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Re-examining the Chronological Framework and Human Occupation Pattern of the North Loess Plateau Using Bayesian Modelling

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Abstract

In 2012, the 400-hectare Shimao site (*2200–1700 cal BC*) in the North Loess Plateau was recognised as a late Neolithic stone fortification. Subsequently, radiocarbon dates from Shimao and neighbouring sites including Dakou, Xinhua and Zhukaigou became available. Given the lack of a comprehensive analysis of the chronological sequence in the region, this study conducts a thorough review of all published radiocarbon dates from the North Loess Plateau spanning 2800 to 1500 BC to reevaluate the current chronology and patterns of human occupation shifts. These dates were subjected to quality control measures, followed by calibration and Bayesian modelling using OxCal v 4.4.4. The analysis reveals a trend of human occupation shifting southward in the region; however, the radiocarbon sequence does not exhibit a clear pattern that aligns with the notion of distinct 'cultural period' transitions suggested by the conventional typo-chronological framework. In light of this, an alternative chronological framework is introduced, emphasising the timing of regional concentration and change of human occupation, to offer another possible interpretation for the transition. This revised framework highlights a dynamic transition that involves integration, reconfiguration and transformation among settlement groups within the region, allowing a coverage of multiple 'cultural groups' in various sub-regions during a single period.

Keywords North Loess Plateau · Shimao · Late Neolithic China · Bayesian chronological modelling · Human occupation shift · Radiocarbon dates

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Introduction

The 400-hectare site of Shimao (*2200–1700 cal BC*) was recognised as a late Neolithic stone fortification in 2011–2012. This extraordinary discovery overturned the prevailing notion of the sparsely populated North Loess Plateau (northern frontier of present-day China) and reignited scholarly curiosity about its role in the process leading to 'Chinese civilisation'. This region is characterised by stone fortification, which is uncommon in the Central Plain. Besides Shimao, several smaller fortifications, dating approximately between 2800 and 1500 BC (Institute of Archaeology, Chinese Academy of Social Sciences [CASS], 2010; Han, 2003, 2008; Sun, 2000, 2016; Tian & Guo, 2004; Wei & Cao, 1999), are scattered across the North Loess Plateau.

In recent decades, more radiocarbon dating of Shimao and some surrounding sites in the southern sector of the North Loess Plateau has become available and has been used to establish the chronological sequence of the entire region, (e.g. Dai, 2016a; Sun, 2016). Although some radiocarbon dates are considered, the currently adopted chronological sequence is primarily built upon ceramic typology, which assumes sites with similar ceramic types are contemporaneous. More importantly, a comprehensive analysis of the available radiocarbon (^{14}C) dates from the region is yet to be undertaken. Therefore, this paper amalgamates recent and older published dates, some predating the 2000s, all of which require recalibration using the most up-to-date calibration curve.

This paper aims to re-examine the conventional typo-chronology in the North Loess Plateau and evaluate the accuracy of the current chronology, which proposes a sequential or contiguous sequence rather than an overlapped one. This paper also reevaluates the hypothesis of a southward shift of human occupation within the region. An alternative chronological framework is developed to offer new insights into interpreting the shifting patterns and contextualising spatial and temporal changes across the region. This framework highlights the shifting pattern as a dynamic process, which is different from the conventional notion of transitions between distinct 'cultural periods'.

In the following, a background of Shimao and the broader region of the North Loess Plateau, the conventional chronological framework currently adopted, and some issues with the application of radiocarbon dates in the past will be provided. After that, the materials and methods will be discussed, followed by the results. Discussions focusing on (1) a re-evaluation of the current chronological framework, (2) the shifting pattern of human occupation, (3) a refined chronological framework, and (4) further implications of the findings for a broader region will be provided before the conclusion.

Shimao and the North Loess Plateau

The North Loess Plateau, covering southern and central Inner Mongolia, northern Shaanxi and northern Shanxi, is located within the northern part of the 'arc' region (Rawson, 2013, 2015), also known as the 'Northern Zone' (see Lin, 1986; Watson, 1971) (Fig. 1). The region is situated in a climate- and environment-sensitive area on

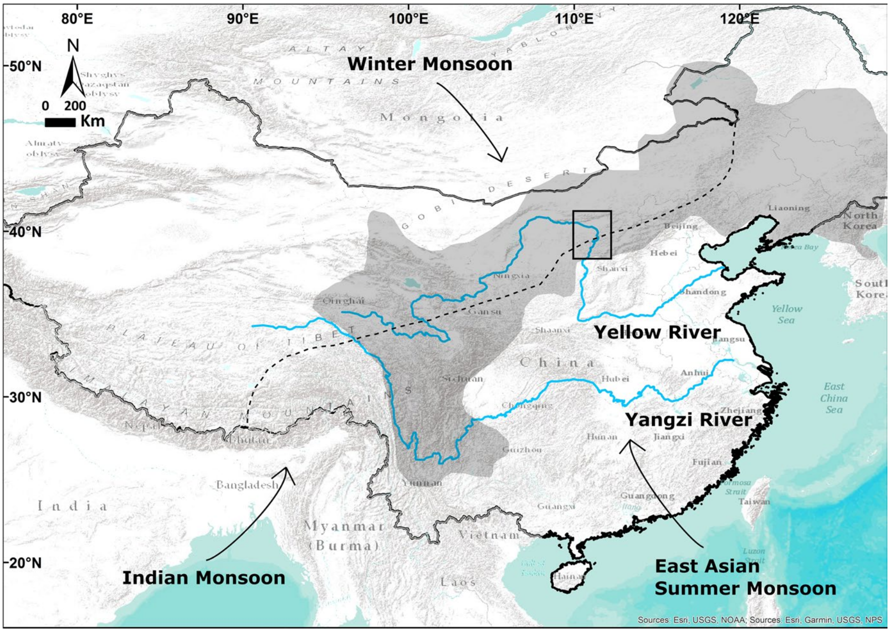

Fig. 1 The directions of sources of the East Asian Summer Monsoon, Indian Monsoon (southwest monsoon) and the westerlies (Liu et al., 2015, Fig. 1). The dashed line denotes the present location of the East AsianSummer Monsoon belt, according to Jiang and Liu (2007). The rectangular box denotes the North Loess Plateau. The shaded area depicts the coverage of the 'arc' defined by Rawson (2013), which refers to the steppe and mountain regions 'from Sichuan in the west, through Qinghai and the Hexi Corridor in Gansu, across parts of Shaanxi, Shanxi, and Inner Mongolia, to northern Hebei and Chifeng in Liaoning in the east', in which bronze knives, herded animals and pastoralism were common. The concept of the 'arc' originally came from the Chinese term '*banyuexing didai'* in Tong Enzheng (1987), which refers to the region covering the plateau area in Qinghai, Ningxia, Inner Mongolia, Liaoning, Jilin, eastern Tibetan Plateau and Sichuan, in which similar environmental conditions and features of using microliths and stone-lined tombs were shared. The Chinese term has been translated by Rawson (2017) as the 'arc'

the fringes of the East Asian Summer Monsoon belt, which brings significant precipitation to a large part of China during the summer months (Fig. 1). Additionally, the Indian Monsoon and winter monsoon bring precipitation in southwest China during the summer and a small amount of moisture to northwestern and northern China in winter, respectively (Fig. 1).

Archaeological sites in the North Loess Plateau can be categorised into four main regional groups: those located south of Daqing Mountain, Daihai Lake, Yulin and Weifen River valley, and Qingshui River valley and the Ordos city). Based on typo-chronological frameworks developed from the sequences outlined in the studies referenced in Table 1, the current four-period chronology is associated with the Ashan III, Laohushan, Shimao, and Dakou (and Zhukaigou) 'cultures' and 'cultural groups' (Fig. 2 and Tables 1 and 2).

In this paper, the groups south of Daqing Mountain and Daihai Lake are considered to be part of the northern sector of the North Loess Plateau, while the Qingshui River valley and the Ordos city fall within the middle sector of the region. Most sites

Table 1 A summary of the cultural sequences in different areas of the North Loess Plateau according to the ceramic typology suggested by CASS (2010), Han (2003, 2008), Sun (2000, 2016), Tian and Guo (2004) and Wei and Cai (1999)

Sun (2000)	Wei and Cao (1999)	Sun (2016)	CASS (2010)	Tian and Guo (2004)	Han (2003, 2008)	Conventional period
3000–2600 BC Ashan III	Before 3000 BC Haishengbulang	3000–2800 BC Haishengbulang	3300–2800 BC Haishengbulang	3500–3000 BC Haishengbulang	3500–2500 BC Haishengbulang	Late Yangshao
	After 2700 BC Ashan III	2800–2500 BC Ashan III	2800–2500 BC Ashan III	Around 2800 BC Ashan III/ Laohushan	3000–2500 BC Ashan III	Yangshao-Longshan transition
	Around 2500 BC Laohushan	2500–2300 BC Laohushan	2500–2300 BC Laohushan	2500–2300 BC Laohushan	2500–1900 BC Laohushan/ Dakou	Early Longshan
		2300–1800 BC Shimao	Around 2000 BC Dakou I/ Zhukaigou	Around 2000 BC Dakou II		Late Longshan
				Around 1800 BC Zhukaigou	1900–1500 BC Zhukaigou	Erlitou

from these three areas were discovered and excavated between the 1970s and 1990s (Neimenggu, 1994, 1997). In contrast, the groups Yulin and Weifen River valley are considered part of the southern sector of the region, with site discoveries and excavations being more recent, mainly conducted from the 1990s onwards. Examples include Zhaimao (Shaanxisheng, 2002), Xinhua (Shaanxisheng & Yulinshi, 2005) and Zhaishan (Shaanxisheng & Yulinshi, 2009).

