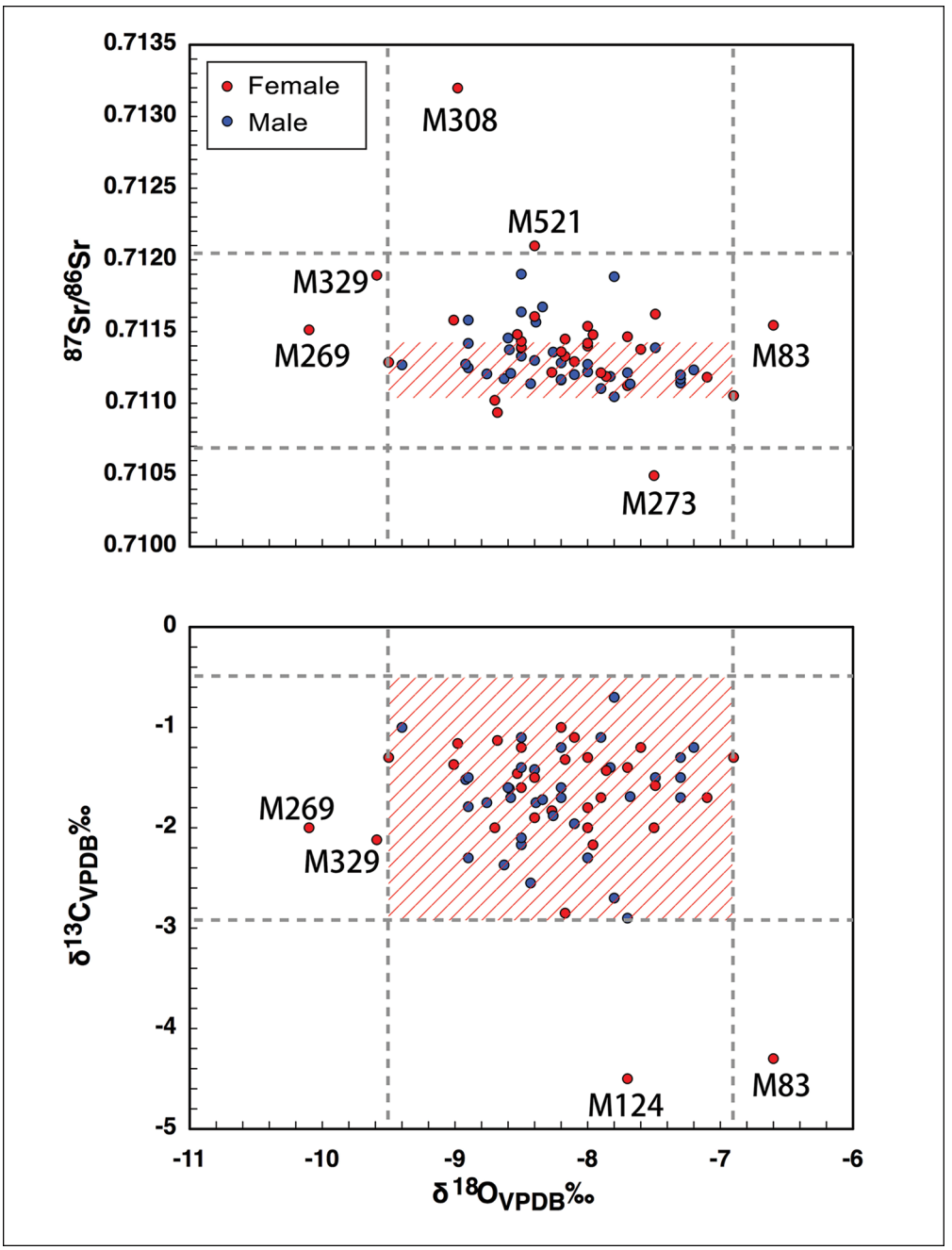

Figure 8. Scatter diagrams of $^{87}Sr/^{86}Sr$ vs $\delta^{18}O$ and $\delta^{13}C$ vs $\delta^{18}O$ of human enamel from Xiajin cemetery. Red circles represent females, blue circles represent males. Grey dashed lines show ranges defined by mean $^{87}Sr/^{86}Sr$ ratio, mean $\delta^{13}C$ and mean $\delta^{18}O$ (± 2 SD in each case, n = 67 human individuals). Red shading shows the $^{87}Sr/^{86}Sr$ ratio range defined by 16 local non-human samples (figure by the authors).

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–0.5‰) defined by Xiajin human samples (Figure 8). Plotting at –4.3‰ and –4.5‰, respectively, these values indicate a mixed C_3/C_4 childhood diet that is inconsistent with known cultivation strategies in southern Shanxi during this period (Song *et al.* 2019).

