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Millet agriculture dispersed from Northeast China to the Russian Far East: Integrating archaeology, genetics, and linguistics

Tao Li[a,1], Chao Ning[a], Irina S. Zhushchikhovskaya[b], Mark J. Hudson[a,*], Martine Robbeets[a]

[a] Eurasia3angle Research Group, Max Planck Institute for the Science of Human History, Jena 07745, Germany
[b] Institute of History, Archaeology and Ethnology of Peoples of the Far East, Russian Academy of Sciences, Vladivostok 690001, Russia

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ABSTRACT

Broomcorn and foxtail millets were being cultivated in the West Liao River basin in Northeast China by at least the sixth millennium BCE. However, when and how millet agriculture spread from there to the north and east remains poorly understood. Here, we trace the dispersal of millet agriculture from Northeast China to the Russian Far East and weigh demic against cultural diffusion as mechanisms for that dispersal. We compare two routes for the spread of millet into the Russian Far East discussed in previous research—an inland route across Manchuria, and a coastal/inland route initially following the Liaodong Peninsula and Yalu River—using an archaeological dataset including millet remains, pottery, stone tools, spindle whorls, jade and figurines. We then integrate the archaeological evidence with linguistic and genetic findings in an approach we term 'triangulation'. We conclude that an expansion of agricultural societies in Northeast China during the Middle to Late Hongshan (4000−3000 BCE) coincided with the arrival of millet cultivation in eastern Heilongjiang and the Primorye province of the Russian Far East. Our findings support the inland, Manchuria route for the dispersal of millet to the Primorye and suggest that, as well as long-distance cultural exchange, demic diffusion was also involved. Our results are broadly compatible with the farming/language dispersal hypothesis and consistent with a link between the spread of millet farming and proto-Tungusic, the language ancestral to the contemporary Tungusic languages, in late Neolithic Northeast Asia.

1. Introduction

1.1. Neolithic expansions in East Asia

Recent research using full genome analyses of human skeletal remains, radiocarbon proxy data for population fluctuations, and chronometric hygiene analyses of excavated plant remains has transformed our understanding of the expansion of agricultural societies in West Asia and Europe (Shennan, 2018). In East Asia, new archaeobotanical analyses are contributing to a re-evaluation of the spread of Neolithic and Bronze Age cultigens in the region (Crawford 2009, 2017, 2018a,b; Nakayama, 2010; Lee, 2011, 2017a, 2017b; Miller et al., 2016; Obata, 2016; Stevens and Fuller, 2017). Site inventories and radiocarbon data have been used to model population dynamics in the Neolithic and Bronze Ages (Wagner et al., 2013; Oh et al., 2017; Leipe et al., 2019). East Asia has a long tradition of research in biological anthropology which has used metric and nonmetric analyses of crania and teeth, as well as genetic data, to understand population dispersals associated with the spread of agriculture (e.g., Hanihara, 1991; Matsumura and Hudson, 2005; Pietrusewsky, 2010; Matsumura and Oxenham, 2014; Matsumura et al., 2019; Hudson et al., 2020). Palaeogenomic analyses are beginning to build on those results (Lipson et al., 2018; McColl et al., 2018). Finally, research in archaeolinguistics is contributing to a deeper understanding of farming dispersals in Northeast Asia, a region which received little attention in previous scholarship (Miyamoto, 2016; Robbeets, 2017a, 2017b, 2020; Robbeets et al., 2020; Sagart et al., 2017; Whitman, 2011).

Despite these advances, it has become clear that the expansion of domesticated crops and animals across East Asia was complex. The dispersal of millet agriculture was discontinuous and non-linear, *i.e.*, it did not follow a simple 'wave of advance' (Stevens and Fuller, 2017; Leipe et al., 2019; Li, 2020). In some cases, agricultural systems appear to have expanded through demic diffusion. Following the farming/language dispersals hypothesis (Renfrew, 1987; Bellwood and Renfrew, 2003), it is sometimes possible to propose linguistic correlates for such movements (Bellwood, 2005; Hudson, 1999; Miyamoto, 2016;

* Corresponding author at: Eurasia3angle Research Group, Max Planck Institute for the Science of Human History, Kahlaische Straße 10, 07745 Jena, Germany.
E-mail address: hudson@shh.mpg.de (M.J. Hudson).
[1] Present address: Department of Archaeology, School of History, Wuhan University, Wuhan 430072, China.

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Robbeets, 2017a, 2017b). In other cases, local groups apparently accepted new crops and food technologies through processes of cultural transmission (Barton and An, 2014; Jeong et al., 2018; Long et al., 2018). From the Bronze Age, new social and economic processes of ancient 'globalisation' also began to affect the spread of plants and animals (Boivin et al., 2012; Liu and Jones, 2014; Hudson, 2019, 2020).

1.2. Millet cultivation and expansions

Although it is still debated whether or not millet agriculture developed independently in more than one centre in northern China (Crawford, 2009, 2017; Jia, 2007; Lu et al., 2009; Bettinger et al., 2010; Cohen, 2011; Shelach-Lavi et al., 2019), broomcorn and foxtail millets were being cultivated in the West Liao River basin by the sixth millennium BCE (Fig. 1) (Zhao, 2004, 2011; Leipe et al., 2019).[2] However, this cultivation was initially practiced only at a very few sites (Sun, 2014: 102) and did not become more intensive and widespread in the region until the Middle-Late Hongshan (4000–3000 BCE) (Li, 2020). The earliest agricultural settlement in the Liao River area seems to have been characterized by low population densities and it was only at the end of the Neolithic that population densities reached levels where internal packing became significant (Drennan and Peterson, 2008; Wagner et al., 2013; Stevens and Fuller, 2017). In the fourth millennium BCE, both millet and rice agriculture began to expand in many regions of East Asia, including areas where cereal cultivation had previously been absent (Stevens and Fuller, 2017; Leipe et al., 2019). It was at this time that millet agriculture first appeared in the Primorye (Maritime) province of the Russian Far East (Table 1). However, it remains poorly understood from which part of Northeast China, and following which route(s), millet agriculture reached the Primorye.

It is widely agreed that millet agriculture was not an independent invention in the Primorye but introduced from Northeast China (Aikens et al., 2009; Cassidy and Vostretsov, 2007; Kuzmin, 2013; Sergusheva and Vostretsov, 2009). Although Kuzmin et al. (2002) mention the presence of *Setaria viridis* (the wild ancestor of foxtail millet) in the Primorye, this is almost certainly an archeophyte introduced as a weed and there is no evidence that millet was native to the Russian Far East. This means that millet agriculture diffused from northern China to the Primorye; whether this involved demic diffusion (the migration of human populations), cultural diffusion, or a combination of the two will be analysed in the present paper. Within archaeology there has been a long-standing debate over how to identify population movements in the past but new techniques including ancient DNA have had an important influence on the field in recent years (Burmeister, 2017). In East Asia, ecological factors suggest that certain types of agriculture were more likely to diffuse outwards than others. While wet rice cultivation can absorb population increase through intensification of land use, the increased production of millet tends to occur through the agricultural colonisation of new land (Fuller and Qin, 2009; Stevens and Fuller, 2017).

Deforestation is sometimes used as a proxy for prehistoric agricultural land use. In China as a whole, forest cover estimated from pollen data reached a peak in the middle Holocene around 6000 BC but declined thereafter (Ren, 2007). However, in Northeast China forest cover continued to increase until around two thousand years ago (Ren, 2007). Based on two pollen profiles from the Manchurian plain, Makohonienko et al. (2004) concluded that extensive deforestation did not occur until as late as 900–1100 CE and was associated with buckwheat cultivation. The relatively high levels of forest cover reported for late Neolithic Northeast China might be primarily explained by climatic factors (Tasarov et al., 2006; Ren, 2007). While further palaeoenvironmental research is required, the early agricultural colonisation of Northeast Asia by millet farmers may have occurred with relatively low levels of deforestation, despite evidence for high population densities in Neolithic Northeast China (Leipe et al., 2019).

1.3. Millet dispersals to the Primorye: previous research

The problem of agricultural dispersals to the Russian Far East is connected to long-standing debates on the origins of the peoples of Manchuria and the Amur (cf. Levin, 1963; Janhunen, 1996; Pai, 1999; Zgusta, 2015). Many earlier works discussed the expansion of Tungusic populations at the expense of so-called Palaeo-Asiatic groups such as the Nivkh. However, a recent genetic analysis of two early Neolithic individuals from the Primorye found high levels of genetic continuity in the region and concluded that, 'cold climatic conditions … likely provide an explanation for the apparent continuity and lack of major genetic turnover by exogenous farming populations' (Siska et al., 2017). While Russian archaeological approaches to the Neolithic have similarly tended to stress long-term continuities in the region (cf. Hommel, 2018; Popov et al., 2014), several models of Neolithic migration and long-distance contact in the Russian Far East have been proposed.