Current Chronological Framework

The conventional typo-chronology for the North Loess Plateau is outlined in Table 1 (CASS, 2010; Han, 2003, 2008; Sun, 2000, 2016; Tian & Guo, 2004; Wei & Cao, 1999) The transition indicated in this framework denotes periods where one 'culture' or 'cultural group' replace another, with a single dominant 'culture' prevailing during each period. The chronological sequence posits the existence of four distinct periods defined by 'cultures' in the region from 3000 to 1500 BC, with these periods presumed to have developed one after the other (Table 2). Although typo-chronological sequences are valuable for establishing relative dating frameworks, a more precise chronology can be achieved by considering radiocarbon data. Considering both approaches allows for a more reliable estimation of chronological sequences. While the concept of 'cultures' and 'cultural groups' used in archaeology can be problematic, as ceramic typologies alone might not fully represent cultural and ethnic identities or political affiliations (Hein, 2016; Jaffe & Hein, 2020), the terms 'cultures' or 'cultural groups' used in this paper solely refers to settlement groups that shared similarities in ceramic types, built environment and material culture. The terminology is not extended to imply ethnic identity, sociopolitical affiliations, or fixed, homogeneous and bounded groups with distinct shared cultural beliefs.

Problems with the use of Radiocarbon Dates

Significant challenges exist regarding the accuracy of radiocarbon dating and the reliability of past determinations. These issues encompass the possibility of inaccurate calibration of dates. Although the first radiocarbon laboratory was established in 1965 in China, there were still no standardised calibration methods and official calibration curve for radiocarbon determinations back in the 1970s (Xia, 1977). It was not until 1985 that the first high-resolution tree-ring calibration curve was developed, with official recognition following in 1988 (Institute of Archaeology, Chinese Academy of Social Sciences [CASS], 1992, pp. 1–2). Subsequently, different versions of calibration curves have been produced over time, resulting in the most recent version known as IntCal20 (Reimer et al., 2020). For this reason, radiocarbon dates documented in early times, such as those in CASS (1992), require recalibration.

Another issue arises from the use of ^{14}C dates in literature. The radiocarbon dates were sometimes used as supplementary evidence to bolster the typo-chronological sequence. These dates were sometimes chosen to complement the existing cultural sequence. Another related issue is that the half-life used for calculating the cali-

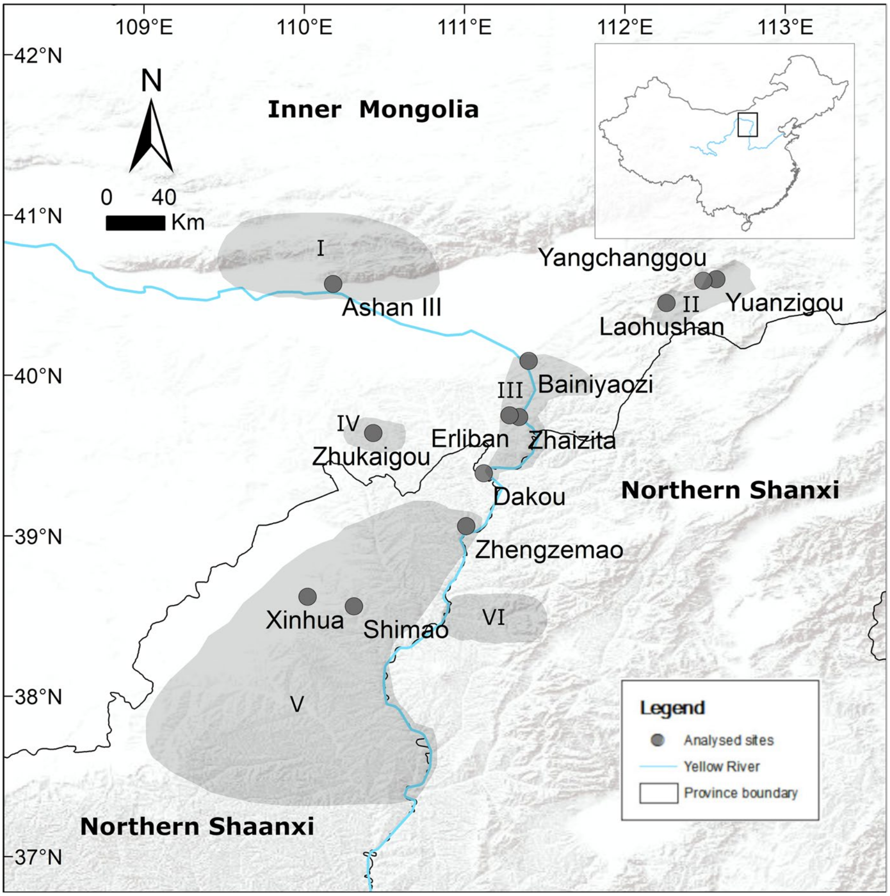

Fig. 2 The four major areas and analysed sites in the North Loess Plateau discussed in this paper. Area one: I. south of Daqing Mountain (Ashan III culture), area two: II. Daihai Lake (Laohushan culture), area three: III. Qingshui River valley (Dakou culture) and IV. Ordos (Zhukaigou culture), area four: V. Yulin and VI. Weifen River valley (Shimao culture). The coordinates are shown on the side of the map

Table 2 The currently accepted chronological framework for the North Loess Plateau according to the sequences outlined in Table 1

Period	Typo-chronology (BC)	'Cultural period' in the North Loess Plateau	Conventional period
1	2800–2500	Ashan III	Yangshao–Longshan transition
2	2500–2300	Laohushan	Early Longshan
3	2300–1800	Dakou I/Shimao	Late Longshan
4	1800–1500	Early to middle Zhukaigou	Erlitou

brated dates was not specified. This becomes problematic when both the 5568 and 5730 half-lives were used, even after the new half-life was established in the 1960s. Although the conventional use of 5568 half-life persists, both values are found in current literature. As a result, the omission of the half-life may introduce uncertainty and potential errors in determining absolute dates. The discrepancies between these half-lives could lead to an offset of 100 years or more in the final date estimations (Godwin, 1962).

In some other cases, the use of ^{14}C dates lacks proper citation of sources, references, or laboratory identifiers and details of dated materials. When crucial information such as uncalibrated age and quality assessment data such as C:N atomic ratios for bone samples are missing, these dates are not suitable for analysis. Following conventions outlined by Millard (2014), it is essential to report radiocarbon determinations accurately, including the ^{14}C yr BP or fractionation-corrected fraction modern values and the laboratory codes and pertinent details. Therefore, quality control checks will be conducted before analysing radiocarbon dates.

Materials and Methods

Quality Assessment

Thirty-two ^{14}C ages derived from 12 archaeological sites were sourced from Chinese radiocarbon dating reports (Anonymous, 1996; CASS, 1992, 1993; Yuan et al., 1994) and journal articles (Atahan et al., 2014; Chen et al., 2015, 2017; Shaanxisheng & Yulinshi, 2005; Sun et al., 2018). These dates were categorised into specific 'cultural periods' based on contextual information obtained from both dating and excavation reports (Table 3). In some cases, samples were collected without meticulous consideration of their stratigraphic context. In these cases where their 'cultural periods' are uncertain a sensitivity test was conducted by comparing models that either included or excluded dates with ambiguous or unknown 'cultural periods'. This test revealed that the models were largely insensitive to the inclusion of such dates when similarities were observed.

The radiocarbon ages analysed in our study include only the dates accompanied by detailed laboratory prefixes, sample sources and dating methods. The sample sources consist of wood charcoal, bones, and, in one case, a lime floor layer. Notably, certain charcoal samples were potentially affected by the 'old wood' problem (Dee & Bronk Ramsey, 2014), due to evidence of existing forests in the North Loess Plateau during the Palaeolithic period (Yang, 2000). To address this potential problem, a charcoal outlier model was incorporated into the phase modelling process to address any potential outliers (Bronk Ramsey, 2009a; Dee & Bronk Ramsey, 2014).

Furthermore, only bone samples featuring samples which had collagen with a C:N atomic ratio between 2.9 and 3.5 were accepted (Brock et al., 2012; van Klinken, 1999). The date generated from the lime material was also included, even though lime is susceptible to the issue of external carbon atom exchange (Pesce & Ball, 2012). Sensitivity testing showed that the outcomes between the models including and excluding this date were similar. The general outlier model was applied in the phase modelling to identify and refine potential outliers (Bronk Ramsey, 2009a).

Modelling Process

We used OxCal 4.4.4 to analyse the radiocarbon corpus, using the IntCal20 calibration curve (Bronk Ramsey, 2009b, 2021; Reimer et al., 2020). We undertook the following analyses: (1) calibration of the individual dates by area, (2) kernel density estimation (KDE) modelling, (3) phase modelling, (4) spatiotemporal plots of dates on time-gradient maps and using coloured animation. All the modelling CQL codes used in the analyses process are included in Online Resource 1.

The KDE approach is useful as a tool for visualising the shape of a dataset's underlying distribution, either with (KDE_Model) or without (KDE_Plot) a Bayesian underpinning approach (Bronk Ramsey, 2017). We use it here to show the distribution of all the ^{14}C dates from the four major areas in the North Loess Plateau (Fig. 2). Subsequently, to probe the data in more detail we explored the precise start and end dates of individual sites using simple phase models (Online Resources 2 and 3). Five sites that have more than one date measurement are considered here.