The $\delta^{18}O$ results

The $\delta^{18}O$ values of human tooth enamel from Xiajin have a range of –10.1 to –6.6‰, with a mean of –8.2 ± 0.64‰ (±1SD, $n = 67$). Using two standard deviations from the mean, we define a range of –9.5 ‰ to –6.9‰ for those individuals growing up around Xiajin (Figure 8, Table S2). The $\delta^{18}O$ values of three females fall outside of this range, with M83 showing an elevated value and M269 and M329 showing depressed values in comparison with other individuals from the area (Figure 8). We infer that M269, M83 and M329 were non-locals who migrated to the Xiajin area during early childhood.

Discussion

Multi-isotope ($^{87}Sr/^{86}Sr$, $\delta^{13}C$, $\delta^{18}O$) analyses indicate that 24 out of the 67 individuals from the Xiajin cemetery potentially grew up in areas more than 25km away from their final resting places. This group includes 17 females and seven males. These non-locals account for 36 per cent of the sampled population and 55 per cent of the 31 females. At least seven females (M83, M124, M269, M273, M308, M329, M521) appear to have migrated to Xiajin from three different areas outside the Linfen Basin (Figures 8 & 9). M273 has the lowest $^{87}Sr/^{86}Sr$ ratio, which may indicate a childhood in the Shandong coastal area (Figure 7, Table S3), while M521 and M308 exhibit the highest $^{87}Sr/^{86}Sr$ ratios. Although most areas in southern Shanxi have uniform strontium isotope ratios under the influence of the loess soils, the northern foothills of Zhongtiao Mountain and the Taihang Mountain, more than 100km away in southern Shanxi, are composed of gneiss, granite, sandstone and other rocks with high Rb/Sr ratios. The radiogenic strontium content of water and plants in that area is thus high, with strontium isotope ratios averaging between 0.7120 and 0.7130 (Figure 7, Table S3), and it cannot be ruled out that M521 came from the Zhongtiao Mountain or Taihang Mountain area. The isotopic signatures of M273 and M308 lie beyond southern Shanxi, however, and these individuals are likely to have come from coastal areas and the southern Haidai region, respectively, more than 700km to the east.

The $\delta^{13}C$ values for individuals M83 and M124 indicate a mixed C_3/C_4 diet in early childhood. Although rice (a C_3 plant) was cultivated in southern Shanxi during the Longshan period (Song *et al.* 2019), archaeobotanical and stable isotope studies reveal that C_4 crops, including foxtail and broomcorn millets, dominated diet in this area (Zhao & He 2006; Zhang *et al.* 2007; Chen *et al.* 2012). In contrast, in the Haidai region and Upper Huai River Valley, crop cultivation was more diverse (He *et al.* 2017) and isotopic signatures indicate a mixed C_3/C_4 diet at sites such as Liangchengzhen (Lanehart *et al.* 2011), Xigongqiao (Hu *et al.* 2005), Wadian (Chen *et al.* 2012; Zhou 2017), Haojiatai (Zhou 2017; Li *et al.* 2021), Meishan (Zhou 2017) and Xiazhai (Zhou 2017). Individual M83 further demonstrates the highest $\delta^{18}O$ value of all individuals (–6.6‰; Figure 8), indicating a childhood