In the 1960s, Okladnikov and Brodiansky (1969) proposed an independent centre of plant (mainly millet and soybean) domestication in the Primorye, Korea and Manchuria, using evidence from stone tools and ceramic decoration (see Kuzmin, 2013). Perhaps the first model for the diffusion of millet from China to the Russian Far East was proposed by Yan (1993) who argued that by 4000 BCE or slightly earlier, millet cultivation moved east from the West Liao basin, reaching Liaodong from where it crossed the Yalu River into Korea and then, from the second millennium BCE, moved back north toward Jilin and Heilongjiang from where it finally reached the Primorye. By contrast, from the late 1990s, Kuzmin used radiocarbon chronologies to argue that millet farming spread directly from Northeast China to the Primorye (Kuzmin, 2013). A long history of material exchanges between the two regions led Kuzmin to suggest cultural diffusion as the most likely explanation for this process. Kuzmin (2013: 5) shows three possible routes for millet dispersals from Northeast China to the Russian Far East but does not discuss details. Vostretsov (2005) outlined two routes of millet dispersal with population migrations from Northeast China to the Primorye: the first along the valley of the Tumen river (southern route) and the second along the Razdol'naya (Suifen) river (northern route). Vostretsov linked these migrations to the appearance and expansion of the Zaisanovka culture or Zaisanovka cultural tradition.

There is currently no standard interpretation of the 'Zaisanovka culture' in the archaeology of the Russian Far East. There are three main terms in use for this phenomenon: 'Zaisanovka culture' (e.g., Miyamoto, 2014; Leipe et al. 2019); 'Zaisanovka Neolithic (cultural) community' (e.g., Yanshina and Klyuev, 2005); and 'Zaisanovka cultural tradition' (e.g., Vostretsov, 2005). Although the latter two terms are not commonly used, the debate over terminology seems to be the result of the complicated nature of the archaeological phenomenon itself, as well as the incomplete process of analysis and systematisation. Zaisanovka was certainly a cultural community prolonged in time and space. All specialists agree that the sites belonging to this 'culture', or 'cultural tradition/community', show some variability of artifact typology, while certain permanent, stable features are also noted. However, a common explanation of this variability has not yet been adopted. In general, it is widely assumed that this cultural/archaeological phenomenon was the result of wave-like processes of population migration from Northeast China. However, concrete details of this migration and the formation of new cultural unities in the Primorye region are not yet clear. In this article we use the term 'Zaisanovka culture', taking into account the obvious temporal and spatial variability of this 'culture'.

Given evidence for affluent hunter–gatherers in the Primorye, especially at the Boisman site (Popov et al., 2014; Popov and Tabarev, 2016), the question of the relationship between foraging and farming economies has been explored by Vostretsov (1999, 2006) who proposed

[2] Unless otherwise noted, all radiocarbon dates are calibrated and given in calendar years.

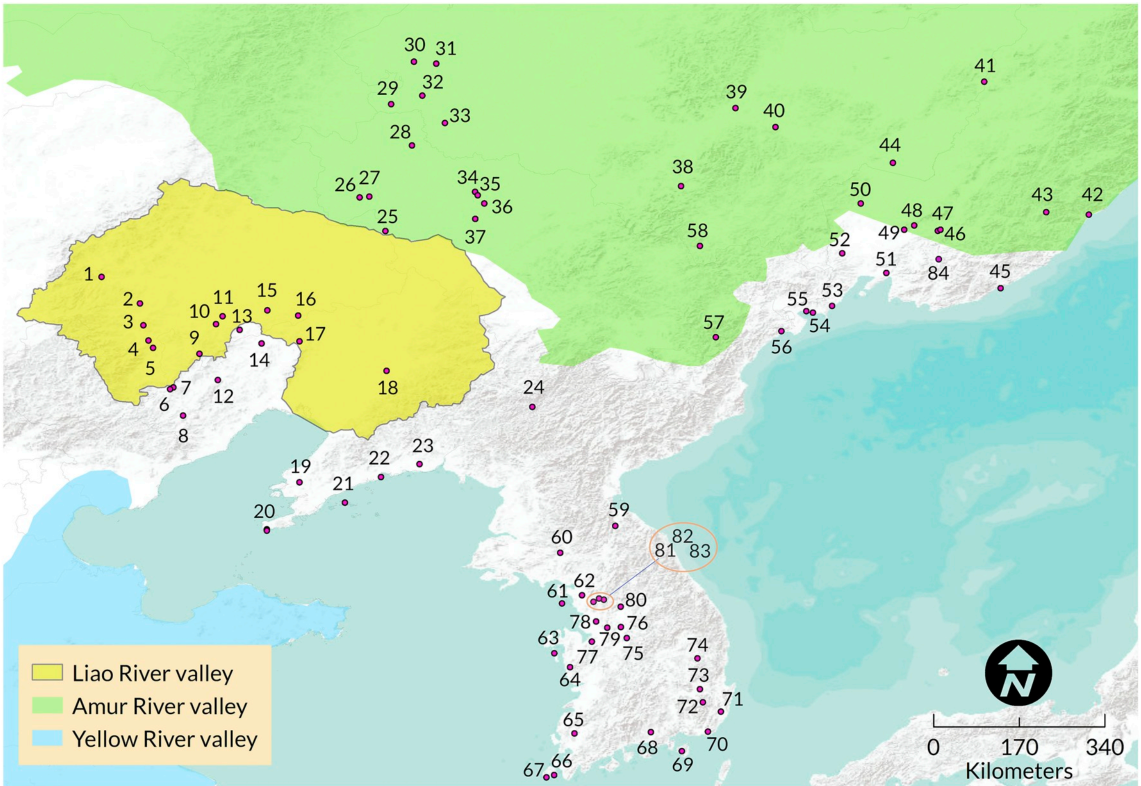


Fig. 1. Sites investigated in this study.

Fig. 1
Key to sites.

1. Baiyinchanghan 白音长汗
2. Nanwanzi 南湾子
3. Xinglonggou 兴隆沟
4. Erdaojingzi 二道井子
5. Weijiawopu 魏家窝铺
6. Sanguandianzi 三官甸子
7. Niuheliang 牛河梁
8. Dongshanzui 东山嘴
9. Reshuitang 热水汤
10. Xinglongwa 兴隆洼/Zhaobaogou 赵宝沟
11. Xiaohexi 小河西
12. Banlashan 半拉山
13. Dawopu 大窝铺
14. Hutougou 胡头沟
15. Sanjiazi 三家子
16. Xiaonailingao 小奈林稿
17. Chahai 查海
18. Xinle 新乐
19. Wangbaoshan 王宝山
20. Wangjiacun/Guojiacun 王家村/郭家村
21. Xiaozhushan 小珠山
22. Beiwutun 北吴屯
23. Houwa 后洼
24. Dazhuxian 大朱仙
25. Haminmangha 哈民忙哈
26. Zhangjiantuozi 张俭坨子
27. Aobaoshan 敖包山
28. Houtaomuga 后桃木噶
29. Dongwenggenshan 东翁艮山
30. Tengjiagang 滕家岗
31. Lijiagang 李家岗
32. Jiushanmen 九扇门
33. Maodu Xila 毛肚西拉
34. Jubaoshan 聚宝山
35. Yaojingzi 腰井子
36. Zuojiashan 左家山
37. Yuanbaogou 元宝沟
38. Yabuli 亚布力
39. Wokenhada 倭肯哈达
40. Daobeishan 刀背山
41. Xiaonanshan 小南山
42. Lidovka 1
43. Chertovy Vorota
44. Xinkailiu 新开流
45. Valentin-peresheek
46. Risovoe 4
47. Sheklyaevo 7
48. Rettikhovka-Geologicheskaya
49. Mustang 1 and Bogolubovka 1
50. Novoselishche 4
51. Kirovsky
52. Krounovka 1
53. Boisman 2
54. Gvozdevo 4
55. Zaisanovka 1, 2, and 7
56. Sop'ohang
57. Pomuigusok
58. Yinggeling 莺歌岭
59. Kosan-ri
60. Chitam-ni
61. Amsa-dong
62. Unseo-dong
63. Anmyundo
64. Boryeong
65. Oun 1
66. Gulpo-ri
67. Songgun-gil
68. Pyeonggeodong
69. Sanchon-ri
70. Tongsamdong
71. Ulsan Sejuk-ni
72. Ojin-ri
73. Songjuk-gil
74. Tongchon-dong
75. Munam-ri
76. Yongdae-ri
77. Asan-si
78. Osan-si
79. Binong-san
80. Anganggol
81. Neunggok-dong/Namkyung-ni
82. Amsa-dong
83. Hanam-si
84. Vodopadnoe-7

a model wherein migrating farmers expanded after climate change caused a deterioration of maritime hunter–gatherer habitats. However, Kuzmin (2013) has criticized the chronology of Vostretsov's scheme. Jia (2007) played down the role of population dispersals in the spread of agriculture in Northeast China and instead applied Zvelebil and Rowley-Conwy's (1984) 'availability model' of forager/farmer interaction, but he did not discuss implications for the Russian Far East.