In the phase modelling, the dates were assigned to four clusters of results, based on known information, as recorded in Table 3. We tested various priors on the data, considering overlapping, sequential and contiguous models, as well as using outlier models. We wanted to explore the effect of different priors on the posterior results and the comparisons between the new results and the previous archaeological date ranges of the four periods in Table 2. The dates of Dakou1, Dakou2, Zhukaigou7 and Zhukaigou8 were omitted because they consist of several phases and their 'cultural' context is unknown.

The agreement indices in OxCal were used to assess the reliability of fit of the phase models (Bronk Ramsey, 1995). The agreement indices for each model run indicated a good agreement between the priors and the posterior results (see supplementary information). After the testing of different phase models and sensitivity testing, we found that while the overlapping model can be established, both the sequential and continuous models can only be established when the charcoal outlier model is also applied.

The last part of the analysis focuses on the spatial distribution of the dates. This involves the display of unmodelled calibrated dates on a 3 × 5 time-gradient map and a coloured animation presented in Online Resource 6. One reason for conducting this analysis is to test the presumed 'cultural periods' across the North Loess Plateau by grouping the four presumed periods in different colours. This helps to determine whether the four presumed periods developed in sequence, or a different pattern can be identified. Another reason is to understand the shift in human occupation across the region, as indicated by the concentration of the dates over time and space. The final reason is that the transition pattern of dates and human occupation, together with the unmodelled results from the analysis of calibration of dates by area, provides useful information for adjusting the current framework.

Table 3 The details of the radiocarbon dates analysed in this paper

Laboratory code	Analysis code	Area	Materials	Sample reference and 'cultural' context	Period	Dating method	C:N	^{14}C age BP	Reference
BK87072	Yuanzigou1	Daihai Lake	Charcoal	F3042	2	Conventional	N/A	4772±100	Yang (2000)
WB84-78	Zhukaigou1	Ordos city	Charcoal	II T228(4)	3	Conventional	N/A	4679±80	CASS (1992, pp. 59–60)
ZK1184	Ashan1	South of Daqing Mountain	Charcoal	II(3)H5	1	Conventional	N/A	4655±70	CASS (1992, pp. 60–61)
BK87069	Yuanzigou2	Daihai Lake	Charcoal	F3043	2	Conventional	N/A	4496±90	Yang (2000)
BK92087	Zhengzemao1	Yulin	Charcoal	丙區T51 F4	1	Conventional	N/A	4349±60	Anonymous (1996)
BK79053	Zhukaigou2	Ordos city	Charcoal	III T23(5)	3	Conventional	N/A	4325±90	CASS (1992, pp. 59–60)
BK87071	Yuanzigou3	Daihai Lake	Charcoal	F3045	2	Conventional	N/A	4259±90	Yang (2000)
ZK1185	Ashan2	South of Daqing Mountain	Charcoal	I(3)H39	1	Conventional	N/A	4218±70	CASS (1992, pp. 60–61)
BK81005	Ashan3	South of Daqing Mountain	Charcoal	H8	1	Conventional	N/A	4208±80	CASS (1992, pp. 60)
ZK2242	Zhaizita1	Qingshui River valley	Charcoal	T4(2) H48	2	Conventional	N/A	4174±60	CASS (1992, p. 63)
BK81004	Ashan4	South of Daqing Mountain	Charcoal	H14	1	Conventional	N/A	4121±80	CASS (1992, pp. 60–61)
ZK2642	Bainiyaozi1	Qingshui River valley	Charcoal	BD, pp. F3	1	Conventional	N/A	4110±107	CASS (1993)
BK87073	Yuanzigou4	Daihai Lake	Charcoal	Y3005	2	Conventional	N/A	4062±100	Yang (2000)
BK87070	Yuanzigou5	Daihai Lake	Charcoal	F3041	2	Conventional	N/A	4004±70	Yang (2000)
WB84-44	Laohushan1	Daihai Lake	Charcoal	Kiln Y3	2	Conventional	N/A	3761±70	CASS (1992, p. 59)
ZK2241	Erliban1	Qingshui River valley	Charcoal	T2(6)下H10	3	Conventional	N/A	3703±65	CASS (1992, p. 62)
SI2940/OZO945	Dakou1	Qingshui River valley	Human bone	Unknown	Unknown	Conventional	3.5	3780±40	Atahan et al. (2014)
BA121536	Shimao1	Yulin	Charcoal	F1, pp.1	3	AMS	N/A	3730±25	Sun et al. (2018, p. 38)
SI2942/OZO946	Dakou2	Qingshui River valley	Human bone	Unknown	Unknown	Conventional	3.4	3720±45	Atahan et al. (2014)
OZM232	Zhukaigou7	Ordos city	Human bone	Unknown	Unknown	AMS	3.2	3680±40	Atahan et al. (2014)
SI2936/OZO954	Shimao2	Yulin	Human bone	Unknown	3	AMS	3.2	3570±50	Atahan et al. (2014)
SI2938/OZO956	Shimao3	Yulin	Human bone	Unknown	3	AMS	3.5	3555±45	Atahan et al. (2014)

Table 3 (continued)

Laboratory code	Analysis code	Area	Materials	Sample reference and 'cultural' context	Period	Dating method	C:N	^{14}C age BP	Reference
SI1595/OZN206	Xinhua1	Yulin	Human bone	Unknown	3	AMS	3.2	3555 ± 35	Atahan et al. (2014)
BA121534	Shimao4	Yulin	Lime floor	F6:1	3	AMS	N/A	3545 ± 30	Sun et al., (2018, p. 38)
SI2937/OZO955	Shimao5	Yulin	Human bone	Unknown	3	AMS	3.4	3540 ± 45	Atahan et al. (2014)
WB84-79	Zhukaigou3	Ordos city	Charcoal	I(4)H1058	3	Conventional	N/A	3416 ± 70	CASS (1992, pp. 59–60)
SI2935/OZO953	Shimao6	Yulin	Human bone	Unknown	3	AMS	3.4	3515 ± 50	Atahan et al. (2014)
OZM221	Zhukaigou8	Ordos city	Human bone	Unknown	Unknown	AMS	3.2	3500 ± 40	Atahan et al. (2014)
BK89121	Yangchanggou1	Daihai Lake	Charcoal	88楊F2, pp.100	4	Conventional	N/A	3362 ± 70	Yuan et al. (1994)
BK80028	Zhukaigou6	Ordos city	Charcoal	V(2)H5018	4	Conventional	N/A	3324 ± 70	CASS (1992, pp. 59–60)
Zhukaigou4	Zhukaigou4	Ordos city	Charcoal	I(3) H1071, 1073	4	Conventional	N/A	3222 ± 70	CASS (1992, pp. 59–60)
WB84-77	Zhukaigou5	Ordos city	Charcoal	I(3)H1055	4	Conventional	N/A	3192 ± 85	CASS (1992, pp. 59–60)

The 'period' here corresponds to the information listed in Table 2. All radiocarbon dates in this table were calculated using the 5568 BP 'Libby' half-life

Results

The results presented in this section include: (1) the calibration of single dates, (2) the KDE modelling, (3) the phase modelling, and (4) the spatiotemporal plots of dates.

Calibration of Single Dates

The calibration of dates grouped by the four areas within the North Loess Plateau is presented in Fig. 3 and Table 4. This is a useful way of visualising the broad data-

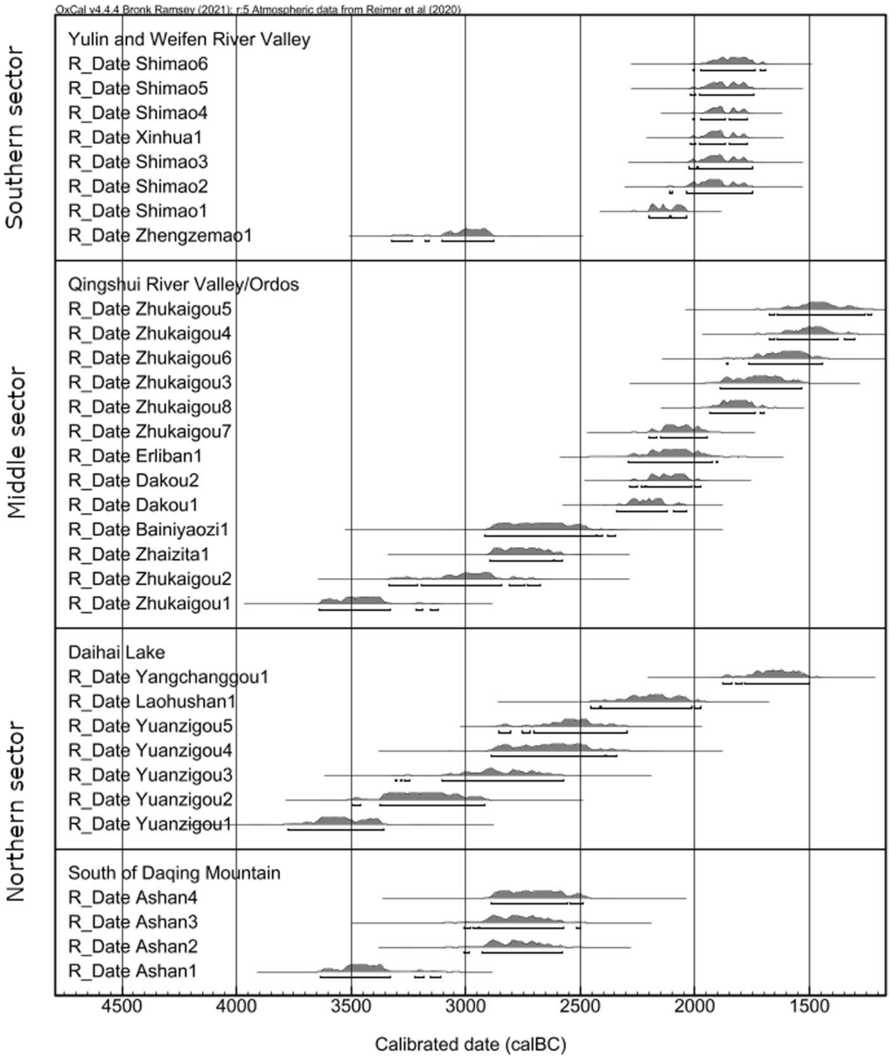

Fig. 3 The distribution of unmodelled calibrated dates grouped in the four areas within the North Loess Plateau. The dates are shown in cal BC with 95.4% probability indicated by the lines under the date distributions