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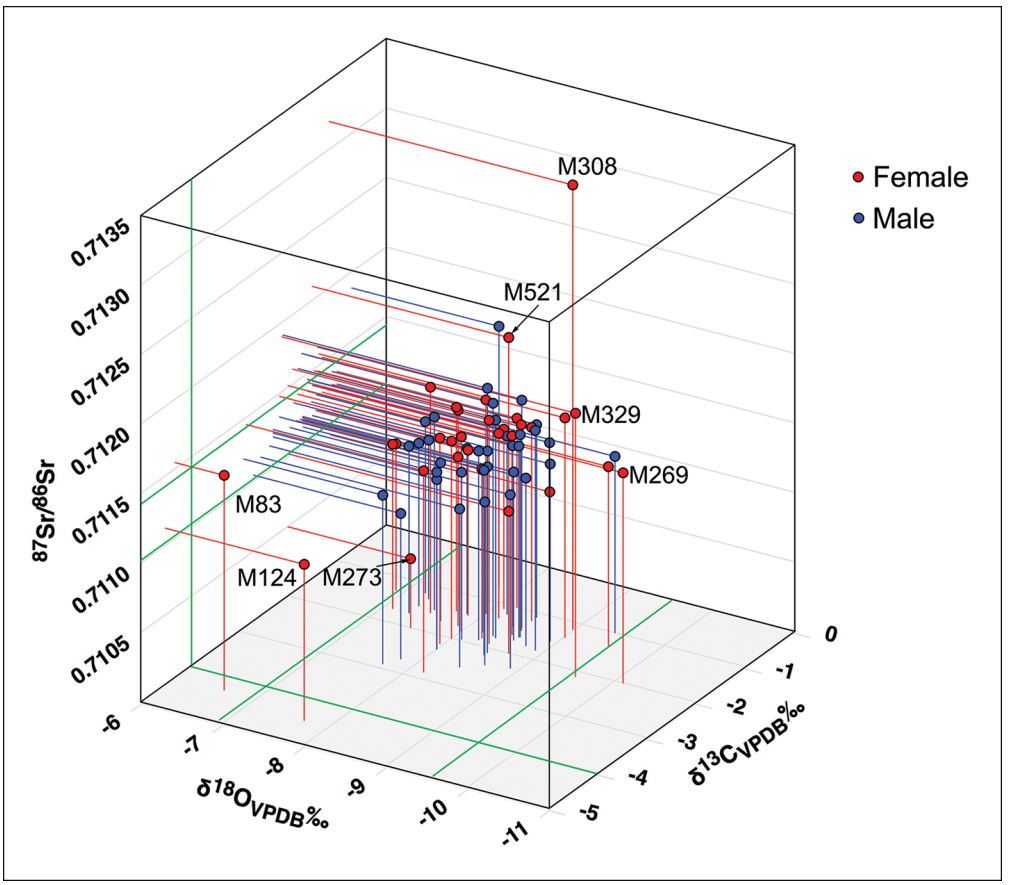

Figure 9. Three-dimensional scatter plot of $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and $\delta^{13}C$ of human enamel from Xiajin cemetery (figure by the authors).

at a lower elevation and closer to the sea. M83 and M124 therefore probably originated from the Haidai region. In contrast, the more negative $\delta^{18}O$ values of M269 and M329 combined but with $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ values similar to the rest of the Xiajin sample suggest that these individuals came from an area further from the sea, at a higher altitude and with a lower average temperature, perhaps the north-west highlands.

Multi-isotopic signatures are more variable among female than male individuals in Xiajin cemetery and almost all outliers are female (Figure 9). These results suggest a high proportion of female mobility within a wide geographical region, and the long-distance migration of several individuals from beyond the Taosi cultural area. At the contemporaneous sites of Lajia and Xichengyi (Figure 1), all the individuals with non-local isotopic signatures are female (Zhao 2012; Zhao *et al.* 2016). This greater variability in the geographical origins of females compared with males at Xiajin, and other Taosi sites, suggests a pattern of female exogamy (Ericson 1985), a practice that is widely cited as a key factor in high female mobility in other world prehistoric contexts (Knipper *et al.* 2017).

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During the Taosi cultural period (*c.* 2300–1900 BC), societies in the Middle Yellow River Valley became increasingly patriarchal (Zhang 1987, 2000). Social differences between the sexes are apparent in burial customs at the Taosi and Xiajin cemeteries, where the large graves are all of males. Exogamous marriage systems are often observed within patrilineal clan societies resulting from a prohibition of marriage within the clan (Zhang 1987; Yu 2000). Female mobility for marriage generally occurs during adolescence and these individuals may be buried in the place to which they moved; however, their teeth maintain an isotopic record of their early childhood home. Analysis of the third molar (in which enamel forms between the age of eight and 16 years) of non-local individual M269 gives an outlying $\delta^{18}O$ value that suggest this female did not relocate to Xiajin until aged 16 or older. Such results are consistent with a system of female exogamy.

A survey of family genealogies in rural districts of Shanxi Province in the 1930s found that the majority of women who moved for marriage came from villages within 5km of their husbands' homes (Han 2017). During the Longshan period this 5km radius around a central settlement represented an area of self-sufficiency, within which production, intermarriage and ritual met the social needs of the population (Sun 2020). Multi-isotope analyses suggest that seven males (19.4%) from the cemetery grew up beyond the Xiajin area (within a 25km radius), but all still within the wider Taosi culture area. These males probably came from villages in the region near the central settlement. In contrast, of the 17 females with non-local isotopic signatures, only 10 moved from surrounding areas; at least seven females migrated to Xiajin from more distant regions. Why did these individuals travel so far, even from Shandong and the north-west highlands, when most exogamy occurred within 5km of the central settlement?