The most detailed archaeological analysis of the spread of millet farming into the Russian Far East has been published by Miyamoto (2014) who proposed that cord-marked pottery, willow-leaf polished stone arrowheads, and what he calls 'northern Chinese style agricultural tools' were associated with the spread of millet into the Primorye around 3400 BCE. Miyamoto identifies the Yabuli site in eastern Heilongjiang as a possible source for cultural influences on the Zaisanovka culture of the Primorye. Robbeets (2017a) has summarized archaeobotanical and linguistic evidence to propose two separate dispersals of millet farming from the West Liao basin: (1) a coastal route from the southern Liaodong peninsula to Korea, which was probably associated with proto-Japano-Koreanic; and (2) an inland route across Manchuria to the Primorye, probably associated with proto-Tungusic.

There have been few attempts to test these various models for the spread of millet farming into the Russian Far East. Here, we make a preliminary comparison of the two most explicit archaeological models, those of Yan (1993) and Miyamoto (2014) using a large data set of sites from Northeast Asia (Fig. 1). While both Yan and Miyamoto consider Northeast China as the source region for millet farming in the Primorye, the routes they propose differ significantly in timing and direction. Yan (1993) suggested that millet spread first to Korea before expanding northwards to the Primorye after 2000 BCE; Miyamoto (2014), in contrast, proposed that millet farming expanded to both the Korean Peninsula and the Russian Far East at around the same time (ca. 3500–3000 BCE) but in two separate movements, one from Liaodong to northwest Korea and another from Jilin and Heilongjiang to the Primorye. In this paper, we distinguish Yan and Miyamoto's routes as the 'Yalu' and 'Manchuria' models, respectively (Fig. 2). After comparing the archaeological evidence for these two models, we triangulate our archaeological observations with findings from human genetics and linguistics and attempt to distinguish between demic and cultural diffusion as driving forces behind the dispersals. The two hypotheses considered here are, as far as we are aware, the main routes so far proposed for the dispersal of millet farming to the Primorye. While this does not rule out the possibility of other routes, it can be noted that both routes are consistent with geographical constraints and affordances in Northeast Asia as discussed in previous research (Wada, 1938; Janhunen, 1996).

1.4. Natural setting and environment

'Northeast China' refers to Liaoning, Jilin and Heilongjiang provinces as well as eastern Inner Mongolia. The West Liao, located primarily in Inner Mongolia, is a major tributary of the Liao River. The West Liao basin is a transitional zone between the Inner Mongolian Plateau and the Manchurian plain. Terraces along the West Liao and other tributaries of the upper Liao were often used for agriculture and habitation in the Neolithic (Han, 2010: 3; Sun, 2014: 7). East of the West Liao basin lies the agriculturally fertile Manchurian plain, historically an important corridor to the north where the Songhua (Sungari) river connects to the Amur (Wada, 1938). The Manchurian plain is still an important centre of millet agriculture in China (Huang et al., 2017).

The Liaodong region refers to the Liaodong Peninsula and the Dandong area in eastern Liaoning province. Located in mountainous eastern Liaoning close to the Bohai and Yellow Seas, the Liaodong region is strongly influenced by the maritime climate.

The Primorye borders Jilin and Heilongjiang provinces to its west and the Democratic People's Republic of Korea to its south. Due to the temperature, humidity, wind, and frequent fog, the Primorye is warmer than elsewhere in the Russian Far East. However, only some areas of the region have potential for agriculture, primarily the Prikhankaiskaya plain (also known as the Khanka-Ussuri or Khanka plain) lying between Lake Khanka in the north and Amur Bay in the south. Occupying a large part of western Primorye and the part of Northeast China around Lake Khanka, this plain is mostly the basin of the Razdol'naya (Suifen) river with its fertile alluvial soils, low relief, developed hydrology, and a more favourable climate than along the seacoast. The Prikhankaiskaya plain has formed the main agricultural area of the Primorye since the nineteenth century and most Neolithic sites with evidence of millet are located on this plain and the basin of the Razdol'naya (Suifen) river.

The Korean Peninsula lies in the temperate monsoon zone and, from south to north, divides into five zones by modern vegetation: (1) evergreen broadleaf forest of evergreeen oaks, schima and laurels; (2) mixed mesophytic forest; (3) deciduous forest dominated by oaks; (4) mixed northern hardwoods dominated by birch; and (5) montane coniferous forests (Pearson, 1974; Shin et al., 2012). Millet farming

Table 1
Chronology of the main periods discussed in this paper, based on Kuzmin (2006), Sun (2014:2), Wang (2005:118) and Zhushchikhovskaya (2006).

Periods/Dates (BCE)		Northeast China			Russian Far East	Periods/Dates (BCE)	
		West Liao River basin	Liaodong peninsula	Jilin and Heilongjiang	Primorye		
Bronze Age	500–1	Shuiquan		Hanshu Phase II	Palaeometal Age cultures	1000 BCE–400 CE	Bronze Age
		Jinggouzi					
	1500–800	Upper Xiajiadian	Shuangtuozi II	Xituanshan			
	2000–1500	Lower Xiajiadian	Shuangtuozi Phase I	Hanshu Phase I			
				Baibaojin			
				Gaotaishan			
Neolithic	3000–2000	Xiaoheyan		Pianbuzi	Zaisanovka	3800–1300	Late Neolithic
			Upper Xiaozhushan	Upper Zuojiashan			
				Angangxi			
	3500–3000	Hongshan	Middle Xiaozhushan	Lower Yinggeling	Boisman	4400–3000	Early
	4000–3500						
	4500–4000		Houwa	Lower Zuojiashan (Phase III)			
	5000–4400	Zhaobaogou	Lower Xiaozhushan				
	5200–5000	Fuhe		Lower Zuojiashan (Phase I and II)			
				Xinkailiu	Rudnaya	5500–3900	Neolithic
	6200–5400	Xinglongwa					
	7000–6500	Xiaohexi					

very likely occurred first in the northern peninsula before it spread to present-day South Korea (Bale, 2001; Lee, 2011). However, large parts of northeastern North Korea are covered in mountains ranging up to 2743 m in altitude and Neolithic agriculture may have been concentrated in the western coastal plains of the northern peninsula.

A study of Neolithic site locations in the West Liao basin found that an overwhelming majority (~96.7%) are located south of latitude 43°30’N (Jia et al., 2016). Due to environmental constraints, this is posited as the ‘natural northern limit of [agriculture-based] Neolithic Cultures in Northeastern China during the Holocene Optimum’ (Jia et al., 2016: 10). Many map projections give the impression that the Primorye is located much further north than the West Liao River. However, all of the Russian Far East sites with millet remains discussed in this article are located at around the same latitude as the West Liao sites, with Novoselishche 4 at 44° 39–40′N as the most northerly Neolithic site with millet.

Paleoenvironmental reconstructions suggest that the West Liao valley was warm and humid between 6000 and 4000 BCE, with the landscape covered by deciduous and coniferous forests consisting mainly of walnut (*Juglans mandshurica*), Chinese ash (*Fraxinus chinensis*) and pine trees (Tian, 2004: 4). The average annual temperature was about 3 °C higher than today and annual precipitation was 400–500 mm (Tian, 2004: 66, 4). Beginning around 4000 BCE, the climate in North China fluctuated more noticeably. The period 4000–3000 BCE was characterized by an overall shift from warm and humid to a moderately warm but increasingly dry climate. More dramatic cooling events occurred after 3500 BCE, evidenced by a decrease in broadleaved deciduous forests, an increase in coniferous trees, and a sea level decline (Shi and Kong, 1992: 61–62). The initial spread of millet farming to the Primorye occured during a period of warmer but changing climate (Lutaenko et al., 2007).

2. Routes of millet dispersal: Yalu vs. Manchuria models

2.1. Archaeological evidence

2.1.1. Millet remains

Flotation work at Xinglonggou in the West Liao basin has identified remains of broomcorn and foxtail millet with direct AMS dates of 5720–5660 BCE (Zhao, 2004, 2011) (Table 2). While Zhao (2011) argued that these millets were morphologically domesticated, he writes that, ‘Xinglonggou residents still relied on hunting and gathering for food, and agricultural products produced by millet farming and animal husbandry only supplemented their diet.’ Stevens and Fuller (2017: 160) note that the Xinglonggou *Panicum* grains were small and ‘consistent with an early pre-domestication cultivation stage, not domestication.’ Apart from Xinglonggou, there are very few sites (e.g., Sidaozhangfang and Halahaiwa in Inner Mongolia [Sun, 2014: 112–113]) that have yielded millets associated with Xinglongwa or Zhaobaogou period contexts. By contrast, millet became noticeable at more sites in the West Liao area during Middle to Late Hongshan times, including Xinglonggou Locality 2, Weijiawopu (4000–3500 BCE) in Chifeng (Sun and Zhao, 2013), and Haminmangha (3600–3100 BCE) in eastern Inner Mongolia (Sun et al., 2016).