Table 4 The unmodelled calibration of dates grouped in the four areas within the North Loess Plateau

Code	Calibrated dates 95.4% (BC)
Yulin	
Shimao6	2011–1693
Shimao5	2018–1746
Shimao4	2010–1769
Xinhua1	2021–1770
Shimao3	2026–1750
Shimao2	2113–1751
Shimao1	2203–2035
Zhengzemao1	3323–2879
Qingshui River valley and Ordos	
Zhukaigou5	1676–1231
Zhukaigou4	1678–1304
Zhukaigou6	1864–1445
Zhukaigou3	1892–1533
Zhukaigou8	1934–1695
Zhukaigou7	2198–1947
Erliban1	2290–1901
Dakou2	2284–1974
Dakou1	2344–2039
Bainiyaozi1	2916–2349
Zhaizita1	2895–2581
Zhukaigou2	3337–2675
Zhukaigou1	3642–3121
Daihai Lake	
Yangchanggou1	1878–1499
Laohushan1	2454–1976
Yuanzigou5	2857–2297
Yuanzigou4	2889–2344
Yuanzigou3	3307–2574
Yuanzigou2	3493–2915
Yuanzigou1	3774–3356
South of Daqing Mountain	
Ashan4	2888–2488
Ashan3	3011–2502
Ashan2	3008–2577
Ashan1	3635–3112

The dates are shown in cal BC with 95.4% probability. The table corresponds to the results shown in Fig. 3

set. These show that the dates from the south of Daqing Mountain and Daihai Lake concentrate between *3770 and 2300 cal BC*, while four dates from the Qingshui River valley and one date from Yulin also fall within this period. The dates from the Qingshui River valley and Yulin concentrate between *2300 and 1230 cal BC*, and two dates from Daihai Lake also fall within this period. This pattern suggests that the dates from the northern sector are generally earlier than those from the southern sector. The dates from the middle sector cover the entire period from around *3770 to 1230 cal BC*, with a significant overlap between the northern sector between *3770 and 1900 cal BC* and the southern sector between *2200 and 1690 cal BC*.

KDE Modelling

The KDE model approach enables a more detailed analysis of the radiocarbon results. The model shows that the dates are concentrated in one small peak and two major peaks (Fig. 4). The small peak is between *3800 and 3200 cal BC*, but this only covers four dates. The first major peak is between *3200 and 2400 cal BC*, and the second is between *2300 and 1300 cal BC*. This indicates that the analysed dates appear to be divided into one small cluster and two major clusters of results.

Phase Modelling

The overlapping model can stand alone, while both the sequential and contiguous models can only be established if the charcoal outlier model is applied, which treats all the charcoal-sampled dates as outliers. This suggests that both the overlapping model and sequential or contiguous models can be valid, with the precondition for the latter being that early dates were affected by the 'old wood' problem.

The overlapping model, shown in Fig. 5 and the corresponding data in Table 5, reveals that dates from presumed periods 1, 2 and 3 overlap between *3640 and 2680 cal BC*; periods 2 and 3 overlap between *2450 and 1900 cal BC*; and periods 3 and 4 overlap between *2110 and 1380 cal BC*. The result shows that, if the 'cultures' or 'cultural groups' were overlapped, the dates of period 1 would fall between *3620 and 2480 cal BC*, period 2 falls between *3710 and 2040 cal BC*, period 3 falls between *3630 and 1560 cal BC*, and period 4 falls between *1740 and 1380 cal BC.*

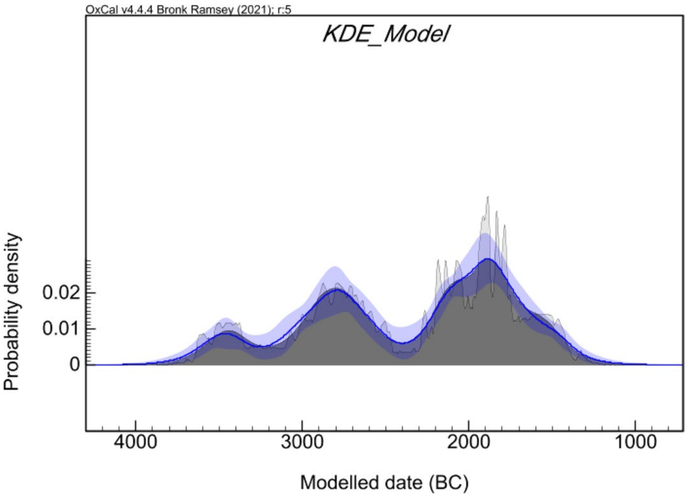

Fig. 4 The KDE model that shows the underlying distribution of the dates described in this paper. The higher peaks show a higher probability density, indicating that the dates are more concentrated at these points. The dark grey distribution represents the sampled KDE estimated distribution. The light grey distribution is the sum distribution, an alternative method for date summary in OxCal, which has not been smoothed by the KDE method. The blue line and the lighter blue overlay show the mean and one standard deviation for the snapshots of the KDE distribution generated during the Markov chain Monte-Carlo (MCMC) process, respectively (Bronk Ramsey, 2017)

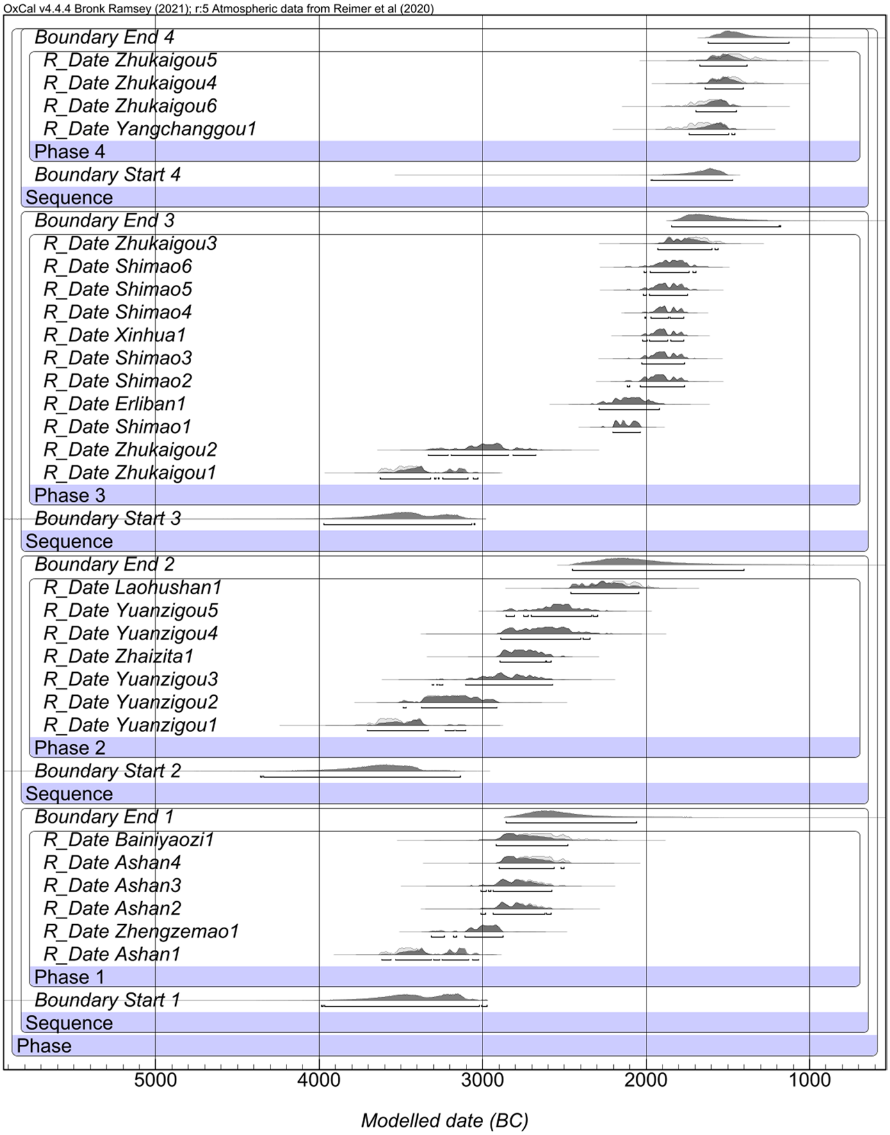

Fig. 5 The modelled calibrated dates in the overlapping model. The transparent distribution shows the unmodelled calibrated dates. The solid distribution shows the modelled and/or refined dates. The dates are shown in cal BC with 95.4% probability indicated by the lines under the date ranges