Shangshu Yaodian (尚书·尧典) records that emperor Yao (尧) married his two daughters to Shun (舜), who then inherited the throne from him. The archaeological discoveries of the Taosi city are highly consistent with the recorded "Pingyang, the capital of Yao", therefore many scholars believe that the Taosi city is the capital of Yao (Li 1985; Zhang 2010; He 2015). Historical studies suggest that the Yao belonged to the Huaxia (华夏) ethnic group. The Huaxia ethnic group is distributed in the Loess Plateau and the middle reaches of the Yellow River (Xu 1985). Shun was from the Dongyi (东夷) ethnic group (Li 1983; Dong 2000) which may be represented by the Dawenkou and Longshan culture in the Haidai region (Li 1983). Marriage between Shun and Yao's daughters united these two regions and created a political alliance between the Huaxia and the Dongyi that may have formed the foundations for the Erlitou state in the Central Plain.

Recent research on ancient DNA suggests that matrilineal genetics—measured through mitochondrial DNA—were relatively straightforward in Shandong before and during the Dawenkou period, but from the Longshan period onwards matrilineal genetics became more complex (Liu *et al.* 2021). Xue and colleagues (2022) have recently found that during the Longshan period Taosi populations were genetically similar to Shimao groups in northern Shaanxi and to the Longshan in Shandong. These results reflect the prevalence of inter-regional marriage during the Longshan period. Yu (2000) points out that around 5000 years ago chiefdom alliances grew in size, with female exogamy facilitating multi-generational political alliances between ruling families. Our results suggest that inter-regional alliances at

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Xiajin were not focused on just one region but rather extended over several areas, stretching from the coastal Shandong to the Gansu-Qinghai region in the west.

As early as the late fourth millennium BC, there was a network of long-distance cultural connectivity between the elites of different regions across China (Li 2015). During the Longshan period, however, these connections diversified to encompass not only the exchange of material culture and ideas but also political unions, leading to cross-regional alliances; marriages were an important means of maintaining these relationships. Bronze inscriptions of the Zhou Dynasty (1046–256 BC) record a large number of vassal state marriages (Falkenhausen 2006; Liu 2019) and this system of political alliance may already have been maturing in the late third millennium BC.

Beyond China, archaeological evidence from central Europe suggests that patrilocality and female exogamy were also widespread in that region during the Late Neolithic and Early Bronze Age of the third millennium BC (Haak *et al.* 2008; Müller *et al.* 2009; Sjögren *et al.* 2016). In Bronze Age Germany, females were often buried in locations that differ from the isotopic signatures of their childhood homes, while males show continuity of residence throughout their lives. At seven Late Neolithic/Early Bronze Age archaeological sites in the Lech River Valley, Germany, the majority of females not only have isotopic signatures indicative of post-adolescent migration to the area but also lack genetic kinship with other members of these communities; in contrast, biological kinship was apparent between contemporaneous male individuals (Knipper *et al.* 2017; Mittnik *et al.* 2019).

If the rise of patriarchal societies is viewed as a consequence of the acquisition of valuable resources—such as copper and tin, as well as the growing importance of war at the outset of the Bronze Age—then exogamy and political marriages can be seen to be common phenomena in the development of Eurasian societies. Marriage across distant regions not only wrought political alliances but also facilitated the rapid spread of knowledge, technologies and materials. Sheet-cutting jade techniques and bronze metallurgy pioneered elsewhere appear to have been adopted at the Taosi site at this time (Jaang 2015). Jade *zhang* blades, *yues* and knives found in Xiajin burials strongly resemble those of the highland Longshan groups (Deng 2017; Wang & Yang 2018) and a copper bell, unearthed at the Taosi site and the earliest example of a multi-cast copper artefact in the Central Plain (Hwang 2014), is compositionally and morphologically similar to artefacts from Shimao and Xichengyi sites (Wu 2018). Two of the females from Xiajin with low $\delta^{18}O$ values may have come from inland areas, such as northern Shaanxi, Gansu and Qinghai; evidence of smelting and numerous bronze artefacts dating to *c.* 2000 BC have been recovered from these areas (Gansu 2014; Sun *et al.* 2018). Just as female cross-regional migration may have aided the spread of metal technologies across central Europe, female exogamy in the Longshan period may have been an important medium for the spread of metallurgy from the north-west region to the Central Plains.

Conclusion

Multi-isotope analyses of the Taosi culture population at the cemetery of Xiajin indicate high levels of long-distance female mobility; most males either grew up in the immediate environment of Xiajin or within a radius of 25km. These results point to exogamous inter-

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regional marriages between different ethnic and cultural groups. During the Longshan period, states competed to form alliances for political, economic and military advantage, fuelling the expansion of long-distance networks. Marriage between elites played an important role in creating and maintaining these alliances. Alliance through marriage between the Huaxia and Dongyi at the end of the Longshan period not only facilitated the political and cultural integration of these regions but also possibly laid the foundations for the formation of the Erlitou state in the Central Plain.

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Supplementary material

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