In the Liaodong region, broomcorn and foxtail millets have been found at the Wangjiacun site in Dalian from cultural layers radiocarbon dated to 3660–3110 BCE (Ma et al., 2015). At the Houwa site in Dandong, dated from 4370–4159 to 3091–2897 BCE (Xu, 1995), no actual millet remains were found, but stone tools such as grinding slabs and stones, constricted-waist hoes and axes suggest an agricultural context (Xu et al., 1989).

In Jilin and Heilongjiang, finds of Neolithic millets have only been reported very recently. Millets have recently been found at Houtaomuga in Jilin, but details are currently unpublished (see Tang et al. in press). Wang (2018) argues there is no evidence for farming at Houtaomuga prior to Phase IV (ca. 3500 – 3000 BCE). At Tengjiagang (4000–3000 BCE) in Heilongjiang, as well as at the Yabuli and Yinggeling sites in eastern Jilin and Heilongjiang, archaeologists found a diversity of stone tools assumed to have used in agriculture, including

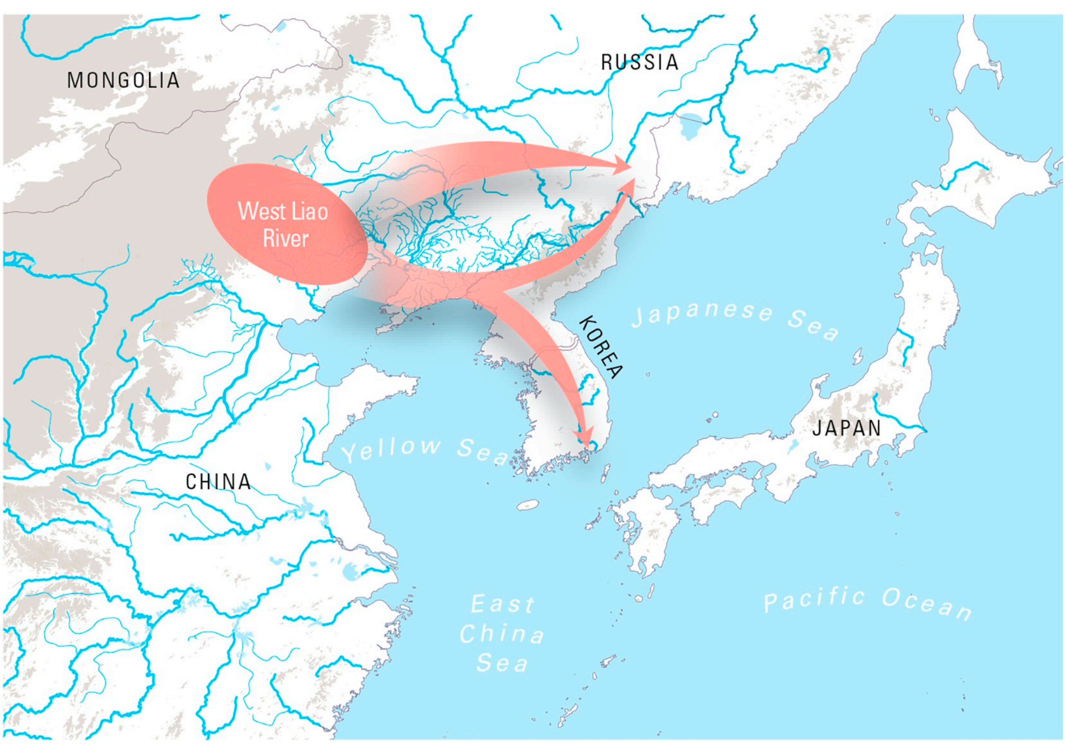


Fig. 2. Schematic representation of two possible routes of millet dispersal to the Russian Far East (the ‘Manchuria’ model and the ‘Yalu’ model).

axes, constricted-waist hoes, adzes, and grinding slabs and stones (Li, 1988; Zhang et al., 1981). It is, therefore, probable that millet agriculture had spread to eastern Jilin and Heilongjiang by at least 3000 BCE.

Although Middle Neolithic millet from North Korea was reported in the 1950s, it seems best to remain sceptical about these remains (Bale, 2001; Lee, 2011). South Korea has ten direct radiocarbon dates on millet dating between about 3600 and 800 cal BCE (Lee, 2011, 2017a, 2017b; Leipe et al., 2019).

In the Primorye, at least 11 Neolithic sites have reported finds of millets and there are 10 direct radiocarbon dates on Neolithic or early Palaeometal Age millets from the province (Leipe et al., 2019; Dorofeeva et al., 2017; Garkovik and Sergusheva, 2014) (Table 2). The oldest millets (3620–3370 BCE) in the Russian Far East are from Krounovka 1 (Komoto and Obata, 2004; Kuzmin, 2013; Sergusheva, 2008:192–195).

Although pigs are reported to have been raised in Hongshan societies in Northeast China (Nelson, 1998), the early millet farming dispersals into the Primorye did not include domesticated animals. Pigs only appeared in the Primorye after around 1000 BC and horses, cattle and sheep were added in the Iron Age and medieval period (Kuzmin, 1997; Kuzmin and Rakov, 2011). In Korea, there is also little or no evidence for domesticated pigs from the Neolithic or Bronze Age (Lee, 2017b: 471).

Finally, it can be noted that the West Liao basin and southern part of the Primorye relied more heavily on broomcorn than foxtail millets, while Liaodong and the Korean peninsula showed the use of both millets in more or less equal proportions.

2.1.2. Stone tools

Miyamoto (2014: 13) emphasizes the importance of what he terms ‘northern Chinese style agricultural stone tools’ in understanding the spread of millet farming. In this category, Miyamoto includes ‘mortars, pestles, and hoes’. However, Miyamoto does not define his terminology, which leads to circular reasoning—since ‘northern Chinese style agricultural stone tools’ are found in both Korea and the Russian Far East, then, following his definition, they must have come from ‘northern China’. The most diagnostic of these tools are the constricted-waist stone hoes (called ‘T-shaped hoes’ by Miyamoto). These hoes have been discovered at the Valentin-Peresheek, Zaisanovka 1 and 7, the lower level of Siny Gai A, Oleny 1 and Mustang sites (Komoto and Obata, 2005; Zhushchikhovskaya, 2006: 115). Similar, yet much older, hoes are known from Xinglongwa sites in the West Liao basin (Fig. 3). Seven such hoes were collected from three house structures at Xinglongwa (6200–5200 cal BCE). At Chahai (6490–5910 cal BCE), 11 houses contained a total of 38 constricted-waist hoes (Liaoningsheng Wenwu Kaogu Yanjiusuo, 1994). At Baiyinchanghan, 70 of these hoes were unearthed from the Xinglongwa cultural layer (Yang, 2014: 10–12) and at Xinglonggou (6050–5550 cal BCE), 92 of the 167 stone tools were constricted-waist stone hoes (Zhongguo and Aohan, 2000). Over 250 constricted-waist hoes—termed ‘spades’ by the excavators—were found in a Xiaohexi phase context at the 12D56 site near Fuxin (Liaoning) with associated radiocarbon dates from the sixth millennium BCE (Shelach-Lavi et al., 2019). By 3000 BCE, constricted-waist stone hoes were widely distributed beyond the West Liao basin in western Jilin at Dazhuxiangou (Jilin and Ji'an, 1977) and Jingu, and in eastern Heilongjiang at Yabuli (Li, 1988). Functional and use-wear analyses have suggested that the constricted-waist hoes from Baiyinchanghan can be divided into three categories based on function (leveling, plowing and digging, and harvesting) (Yang, 2014: 47; see also Miyamoto, 2014: 20). Although no use-wear analysis was done at the 12D56 site, Shelach-Lavi et al. (2019: 4) argue that ‘the fact that [constricted-waist hoes], which are not known from earlier periods in the region, are so dominant suggest[s] that they are associated with [a] new set of activities, probably related to the clearance of woods and the cultivation of the land.’ From this evidence it seems reasonable to propose a link between constricted-waist stone hoes and millet cultivation. While the spread of these hoes to the Primorye is consistent with the Manchurian route for the dispersal of millet, constricted-waist stone hoes are rare in the Liaodong region. Four such hoes are reported from the Lower Houwa levels of the Houwa site (Xu, 1995) but we are unaware of other examples from Liaodong. According to Shin et al. (2012: 90), however, constricted-waist stone hoes became an important cultivation tool in Korea in the Late Neolithic.

Stone axes, both chipped and polished, are also common across Northeast Asia at this time (Fig. 3). While these axes are consistent with a broad process of Neolithicization, they show greater diversity than the constricted-waist hoes and further research is required to determine how they might be related to the dispersal of millet farming.