The contiguous model is shown in Fig. 6 and the corresponding data are shown in Table 6. The result of this model, which incorporates both general and charcoal outlier models, fits well with the analysed dates and reveals the possible date ranges of the four presumed ‘cultural’ periods (Table 2). The highlighted dates in red denote the dates coming from charcoal samples, and the applied charcoal outlier model assumes that these dates are all subjected to the ‘old wood’ problem, which could reveal ear-

Table 5 The modelled dates from the overlapping model

Code	Unmodelled date ranges 95.4% (BC)	Modelled date ranges 95.4% (BC)
Boundary End 4		1427–849
Period 4		
Zhukaigou5	1676–1231	1671–1383
Zhukaigou4	1678–1304	1640–1407
Zhukaigou6	1864–1445	1694–1449
Yangchanggou1	1878–1499	1736–1458
Boundary Start 4		1765–1282
Boundary End 3		1856–1557
Period 3		
Zhukaigou3	1892–1533	1931–1563
Shimao6	2011–1693	2012–1696
Shimao5	2018–1746	2018–1747
Shimao4	2010–1769	2009–1769
Xinhua1	2021–1770	2021–1771
Shimao3	2026–1750	2026–1764
Shimao2	2113–1751	2114–1764
Erliban1	2290–1901	2290–1920
Shimao1	2203–2035	2203–2035
Zhukaigou2	3337–2675	3331–2674
Zhukaigou1	3642–3121	3628–3029
Boundary Start 3		2166–1699
Boundary End 2		2363–798
Period 2		
Laohushan1	2454–1976	2462–2043
Yuanzigou5	2857–2297	2856–2299
Yuanzigou4	2889–2344	2889–2346
Zhaizita1	2895–2581	2895–2581
Yuanzigou3	3307–2574	3309–2573
Yuanzigou2	3493–2915	3488–2915
Yuanzigou1	3774–3356	3706–3102
Boundary Start 2		4195–2163
Boundary End 1		2770–1386
Period 1		
Bainiyaozi1	2916–2349	2918–2479
Ashan4	2888–2488	2900–2501
Ashan3	3011–2502	3010–2579
Ashan2	3008–2577	3010–2584
Zhengzemao1	3323–2879	3316–2877
Ashan1	3635–3112	3620–3023
Boundary Start 1		3722–2375

The dates are shown in cal BC with 95.4% probability. The table corresponds to the results shown in Fig. 5

lier date ranges. After the date adjustment carried out by the charcoal outlier model, the results show that, if these 'cultures' or 'cultural groups' are deemed to have developed in a contiguous manner, the dates for period 1 would fall between *3540 and 2150 cal BC,* period 2 would fall between *2300 and 1840 cal BC*, period 3 would fall

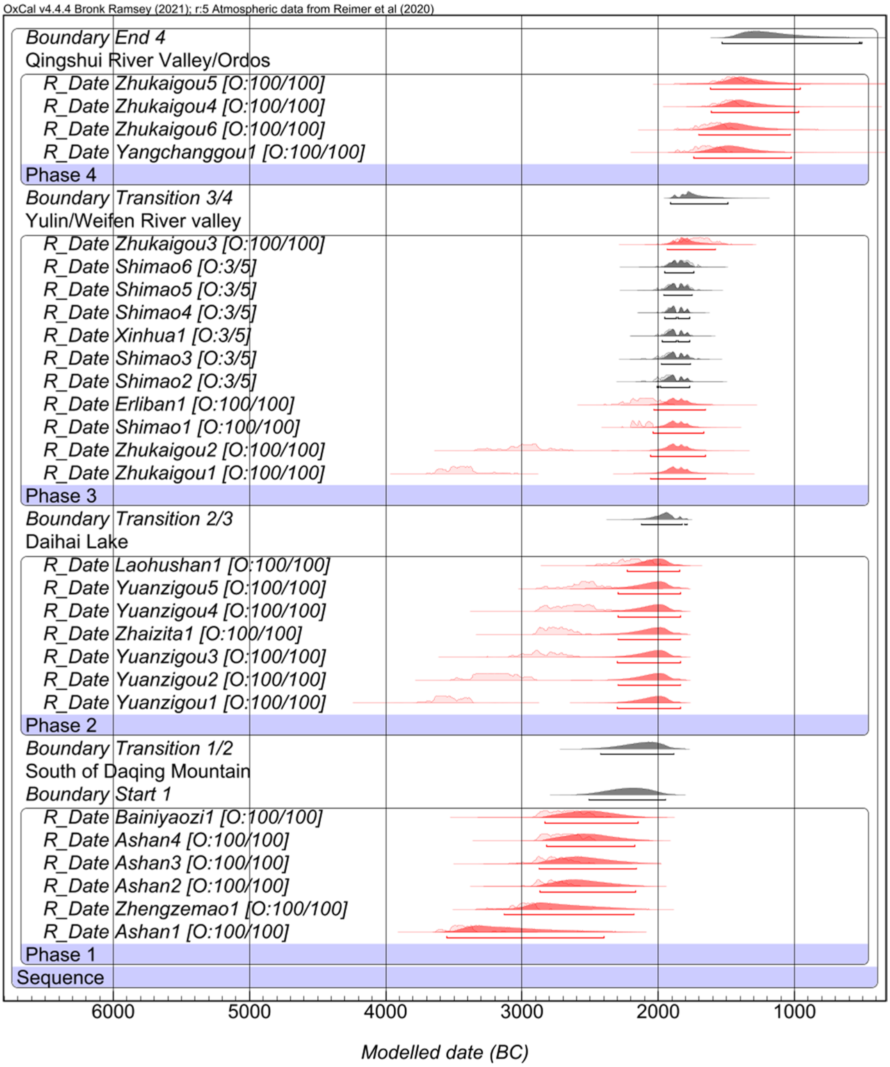

Fig. 6 The distribution of dates in the contiguous model with general and charcoal outlier models. The transparent distribution shows the unmodelled dates, while solid distribution shows the modelled and/or refined dates. The red colours denote the dates deriving from charcoal samples. The letter 'O' denotes the prior and posterior probability of the measurement being an outlier; for general outliers, dates with a posterior probability higher than the prior probability 5% are considered outliers. The dates are shown in cal BC with 95.4% probability, as indicated by the brackets under the date ranges

Table 6 The unmodelled and modelled calibrated dates from the contiguous model with charcoal and outlier models

Code	Unmodelled dates 95.4% (BC)	Modelled dates 95.4% (BC)
Boundary End 4		1530–506
Period 4		
Zhukaigou5	1676–1231	1619–957
Zhukaigou4	1678–1304	1611–973
Zhukaigou6	1864–1445	1705–1033
Yangchanggou1	1878–1499	1738–1028
Boundary Transition 3/4		1913–1492
Period3		
Zhukaigou3	1892–1533	1935–1584
Shimao6	2011–1693	1953–1742
Shimao5	2018–1746	1961–1751
Shimao4	2010–1769	1953–1771
Xinhua1	2021–1770	1972–1771
Shimao3	2026–1750	1978–1765
Shimao2	2113–1751	2011–1768
Erliban1	2290–1901	2035–1656
Shimao1	2203–2035	2041–1664
Zhukaigou2	3337–2675	2057–1652
Zhukaigou1	3642–3121	2057–1652
Boundary Transition 2/3		2121–1786
Period 2		
Laohushan1	2454–1976	2226–1841
Yuanzigou5	2857–2297	2294–1837
Yuanzigou4	2889–2344	2296–1837
Zhaizita1	2895–2581	2297–1836
Yuanzigou3	3307–2574	2300–1836
Yuanzigou2	3493–2915	2298–1836
Yuanzigou1	3774–3356	2300–1836
Boundary Transition 1/2		2424–1886
Period 1		
Bainiyaozi1	2916–2349	2830–2147
Ashan4	2888–2488	2821–2171
Ashan3	3011–2502	2873–2162
Ashan2	3008–2577	2872–2168
Zhengzemao1	3323–2879	3129–2179
Ashan1	3635–3112	3550–2399
Boundary Start 1		2510–1947

The dates are shown in cal BC with 95.4% probability. The table corresponds to the results shown in Fig. 6

between *2070 and 1570 cal BC*, and period 4 would fall between *1730 and 970 cal BC*. The result of the sequential model is similar to that of the contiguous model, and they are presented in Online Resources 4 and 5.

Spatiotemporal Plots

We plotted the data spatially according to the four presumed 'cultural periods' (Fig. 7; the coloured animation is presented in Online Resource 6). This visualisation, which is without any chronological modelling, suggests that dates from the northern sector are somewhat earlier, ranging between *3520 and 2440 cal BC*, while dates from the southern sector are relatively later, ranging between *2130 and 1820 cal BC*. Dates from the middle sector overlap with those in both the northern and southern sectors across the entire period.

The dates attributed to period 1 (blue circles), period 2 (green circles) and period 3 (purple circles) show significant overlap spanning *3760 and 3380 cal BC* (Online Resource 6). Within this timeframe, dates associated with periods 1 to 2 notably overlap between *3520 and 2440 cal BC*, while dates from periods 2 and 3 exhibit notable overlap between *2280 and 2130 cal BC*. Dates linked to periods 3 and 4 (red circles) notably overlap between *1980 and 1820 cal BC*, with period 4 dates extending to around *1360 cal BC*. The spatial distribution indicates that dates from periods 1, 2, and 3 before *2280 cal BC* are concentrated in the northern and middle sectors. Beyond *2280 cal BC*, dates from periods 3 and 4 overlap and are concentrated in the southern and middle sectors. Meanwhile, dates from periods 1 and 2 can be contiguous with those from periods 3 and 4.

Discussion

A Review of the Conventional Chronological Framework

The radiocarbon dating suggests two potential scenarios. One possibility is an overlap in the settlements across the four periods. The other is that it corresponds with the typo-chronological framework for a contiguous or sequential development of 'cultures' as outlined in Tables 2 and 3, under the condition that all the charcoal-sampled dates are affected by the 'old wood' problem. Regardless of which scenario is the case, the calibration of individual dates does reveal a concentration in two main periods: one earlier and one later (Fig. 3). If excluding the four dates (Ashan1, Yuanzigou1, Yuanzigou2 and Zhukaigou1) falling between *3640 and 2920 cal BC,* where the influence of the potential 'old wood' problem cannot be addressed, the dates from the south of Daqing Mountain and Daihai Lake predominantly fall within the earlier range of *3310 and 2300 cal BC*, while dates from Yulin and Qingshui River valley mainly fall within the later range of *2340 to 1230 cal BC* (Table 3).

Similarly, the KDE model indicates two main periods: one between *3200 and 2400 cal BC* and another between *2300 and 1300 cal BC* (Fig. 4). Although there is a small cluster of dates centred around *3500 cal BC*, its relevance to the study period is uncertain, as it predates the study period. The spatial distribution of dates, which is

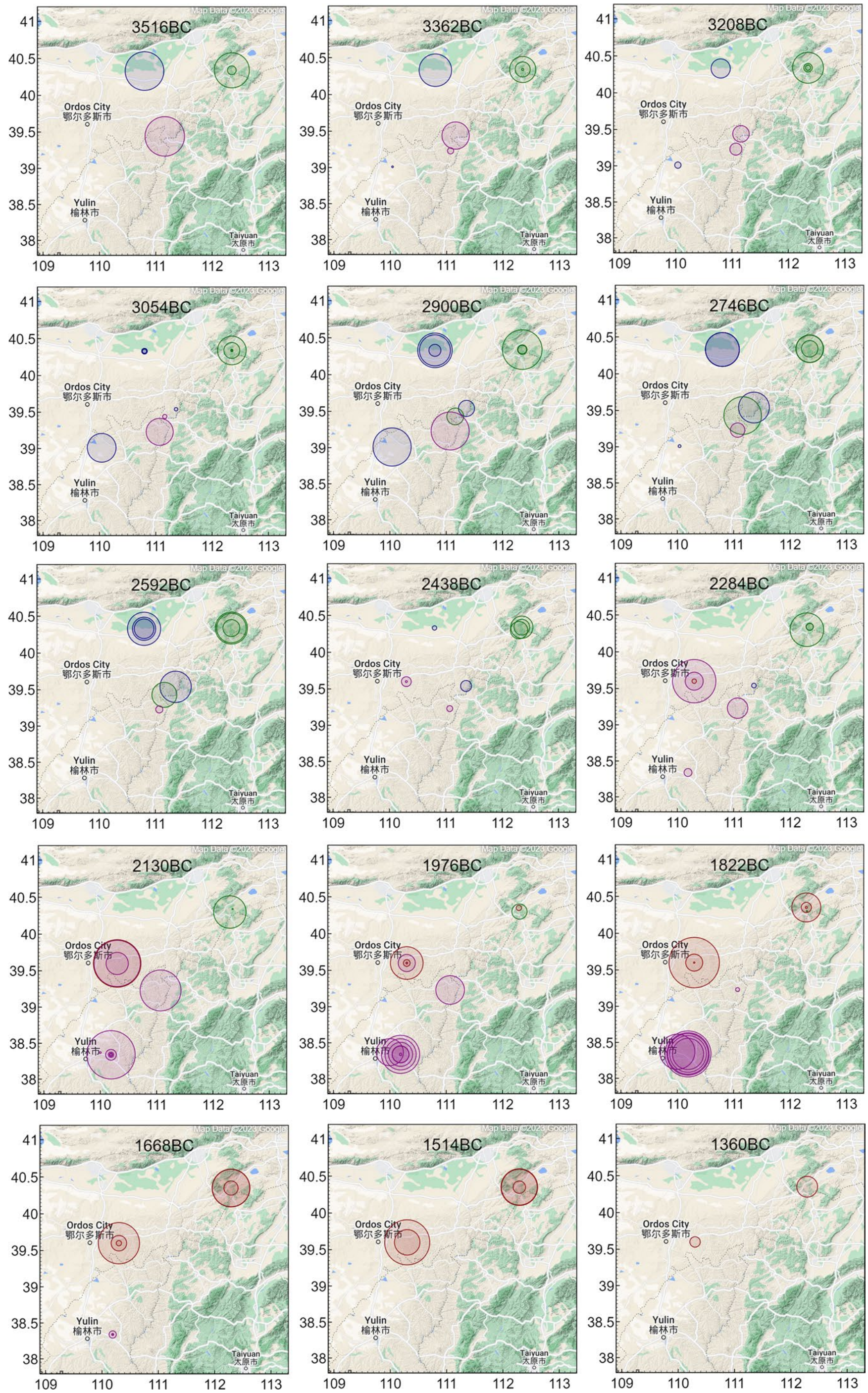

Fig. 7 The spatial distribution of calibrated dates across the North Loess Plateau. Each circle represents the date distribution of each calibrated date

not modelled, reveals that the presumed periods overlap rather than being sequential or contiguous, with dates from the northern sector generally preceding those from the southern sector (Fig. 7 and Online Resource 6).

Taken together, these findings suggest that dates from the North Loess Plateau can be categorised into two major periods: one around *3200–2300 cal BC* and the other around *2300–1200 cal BC*. This more or less shows a chronological order for the settlement groups in the region.

The overlapping modelling result is consistent with the aforementioned ones, indicating that the dates from the presumed periods 1, 2 and 3 are likely to overlap between *3320 and 1920 cal BC* (when excluding the uncertain early dates), and periods 3 and 4 between *2110–1380 cal BC* (Fig. 5 and Table 5).

The alternatives are the sequential and contiguous models, on the condition that all the charcoal-sampled dates are affected by the 'old wood' problem (Fig. 6, Table 6 and Online Resources 4 and 5). In the contiguous model, the dates for period 1 fall between *3540 and 2150 cal BC*, period 2 between *2300 and 1840 cal BC*, period 3 between *2070 and 1570 cal BC*, and period 4 between *1730 and 970 cal BC* (Fig. 6). Similarly, the sequential model shows that the dates for period 1 fall between *2820 and 2320 cal BC*, period 2 between *2530 and 2000 cal BC*, period 3 between *2000 and 1710 cal BC*, and period 4 between *1620 and 1120 cal BC* (Online Resources 4 and 5). Following the adjustments made by the charcoal outlier model, the modelled date ranges for both the sequential and contiguous models tend to be later than the original presumed date ranges, as shown in Table 2.

The Shifting Pattern of Human Occupation

The temporal changes in human settlement patterns reveal a shifting trend in human occupation. According to the spatial distribution of dates shown in Fig. 7, human occupation was predominantly concentrated in the northern sector from around *3360 and 2440 cal BC* (excluding the uncertain early dates). There is a trend of a subsequent shift towards the south around 2280 BC, and it seems to lead to a concentration of occupation in the southern sector between *2280* and *1670 cal BC*. Archaeological evidence indicates the presence of some sites during the early period that existed alongside those in the northern sector (Sun, 2016). Nevertheless, the decline of sites in the northern sector following the development of those in the south still supports the notion of a gradual southward shift of human occupation. This shift is consistent with the conventional chronological framework (Tables 1 and 2), though the interpretation needs further refinement. Rather than a simple transition of 'cultural period', the transition appears to represent a relocation of various settlement groups over time.

A Refined Chronological Framework for the North Loess Plateau

To better understand the temporal and spatial trends in human occupation and related analyses, it is essential to refine the current chronological framework. While typochronology remains a key aspect for periodisation, the approach taken here involves maintaining the existing four-period framework while adjusting the date ranges for these periods. It is important to note that this adjustment does not intend to alter the conventional chronological sequence for the North Loess Plateau but rather offers an additional method to examine spatiotemporal patterns. Instead of focusing on the transition of 'cultures', the revised periodisation approach highlighted the notable shifts in site concentrations from one or more areas to others. Each date range represents a 'parallel occupation period', which signifies times when settlement sites, not limited to a single 'cultural group', concentrated in one or more sub-regions within the North Loess Plateau.

Drawing from the information presented in Table 3 and Fig. 7, coupled with existing archaeological knowledge, the date ranges for the four periods have been adjusted and detailed in Table 7. Dates falling between *3500* and *3000 cal BC,* again, are not included here.

In the revised framework, sites lacking radiocarbon dating are assigned to the adjusted period(s) by combining radiocarbon results with typo-chronological data, and this is illustrated in a four-period map (Table 8 and Fig. 8). It is crucial to consider the typo-chronological information provided here when estimating the assignment of sites to the adjusted period(s), and the application of 'parallel occupation periods' remains valid. It is also worth to note that the primary focus is to identify the changes of human occupations between the northern and southern sectors. Despite potential uncertainties arising from the absence of dating for certain sites in the categorisation, the general patterns remain consistent: settlements in the northern sectors were concentrated during *3000–2400 cal BC* and *2400–2000 cal BC*, those in the southern sector were concentrated during *2000–1700 cal BC*, while the middle sector was occupied during the entire period (Table 7).