The most problematic elements within Miyamoto’s category of ‘northern Chinese style agricultural stone tools’ are what he terms ‘mortars’ and ‘pestles’. By ‘mortars’, Miyamoto means querns or grinding slabs (*metates*) used to grind or de-husk plants; ‘pestles’ are the hand-held stones (*manos*) used on the slabs. Miyamoto (2014: 14) proposes that in Korea these tools were ‘used to de-husk millet grains and to produce flour’. This conclusion is based on use-wear analyses conducted by Nobuhiko Kamijō (e.g., 2008). As summarised by Miyamoto, Kamijō’s studies have found that in northern China and Korea, these grinding tools have use wear indicating ‘a fixed direction of motion consistent with flour production or de-husking millet’ (Miyamoto, 2014: 20). Miyamoto argues that the ‘northern Chinese style’ grinding slabs and stones moved into the Korean peninsula in association with millet farming. Similar tools were not found in the early stages of the Zaisanovka culture at the Krounovka 1 site in the Primorye (Komoto and Obata, 2004) but by the late fourth millennium BCE, one grinding slab and one pestle-shaped stone are reported from Zaisanovka 7 (Komoto and Obata, 2005; Miyamoto, 2014: 21) and there are further examples from later Neolithic and Palaeometal contexts. Miyamoto (2014: 17) argues that these tools from Zaisanovka 7 are typologically unlike those found in northern China and were probably used for grinding nuts. As noted by Fuller and Rowland (2011: 46), however, de-husking millet and de-shelling nuts suggests a similar function. The production of millet flour, by contrast, seems unlikely at this stage. Although Lu et al. (2005) have argued that noodles found in northwest China dated to around 4000 years ago were made from millets, experimental work by Ge et al. (2011) has questioned this conclusion. Ceramic steamers like those found in China are not known from the Neolithic of the Russian Far East and cultivated millet was probably boiled. Several researchers have emphasized the importance of analyzing food processing technologies within a synthetic framework (Fuller and Rowland, 2011; Makibayashi, 2014; Rowland and Fuller, 2018), and further work in this area is needed for Northeast Asia.

A final category of stone tool which may inform us about regional interactions in Northeast Asia is the willow-leaf-shaped polished stone arrowhead. Miyamoto (2014) argues that these arrowheads spread to both Korea and the Russian Far East with northern Chinese style agricultural tools. Such arrowheads are known at Yabuli (Heilongjiang) as well as at Krounovka 1 and in eastern Korea (Miyamoto, 2014). Our dataset supports Miyamoto’s observations, showing willow-leaf polished stone arrowheads at many sites between the Liao River basin and the Primorye. Therefore, stone arrowheads can serve as an additional line of evidence for contacts between Northeast China and the Primorye. However, these willow-leaf polished stone arrowheads were not only associated with agricultural contexts and, *contra* Miyamoto (2014: 23), were also found at the hunter–gatherer Boisman site (see fig. 12 in Popov and Tabarev, 2016).

2.1.3. Ceramics, portable art and spindle whorls

For Miyamoto (2014), pottery provides another important category of evidence for population movement from Northeast China into the Primorye in association with millet dispersals (Fig. 4). Specifically, Miyamoto posits a typological relationship between the cord-marked

Table 2
Early millet finds from the Russian Far East and neighbouring areas of Northeast Asia.

Site	Location	Evidence for millet agriculture	Dates (C14 dates calibrated to 1 σ)	References
Primorye				
Krounovka 1, levels 2–3	Western Primorye, ca. 30 km southwest of Ussuriysk	Carbonized caryopsides of broomcorn millet (n = 23); possible foxtail millet (1 grain + 2 fragments). Both samples from Houses 4 & 5	3620–3370 BCE (NUTA2-5643); 3620–3350 BCE (Beta-171662): dates on charcoal associated with millet seeds	Komoto and Obata (2004); Kuzmin (2013)
Novoselishche 4	Khanka plain, western Primorye	Millet seeds	Direct dates on millets: 2397–2207 BCE (Tka-14081); 1415–1289 BCE (SNU04-192); 1381–1133 BCE (TKa-13487). Dates from charcoal on dwelling floor: 2480–2050 BCE (AA-13400) and 2290–2040 BCE (AA-36748)	Kuzmin (2013); Leipe et al. (2019)
Rettikhovka-Geologicheskaya	Khanka plain, western Primorye	Numerous broomcorn and foxtail millet seeds from storage building adjacent to dwelling	2480–2348 BCE (Poz-99527): direct date on millet; 1880–1530 BCE (SOAN-4239), 1730–1500 BCE (SOAN-4240), 1670–1450 BCE (SOAN-4238): all charcoal dates from dwelling	Kuzmin (2013); Leipe et al. (2019)
Mustang 1	Khanka plain, western Primorye	1 possible foxtail millet seed	3630–3200 BCE (Ki-3151) and 2880–2460 BCE (Ki-3152): charcoal	Kuzmin (2013)
Sheklyaevo 7	Central Primorye	Broomcorn millet	1213–1115 BCE (Poz-99459): direct date on millet; 3320–2900 BCE (AA-60058) on charcoal; 3330–2920 BCE (AA-60053) and 3330–2920 BCE (AA-60051) on food crusts	Kuzmin (2013); Leipe et al. (2019)
Kirovsky	Southern Primorye	Foxtail millet seeds	2980–2580 BCE (Le[RUL]-193): charcoal	Kuzmin (2013)
Gvozdevo 4	Southwest Primorye	Broomcorn millet	2861–2627 BCE (Poz-99460): direct date on millet; 2870–2580 BCE (AA-60612): food crust	Kuzmin (2013); Leipe et al. (2019)
Zaisanovka 1	Southwest Primorye	Small quantity of foxtail millet seeds	2840–2360 BCE (NUTA2-5282) and 2570–2350 BCE (NUTA2-5483): carbonised nuts	Kuzmin (2013)
Bogolubovka 1	Khanka plain, western Primorye	Broomcorn millet	2473–2348 BCE (Poz-99525): direct date on millet; 2560–2150 BCE (SNU07-260): charcoal	Kuzmin (2013); Leipe et al. (2019)
Vodopadnoe 7	Southeast Primorye	Broomcorn millet	2473–2348 BCE (Poz-99526); 2457–2311 BCE (Poz-96977): direct dates on millet	Leipe et al. (2019)
Anuchino 14	Central Primorye	Broomcorn millet	1195–1058 BCE (Poz-99528): direct date on millet	Leipe et al. (2019)
Northeast China				
Nanwanzibei	Inner Mongolia	Broomcorn millet	Cross dated to 7000–6500 BCE	Sun (2014:110–111)
Sidaozhangfang	Inner Mongolia	Broomcorn millet	Cross dated to 6200–5400 BCE	Sun (2014:112)
Houtaomuga	Jilin	Broomcorn millet Foxtail millet, from houses, ditches, and ash pits	Site phases dated to 6000–5000 BCE (Phase II), 4800–3500 BCE (Phase III), 3500–3000 BCE (Phase IV).	Wang (2018), Tang et al. (in press)
Xinglonggou	Inner Mongolia	Broomcorn millet	5720–5660 BCE (TO-12031): direct date on millet	Zhao (2011); Leipe et al. (2017)
Halahaiwa	Inner Mongolia	Foxtail millet Broomcorn millet	Cross dated to 5000–4400 BCE	Sun (2014:113)
Dawopu	Inner Mongolia	Broomcorn millet	Cross dated to 4500–3000 BCE	Sun (2014:113)
Weijiawopu	Inner Mongolia	Foxtail millet Broomcorn millet, from ash pit, house floor, and hearth	Cross dated 4500–4000 BCE	Sun and Zhao (2013)
Haminmangha	Inner Mongolia	Broomcorn millet and foxtail millet from ash pits, house floor, hearth, and household pottery	Cross dated to 3500–3000 BCE	Fu and Sun (2015); Sun et al. (2016)
Xinglonggou Locality 2	Inner Mongolia	Broomcorn millet Foxtail millet	Cross dated to 3300–3000 BCE	Yuan (2016)
Wangjiacun	Liaoning (Liaodong)	Broomcorn millet, Foxtail millet	Cross dated 3660–3110 BCE	Liu (2017:21); Ma et al. (2015)
Korea				
Neunggok	Gyeonggi	Foxtail millet	3636–3524 BCE (Beta252973): direct date on millet	Lee (2017b); Leipe et al. (2019)
Tongsamdong	South Gyeongsang	Foxtail millet from floor fill, House 1	3514–3105 BCE (TO8783): direct date on millet	Lee (2011); Leipe et al. (2019)
Pyeonggeodong	South Gyeongsang	Broomcorn millet	3011–2905 BCE (Beta-252972): direct date on millet	Lee (2017b); Leipe et al. (2019)
Pyeonggeodong	South Gyeongsang	Broomcorn millet	2481–2351 BCE (UCIAMS67219): direct date on millet	Lee (2017b); Leipe et al. (2019)
Sangchonri B	South Gyeongsang	Foxtail millet from outdoor hearth 1	2468–2926 BCE (TO8608): direct date on millet	Lee (2011); Leipe et al. (2019)
Oun 1	South Gyeongsang	Foxtail millet from floor fill, House 104	1074–906 BCE (SNU126): direct date on millet	Lee (2011); Leipe et al. (2019)
Oun 1	South Gyeongsang	Foxtail millet from floor fill, House 104	1073–833 BCE (TO8637): direct date on millet	Lee (2011); Leipe et al. (2019)
Oun 1	South Gyeongsang	Foxtail millet	2857–2462 BCE (TO8607): direct date on millet	Lee (2017b); Leipe et al. (2019)