Further Implications

While the conventional typo-chronological framework is a valuable reference point, the introduction of the concept of 'parallel occupation period' in the revised chronological framework proposed in this study presents an alternative approach to periodisation and the exploration of spatiotemporal patterns within a region. This more flexible and dynamic framework is crucial for discerning changes over time and space and providing a more objective way to interpret these patterns. The conventional method of periodisation, which relies on cultural entities distinguished primarily by ceramic typology, assumes the sequential development of distinct 'cultural groups' within a region. However, the notion that cultural development entails only a single 'culture' occupying a region at any given time may be an oversimplification (Jaffe et al., 2020). It is possible that multiple settlement groups coexisted in a cast region.

Table 7 Refined date ranges for the four periods in Table 2, based on the results from Table 3 and Fig. 7

Current periods (BC)	Adjusted periods (BC)	Major occupied areas in the North Loess Plateau	Sectors in the North Loess Plateau
2800–2500	3000–2400	South of Daqing Mountain and Qingshui River valley	Northern and middle sectors
2500–2300	2400–2000	Daihai Lake and Qingshui River valley	Northern and middle sectors
2300–1800	2000–1700	Yulin and Weifen River valley	Southern sector
1800–1500	1700–1200	Qingshui River valley	Middle sector

Table 8 The assignment of all the sites from the North Loess Plateau to the adjusted four-period framework

Period (BC)	Cultural period	Site	Area	Reference
3000–2400	Yangshao/Longshan transition	Ashan III	South of Daqing Mountain	Baotoushi (1984); Neimenggu and Baotoushi (1984)
		Shamujia	South of Daqing Mountain	Baotoushi (1984)
		Heimaban	South of Daqing Mountain	Baotoushi (1984)
		Natai	South of Daqing Mountain	Baotoushi (1984)
		Xiyuan	South of Daqing Mountain	Baotoushi (1984); Xiyuan (1990)
		Weijun	South of Daqing Mountain	Tian and Guo (2004, p. 331)
		Zhukaigou (zone VII) II	Ordos city	Tian (1988); Neimenggu (1994)
		Xiaoshaowan	Qingshui River valley	Wei and Cao (1999)
		Baicaota II	Qingshui River valley	Neimenggu (1994, p. 183)
		Nanhao	Qingshui River valley	Neimenggu (1994, p. 224)
		Zhaizita I	Qingshui River valley	Neimenggu (1997, pp. 280–326); Wei and Cao (1999)
		Houchengzui II	Qingshui River valley	Neimenggu (1997, p. 151); Cui (2003)
		Bainiyaozi III	Qingshui River valley	Cui (2014)
		Huozhaizimao I	Yulin	Shaanxisheng and Shaanxisheng (2011); Sun (2016)
		Zhaimao I	Yulin	Shaanxisheng (2002)
		Zhengzemao I	Yulin	Sun (2016)
		Wuzhuangguoliang	Yulin	Shaanxisheng (2011)
		Zhaishan	Yulin	Shaanxisheng and Yulinshi (2009)
		Shilouloushan I	Yulin	Shaanxisheng (2016)

Table 8 (continued)

Period (BC)	Cultural period	Site	Area	Reference
2400–2000	Early Longshan	Laohushan	Daihai Lake	Yang (2000)
		Yuanzigou	Daihai Lake	Yang (2000)
		Bancheng (group I)	Daihai Lake	Yang (2000)
		Damiaopo	Daihai Lake	Yang (2000)
		Mianpo	Daihai Lake	Yang (2000)
		Zhukaigou I	Ordos city	Neimenggu and E"erduosi (2000); Tian and Han (2003)
		Yongxingdian	Qingshui River valley	Neimenggu (1994)
		Erliban	Qingshui River valley	Neimenggu (1994, p. 260)
		Zhaizishang II	Qingshui River valley	Neimenggu (1994, p. 181)
		Baicaota III	Qingshui River valley	Neimenggu (1994, p. 183)
		Zhaizita II	Qingshui River valley	Neimenggu (1997, pp. 280–326); Wei and Cao (1999)
		Houchengzui III	Qingshui River valley	Neimenggu (1997, p. 151); Cui (2003)
		Guandi IV	Qingshui River valley	Neimenggu (1997: 85–119)
		Xiata	Qingshui Rivervalley	Li (2007); Zhang and Ding (2016)
		Xicha I	Qingshui River valley	Neimenggu and Qingshuihe (2001); Tang et al. (2004)
		Zhuangwoping III	Qingshui River valley	Neimenggu (1997, pp. 165–178)
		Baiyagou	Weifen River valley	Shanxisheng (2017)
		Huozhaizimao II	Yulin	Shaanxisheng and Shaanxisheng (2011); Sun (2016)
		Zhaimao II	Yulin	Shaanxisheng (2002)
		Zhaishan	Yulin	Shao (2019); Sun (2016); Shaanxisheng and Yulinshi (2009)
		Shilouloushan II	Yulin	Shaanxisheng (2016)
2000–1700	Late Longshan	Bancheng (group II)	Daihai Lake	Yang (2000)
		Zhukaigou II	Ordos city	Neimenggu and E"erduosi (2000); Tian and Han (2003)
		Dakou I	Qingshui River valley	Neimenggu (1994, p. 125)
		Bainiyaozi IV	Qingshui River valley	Cui (2014)
		Muzhuzhuliang	Yulin	Guo (2015)
		Shengedaliang	Yulin	Shaanxisheng et al. (2016)
		Xinhua	Yulin	Sun (2016)
		Zhaimaoliang I–II	Yulin	Wei et al. (2018)
		Zhengzemao II	Yulin	Sun (2016)
		Shimao	Yulin	Shaanxisheng et al. (2013); Shao (2016); Sun et al. (2020)
		Shiluoluoshan III	Yulin	Shaanxisheng (2016)
		Zhaimao	Yulin	Shaanxisheng (2002)
		Huoshiliang	Yulin	Hu et al. (2008)
		Bicun	Weifen River valley	Shanxisheng and Xingxian (2016)

Table 8 (continued)

Period (BC)	Cultural period	Site	Area	Reference
1700–1200	Erlitou	Yangchanggou	Daihai Lake	Neimenggu and Beijing (1991)
		Sandaugou	Daihai Lake	Neimenggu and Beijing (2004)
		Zhukaigou III–IV	Ordos city	Neimenggu and E"erduosi (2000); Tian and Han (2003)
		Qingcaota	Qingshui River valley	Neimenggu and Yikezhaomeng (2006)
		Guandi V	Qingshui River valley	Neimenggu (1997, pp. 85–119)
		Nanhao	Qingshui River valley	Neimenggu (1994, pp. 205–224)
		Dakou II	Qingshui River valley	Neimenggu (1994, p. 125)
		Gaojiaping	Qingshui River valley	Neimenggu (1994, pp. 261–271)
		early Xiaomiao	Qingshui River valley	Neimenggu (1994)
		XichaII	Qingshui River valley	Neimenggu and Qingshuihexian (2001); Tang et al. (2004)
		Zhaizita IV	Qingshui River valley	Neimenggu (1997, pp. 280–326); Wei and Cao (1999)
		Zhuangwoping IV	Qingshui River valley	Neimenggu (1997, pp. 165–178)
		Houchengzui IV	Qingshui River valley	Neimenggu (1997, p. 151); Cui (2003)
		Bainiyaozi V	Qingshui River valley	Cui (2014)

In contrast, the 'parallel occupation framework' proves more suitable in this context as it defines periods based on concentrated settlement entities within specific sub-regions. By embracing this flexible framework, as presented in Table 7, it accommodates the existence of multiple settlement entities in each period, which may or may not demonstrate similar ceramic typologies or stylistic features in other artefacts. This shift towards considering settlements or 'cultures' as groups and moving away from rigid cultural or ethnic identities aligns with the concept of 'social fields', originally a sociological theory, initially reintroduced by Kohl (2008) and later employed by Linduff (2015), who characterised 'cultural groups' as components of 'social fields' sharing similar technologies and ideas.

Applying the 'parallel occupation framework' to the southward trend in early China offers a fresh perspective on its broader transition. This process involves the decline of major settlements such as Liangzhu (3100–2700 cal BC) in the Yangtze River valley (Renfrew & Liu, 2018), as well as the fall of other settlements in the middle Yellow River valley and eastern coastal regions during the third millennium BC. Subsequently, the 'arc' emerged, comprising Shimao (*2200–1700 cal BC*) and Taosi (2300–1900 cal BC) (Brunson et al., 2016), and eventually, the rise of the 'first state' Erlitou (1750–1530 cal BC) in the Central Plain (Zhang, 2017; Zhang et al., 2007, 2019). Scholars have explored the connections between these sites based on the stylistic similarity of artefacts such as jade and bronze bracelets, mace heads, drums, bells, 'jew's harps' musical instruments, stone tools, and stone carvings featuring human or monster motifs (e.g., Dai, 2016b; Jaang et al., 2018; Rawson, 2017; Shaanxisheng et al., 2021; Shao, 2020, 2021). Although linking these major sites provides foundational insights into their interactions, it is essential to broaden the

Fig. 8 The distribution of sites from the North Loess Plateau within the adjusted four-period framework, based on the information from Table 8

exploration to encompass multiple settlement entities beyond linear connections among large sites.

Like the case in the North Loess Plateau, the transformation of human occupation and core development in early China can be viewed as a process of integration, transformation and reconfiguration of various settlement entities across a broader region. Human occupation gradually shifted southwards across the North Loess Plateau around or after *2280 cal BC*. This coincides with the development of the Taosi settlement further south. By *1700 cal BC*, with the decline of Shimao and other smaller sites, some occupations shifted back to the middle sector. In the south of the North Loess Plateau, Taosi also declined, paving the way for the rise of Erlitou in the Luoyang basin around the same period. This trend indicates a reconfiguration and southward shift of settlement entities from the southern sector of the North Loess Plateau, Taosi, and its immediate surroundings towards the Central Plain. However, human occupation may also have shifted to northeast China around that time (Hosner et al., 2016; Wagner et al., 2013).

Moreover, the southward shifting pattern highlights the significant role of the North Loess Plateau in facilitating long-distance interactions that extended beyond present-day China. Positioned as a crossroad between the eastern Eurasian steppe and the Central Plains of China, the North Loess Plateau acted as a melting pot for the exchange of new technologies, ideas and objects from both regions. From the steppe, elements such as stone building technique, metallurgy, bronzes, herding and grassland animals were introduced, while the Central Plains contributed rammed earth building technique, jades, tripods, pigs, dogs and millet cultivation. The exposure to these diverse elements led to the adoption and refinement of new ideas and technologies by the inhabitants of the North Loess Plateau, ultimately contributing to the success of Shimao. The North Loess Plateau played a pivotal role in disseminating certain elements, particularly advanced forms of tripods, herding practices and metallurgical knowledge, southward to Taosi and Erlitou and their broader regions, through interactions and reconfigurations among settlement entities. The rise of Erlitou likely followed a similar process involving the adoption and enhancement of these elements, facilitated by the transmission of knowledge, ideas and practices. The North Loess Plateau or the nearby region does not gain as much attention as northwest China regarding the long-distance transmission of technologies and ideas. Conventionally, northwest China and the Hexi Corridor have long been considered a key region for the initial spread of practices such as grassland animals, metals, metallurgy, exotic plants such as wheat and barley (e.g., Flad et al., 2007; Jaang, 2015; Jones et al., 2011; Linduff, 2015; Linduff & Mei, 2009; Mei, 2003; Sherratt, 2006). An alternative viewpoint proposes that the transmission occurred via the Inner Asian Mountain Corridor from southwest Asia to northwest China (Frachetti, 2012), as well as through the Ejin River region in the northeast of the Hexi Corridor (Jaang, 2015) (Fig. 9). In terms of northern China, Mei (2003) has suggested that metallurgical knowledge might have been transmitted along what he called the ‘steppe road’, which connects the Altai region in southern Siberia to the North Loess Plateau (Fig. 9). However, recent discoveries from Shimao and the North Loess Plateau have prompted a reevaluation of this sequence and indicated that the transmission should be pushed backwards to the late third and early second millennium BC, rather than the early second millennium BC as previously proposed. A similar suggestion is a route passing through the Ordos region, which encompasses the North Loess Plateau, into the Yellow River valley (Rawson, 2015) (Fig. 9).

Before the rediscovery of Shimao, the discussion mainly focused on Zhukaigou in the middle sector of the North Loess Plateau (Fig. 2), based on the discoveries of the Ordos-type bronzes, known as the northern bronze complex (Linduff, 1995; Mei, 2003; Wuen, 1993). These bronzes, found in the middle and eastern sections of the ‘arc’ (Fig. 1), as well as in Mongolia, southeastern Siberia and the Minusinsk basin (Cao, 2014; Lin, 1986; Shelach-Lavi, 2015; Tian & Guo, 1988), have been extensively studied. The bronzes in Zhukaigou, dating to the early second millennium BC, were initially considered later compared to those in northwest China, and this led to

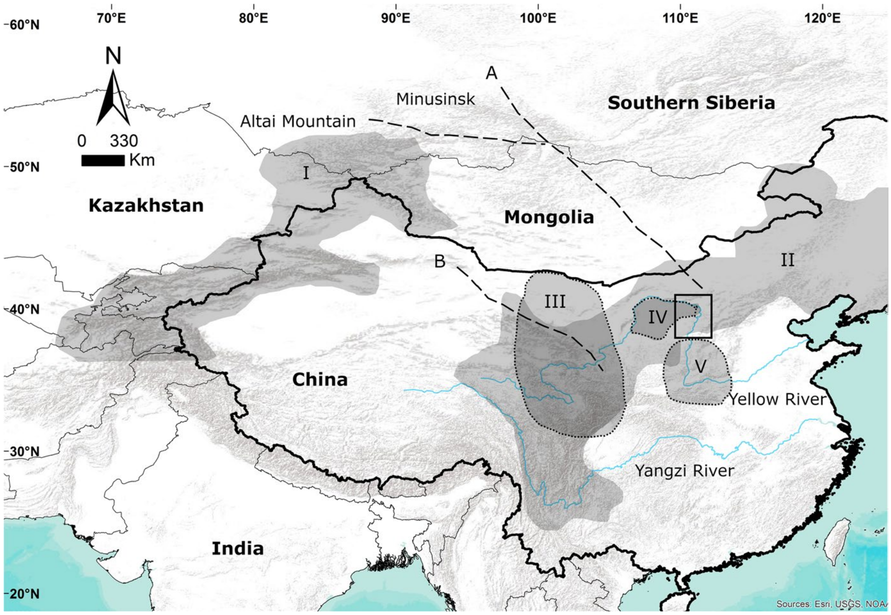

Fig. 9 I: Inner Asian Mountain Corridor; II: the 'arc' defined by Rawson (2013, p. 6; 2015) that refers to regions 'from Sichuan in the west, through Qinghai and the Hexi corridor in Gansu, across parts of Shaanxi, Shanxi, and Inner Mongolia, to northern Hebei and Chifeng in Liaoning in the east'; III: Ejin River Transfer Zone defined by Jaang (2015) that refers to the Ejin river valley to the Helan mountains, covering most portions of Gansu, Qinghai, and Ningxia provinces and the western portion of Inner Mongolia; IV: Ordos region; V: middle Yellow River valley. A: the 'steppe road' defined by Mei (2003, p. 31) that refers to the route that 'runs from the northern frontier of China through Mongolia to southern Siberia and further west'; B: Hexi Corridor. The square shows the North Loess Plateau at the junction of present-day south-central Inner Mongolia, northern Shaanxi and northern Shanxi provinces along the middle Yellow River valley

the region being overlooked as a significant area for the initial long-distance transmission of technology and goods.

The discoveries of metals and grassland animals from the North Loess Plateau are inspiring as they suggest that the transmission of these items and the associated technological knowledge may have occurred through the North Loess Plateau as early as 2200 BC. The southward shifting pattern observed across the North Loess Plateau indicates that this region should be recognised as one of the key regions for exploring early long-distance transmissions. Situated to the south of the steppe, the North Loess Plateau provided a feasible route for southward transmission, even if these events occurred later than those in northwest China.

Additionally, northeast China emerges as another key region, based on the findings of animal-head bronze knives that originated from southern Siberia, dating back to as early as 1600 BC (Linduff, 2015; Shelach-Lavi, 2015) (Fig. 9). However, the fortifications, grassland animals and metals discovered in northeast China are about 200 years later than those found in the North Loess Plateau (Guo et al., 2016; Jaang, 2015). Future research, particularly studies that consider a broader region beyond individual major sites, is needed to further explore the hypothesis of the 'northern route' for the transmission of these technologies and ideas.

Conclusion

The findings presented in this paper challenge the alignment between radiocarbon chronology and the conventional typo-chronology. While the radiocarbon chronology indicates that sites in the northern sector of the North Loess Plateau are generally older than those in the southern sector, the development of 'cultures' may have overlapped or proceeded in a sequential or contiguous manner if the dates are affected by the 'old wood' issue. Although the southward shifting pattern of human occupation appears to correspond with the pattern implied in the typo-chronology, it is more accurately interpreted as an integration, transformation and reconfiguration process of settlement groups across the region, instead of a one-way and static 'cultural transition'. The southward transition that occurred around or after *2280 cal BC* should be viewed as part of a prolonged and ongoing process in early China during the late third to early second millennium BC. Through continuous contacts and reconfigurations among different settlement entities, sites such as Shimao and other smaller sites, as well as Taosi, developed around or after 2300 BC. After these sites declined successively, new ideas and technologies were transmitted to Erlitou after 1900 BC.

In the broader context, the long-distance transmission between the eastern Eurasian steppe and the Central Plain can also be understood as a continuous process of interaction among different settlement entities across a vast region. The southward shift observed in the North Loess Plateau is indicative of a larger trend in early China, positioning the North Loess Plateau as a significant region in the initial transmission process, alongside northwest China. This calls for future research to reconsider and reinterpret the interaction within early China and the initial long-distance transmission process, with the application of a holistic regional approach rather than solely focusing on individual sites.

To better interpret such a dynamic process, the 'parallel occupation framework' developed in this paper seeks to redirect attention from the traditional 'cultural period' towards considering the concept of concurrent occupations within a single timeframe. This approach presents a more flexible and objective method of periodisation in the North Loess Plateau. By employing this framework, a holistic comprehension of changes across both space and time can be achieved, making it applicable to a broader research project aimed at unravelling the demographic, socioeconomic, and urban development dynamics, as well as the factors contributing to the success of Shimao. It supports the interpretation of the southward developmental trajectory in early China as a dynamic process involving reconfigurations among various settlement groups.

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