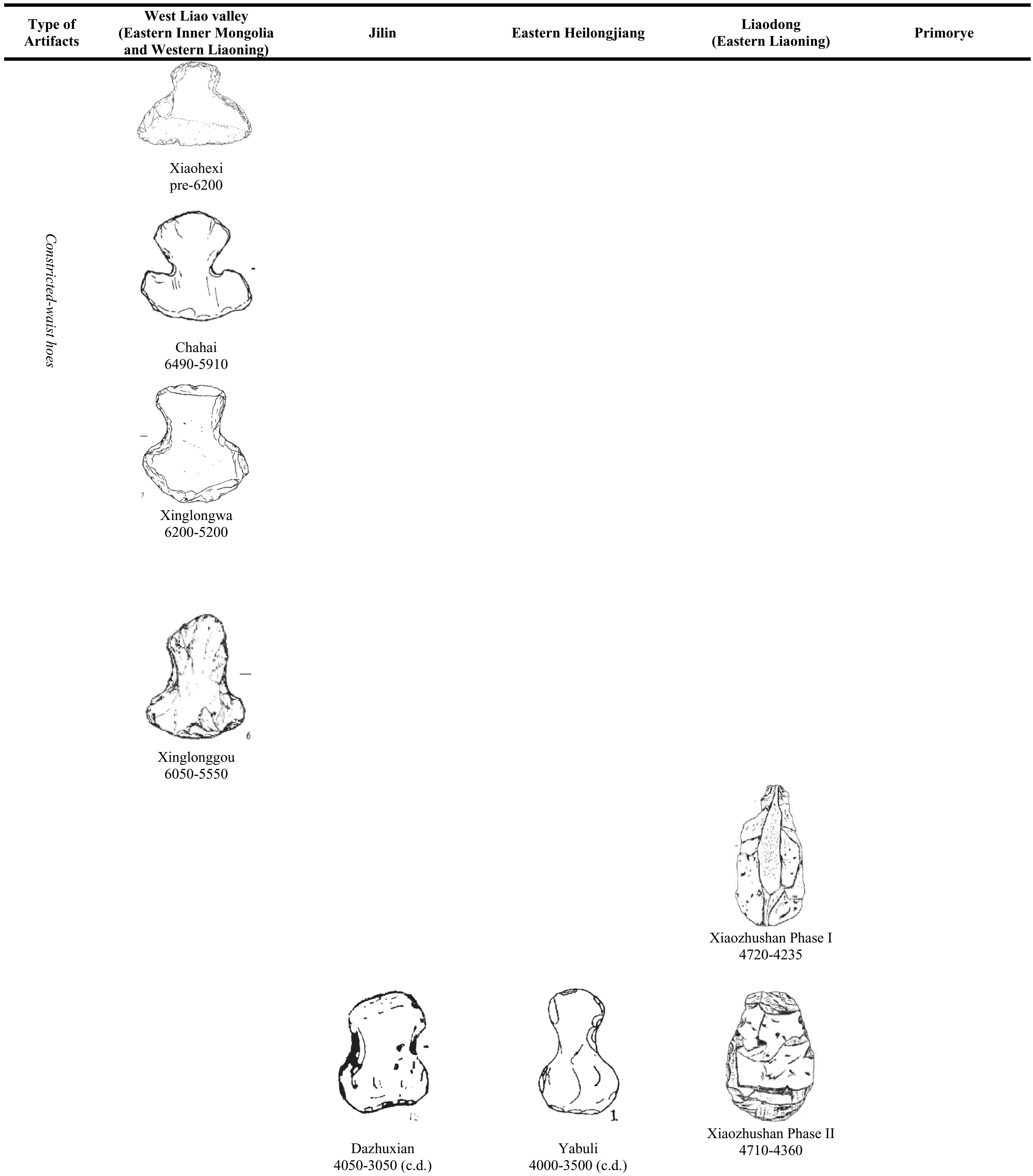


Fig. 3. Stone hoes and axes found in the West Liao valley, Jilin, eastern Heilongjiang, eastern Liaoning, and the Primorye (dates are BCE; c.d. = cross-dated with contemporaneous sites for which radiocarbon dates are available).

pottery of the Khanxi 1 type, interpreted as belonging to the earliest stage of the Zaisanovka culture, and ceramics from Yabuli in Heilongjiang. This leads him to propose that the 'cord-marked pottery of the earliest Zaisanovka Culture spread from the inland area of the Mudanjiang River and the Suifen River valley' where 'inland foragers acculturated with northern Chinese agriculture' and then migrated to the Primorye around 3480 cal BCE (Miyamoto, 2014: 19). Cord-marked/impressed ceramics had a wide temporal and geographical distribution in prehistoric East Asia, and have sometimes been the subject of extreme claims of long-distance relationships (e.g., Kharakwal et al., 2004). Miyamoto's proposal is a more limited one of typological influences over a distance of around 300 km. Tan et al.

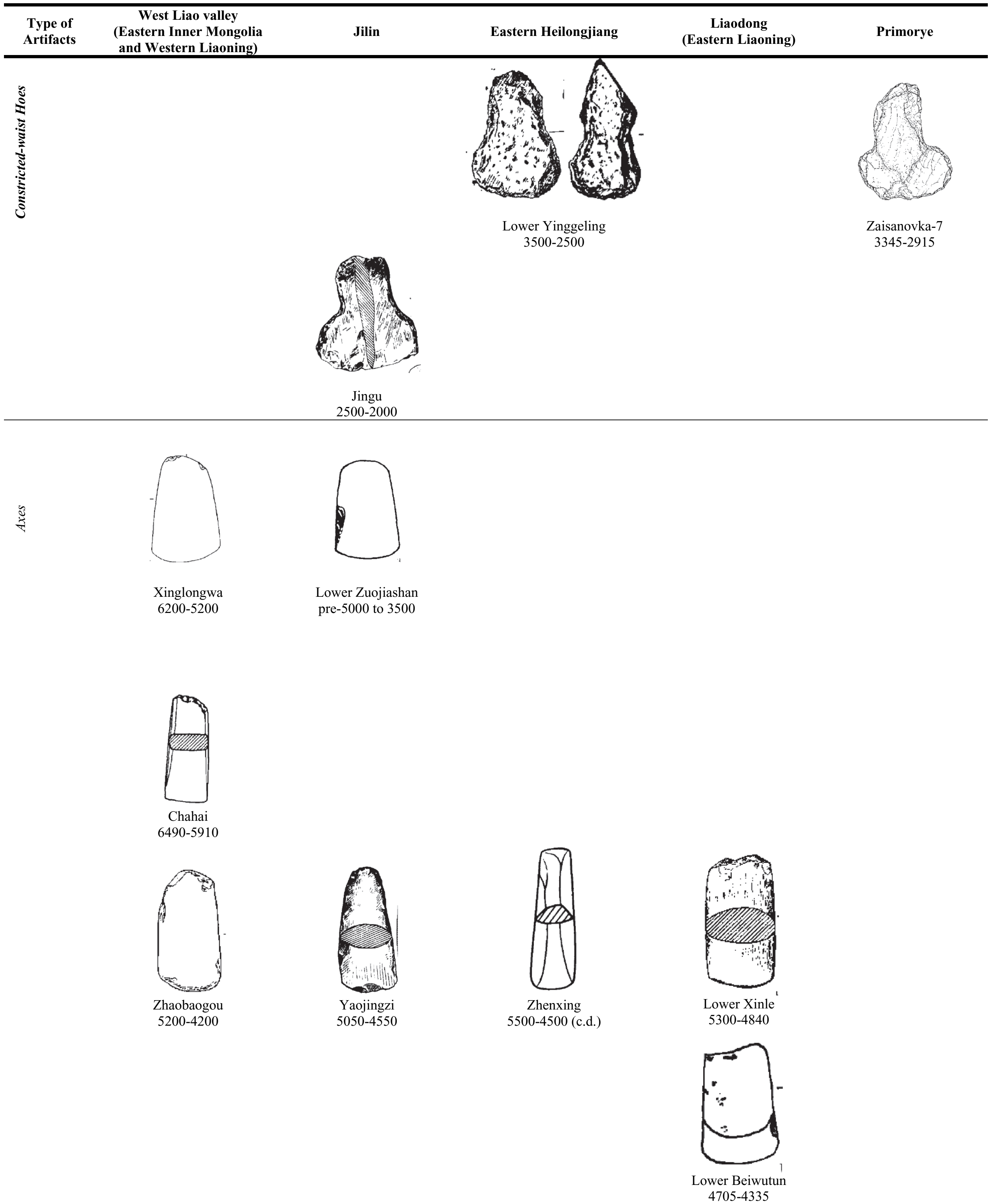


Fig. 3. (*continued*)

(1995) note that the Yabuli-Beishachang ‘culture’ also has constricted-waist stone hoes, stone grinding slabs and stones, and willow-leaf polished stone arrowheads.

Previous research has argued that later Zaisanovka ceramics (of the second millennium BCE) can be divided into fine and coarse wares, and that there may be links between the Zaisanovka fine wares and the

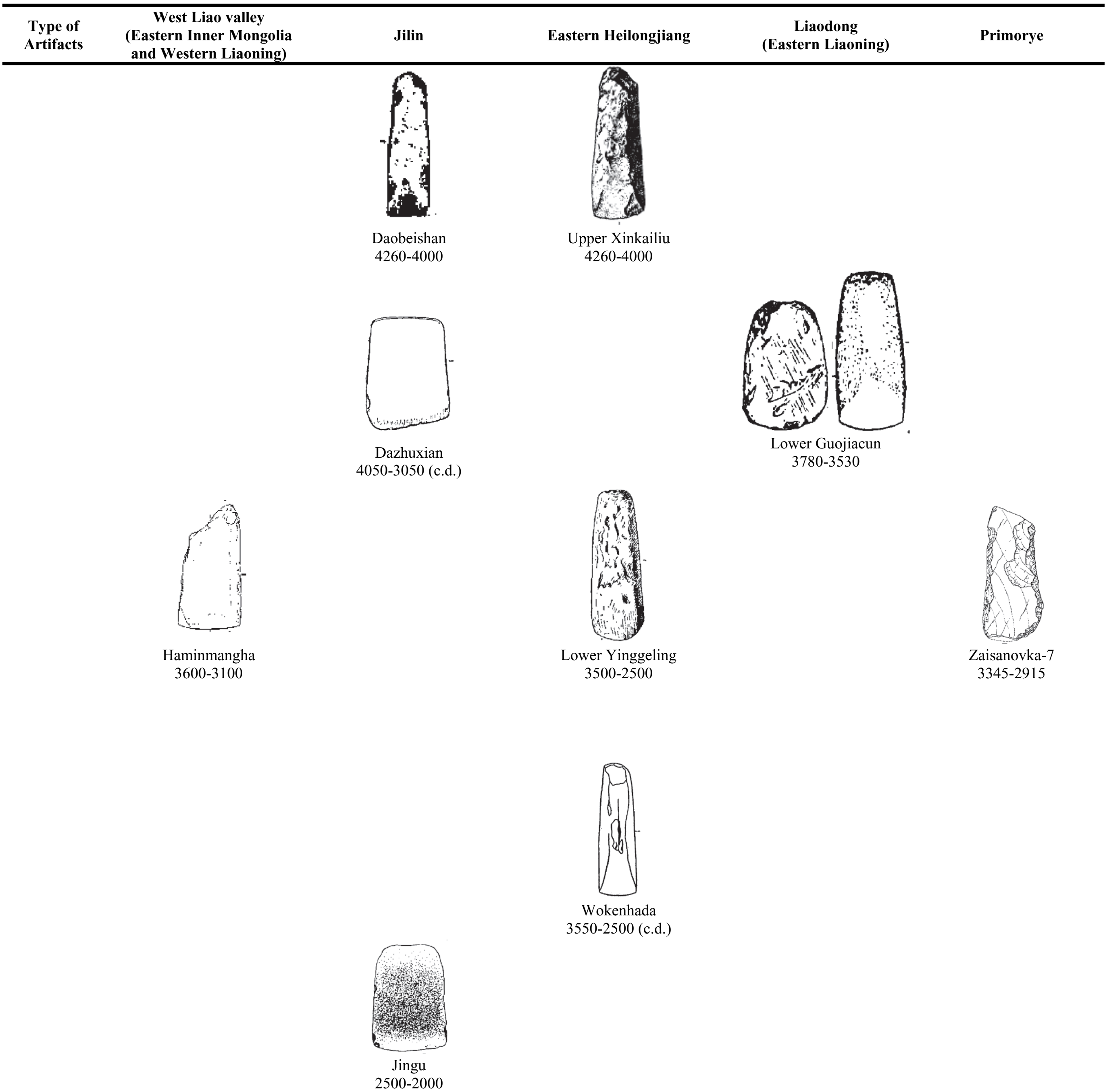


Fig. 3. (*continued*)

ceramics of the Bronze Age Andronovo culture of southern Siberia and Central Asia (Zhushchikhovskaya, 2005: 120–124). However, early sites of the Zaisanovka culture have only coarse wares. In Korea, the spread of millet cultivation seems to have been associated with the expansion of the very different Chulmun ('comb pattern') pottery (Miyamoto, 2014). Other categories of ceramic artifact such as flat-bottomed cylinders may provide further indications of cross-regional contacts in Neolithic Northeast Asia (Wang, 2012; Du, 2014), but it seems that the pottery of the early millet farmers of the Primorye underwent influences from several regions and further research is required.

Anthropomorphic figurines were found at the 8000-year-old Xinglonggou site in the West Liao basin and, no later than 3500 BCE, human and animal figurines made of pottery or stone became widely distributed toward the north and east, for example, at Aobaoshan, Zuojiashan and Yuanbaogou in western Jilin. In the Primorye, a few anthropomorphic and animal figurines were discovered at sites of the Zaisanovka culture (Zhushchikhovskaya, 2006; Komoto and Imamura, 1998). At Siny Gai A, human face images made of ceramics and bone were found with a few animal figurines including turtle-like figures. Stylistic similarities with human head figurines of the Lower Houwa culture may be noted. A ceramic human mask from Novoselishche 4 was found in the Neolithic pit house which also produced millet remains. Some stylistic similarity with human heads from Neolithic sites in Inner Mongolia may be supposed. At Valentin-Peresheek, there were two examples of anthropomorphic relief figures on the walls of ceramic vessels. The lower, Zaisanovka horizon at Kievka 1 produced a female-like ceramic figurine. Gvozdevo 4 produced a ceramic figure of a deer and a fragment of a ceramic animal-like figurine came from Sheklyaevo 7 (Klyuev et al., 2003; Krutykh et al., 2010).

In the Liaodong region, there were animal (pig, fish, bird, etc) and human figurines at Houwa (Xu et al., 1989). But unlike in the West Liao area, figurines in Liaodong were never related to altars or public architecture and they seemed to have been assigned less ritual and symbolic significance than in western Liaoning and the Jilin-Heilongjiang region. Figurines were extremely rare in Neolithic Korea where they were mostly limited to the southern coastal area (Komoto and Imamura, 1998).

Spindle whorls are found at Xinglongwa sites dated to 8200 to 7500 years ago (Qiao, 2014). At Houwa (4370–4159 to 3091–2897 BCE) in Liaodong, 104 spindle whorls were found, all of which were of a similar shape as those found in the West Liao basin (Xu et al., 1989). In the Primorye, spindle whorls are known from the fourth millennium BC at early sites of the Zaisanovka culture but not from the Rudnaya or Boisman cultures (Furusawa, 2007; Tabarev, 2014). Furusawa (2007) notes typological differences between the early spindle whorls of the Primorye and those from Liaodong. While he does not discuss influences from Jilin or Heilongjiang, Furusawa (2007) raises the possibility of contact with cultures in the Amur valley to the north. However, the sites of the Zaisanovka culture do not contain clear evidence of contacts with the Lower Amur region. Nelson et al., 2020 point out similarities between the early spindle whorls of the Primorye and those from the West Liao area. The Zaisanovka 7 site has also produced 586 notched weights. Two of these were made of clay and are reported as possible loom weights (Komoto and Obata, 2005). The others, made of stone, are described as net sinkers. The location of the site near where the Gladkaya River flows into the Expedicia Inlet of the Sea of Japan, together with the excavated fish and mollusc remains, suggest that net sinkers would have been an important tool for the Neolithic inhabitants of Zaisanovka 7. However, Sarah Nelson (1975); Kent and Nelson, 1976; Nelson et al., 2020) has long argued that archaeologists tend to play down the importance of loom weights in the archaeological record and the presence of spindle whorls in Neolithic sites of the Russian Far East certainly implies the importance of new weaving technologies.

2.1.4. Jade

Neolithic jade ornaments were widely distributed across Northeast Asia including the Primorye (Fig. 5). Deng and Deng (2017: 21–22) argue that jade *jue* slit-rings were first produced in the Liao River basin. By 5000 BCE, jade *jue* had reached Jilin and Heilongjiang in the north and Shandong in the south. At Xiaonanshan in eastern Heilongjiang, more than 70 jade artifacts were dated to between 6000–5000 BCE (Jiamusishi and Raohexian, 1996; Zhao et al., 2013:76). Between 5000 and 4000 BCE, *jue* and other jades (*guan* tubes, *zhu* beads, *bi* discs) reached the Primorye, the Yangtze River valley and the Japanese Islands. These finds across such a wide landscape suggest contact between the West Liao and eastern Heilongjiang as early as 8000–7000 years ago. Such contacts continued through Hongshan times (4500−3000 BCE), evidenced by jade *bi* and joined *bi* discs widely distributed from the West Liao basin to Jilin and Heilongjiang at sites including: (1) Hutougou, Niuheliang, and Sanguandianzi in western Liaoning (Liu, 1995); (2) Yaojingzi and Daobeishan in central and western Jilin (Zhou, 2000); (3) Lijiagang, Angangxi, and Dongwenggenshan in western Heilongjiang (Liu, 2000); (4) Huoshaozuizi in southeastern Heilongjiang (Yu, 1992); and (5) Xiaonanshan, Yabuli, and Wokenhada in eastern Heilongjiang (Liu, 2000; Zhou, 2000).

Compared to the Liao basin and Jilin and Heilongjiang, Liaodong has fewer Neolithic jades. Dated between 5000 and 3000 BCE, the Liaodong jades are reported mainly at Xiaozhushan, Wujiacun, Houwa, Beiwutun, Guojiacun and Santangcun (Zhou, 1999). The northeastern part of Liaodong has older jades than the southern part, suggesting a dispersal route from north to south (Zhou, 1999: 20). The Liaodong jades distinguish themselves from elsewhere in Northeast China by their shapes and forms (Zhou, 1999: 20–21). We conclude that the use of jade started later (probably not until the Middle Hongshan) in the Liaodong region where Neolithic people developed their own traditions of making and using jade despite influences from the Liao basin. Curved, tubular and globular types of jade have been reported from Neolithic Korea (Lee, 1998: 350–358; Bausch, 2017). Jade *jue* are known from Munam-ni (Shin et al., 2012). However, common Northeast Chinese jade types such as *jue*, *shao*, *bi* and joined *bi* are rare in the Korean peninsula.

The Devil's Gate (Chertovy Vorota) site in the Primorye, belonging to the Neolithic Rudnaya culture, has finds of one *jue*, four *shao*, one *bi*, as well as other artifacts made on jade-like material. Human remains from Devil's Gate were radiocarbon dated to 5726–5622 BCE (Siska et al., 2017). Two jade *jue* and one shell artifact similar in shape to a joined *bi* were found at Boisman 2 (Popov and Tabarev, 2016: 403). A set of stone ornaments similar to *bi*, joined *bi* and *shao* were identified at the multi-layered Sheklyaevo 7 site. This set is said to be connected with the horizon of the Rudnaya culture recognized at this site (Klyuev et al., 2003). These artifacts suggest that as early as the sixth millennium BCE, the Primorye shared with Northeast China not only jades of the same shapes but also similar jade production techniques (string sawing) (Deng and Deng, 2017). However, true jade or jade-like objects are not known from Zaisanovka culture sites. In sum, although the evidence indicates that jades dispersed from the West Liao region to the Primorye, the early dates suggest that the spread of jades preceded the dispersal of millet agriculture. The jade evidence supports a long-existing exchange corridor which may have facilitated later millet dispersals.

2.1.5. Stone circles

Neolithic stone circles (*jishizhong*) are found in eastern Inner Mongolia and are also common in Liaodong, especially in Dalian where they are mostly dated to between 3000 and 2600 BCE, thus post-dating the Hongshan culture (Xu and Tian, 2013). *Jishizhong* have: (1) stone piles which form a circle on the ground surface; (2) human burials at the centre, associated with finely-made objects such as jades and painted pots; (3) some *jishizhong* have earthen mounds. Song (2018) argues that the use of stone circles in Dalian was an influence from the West Liao basin. Song (2018:40–41) also mentioned finds of similar stone circles at Shido and Chimchon-ri in North Korea dated to between 1500 and 1000 BCE and suggested that stone circles on the Korean peninsula were introduced from Liaodong. No such stone circles are known from the Russian Far East or from Jilin and Heilongjiang. While further research is required, the *jishizhong* stone circles may support Neolithic contacts between Liaodong and the Korean peninsula.

2.1.6. Summary of archaeological evidence

Although there are relatively few well-dated sites with millet remains from our study area, the available evidence supports an expansion of millet cultivation in Northeast Asia from the mid sixth millennium BCE in the West Liao River basin to the mid fourth millennium BCE in southern Korea and the Primorye. Based on current evidence, it seems probable that millet farming spread more or less simultaneously to Korea and the Primorye, as proposed by Kuzmin (2013) and Miyamoto (2014). In the Primorye, the dispersal of millet farming was associated with Northeast Chinese types of stone agricultural tools, especially grinding slabs and pestles and constricted-waist hoes. However, these tools appear at a certain stage of the Zaisanovka culture, slightly after the initial appearance of millet cultivation. Cord-marked pottery from Heilongjiang may be further evidence for contact between Northeast China and the Zaisanovka culture. It is also likely that spindle whorls and spinning technology arrived in the Primorye from Northeast China in association with millet farming (Nelson et al., 2020). The evidence from jades and perhaps portable art suggests very wide and long-term exchange networks across Northeast Asia into the Primorye. Those networks can be assumed to have played a role in building hunter–gatherer resilience (cf. Hudson et al., 2012; Fitzhugh et al.,

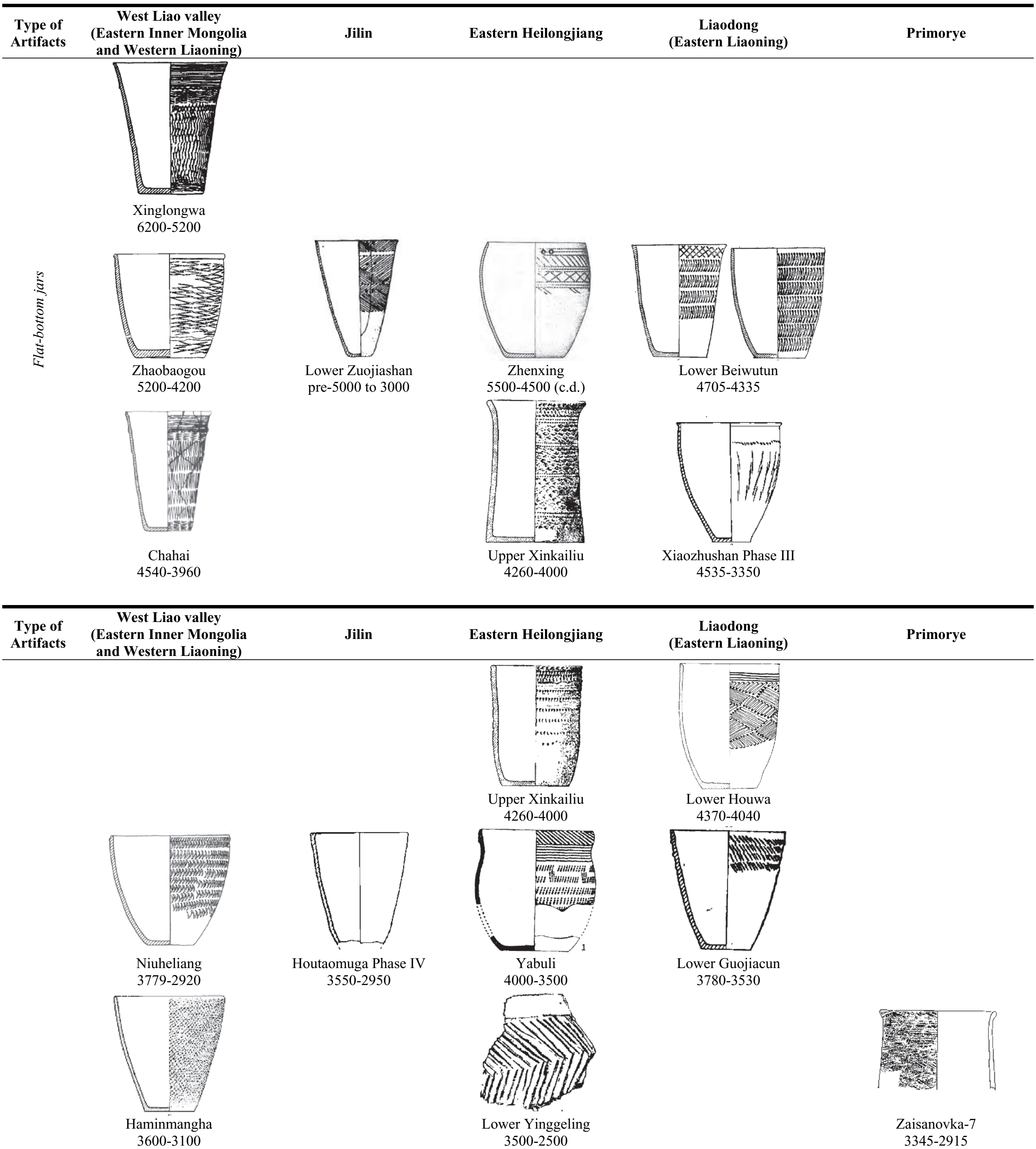
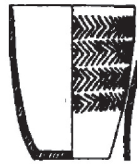
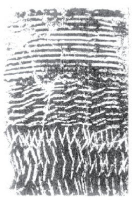
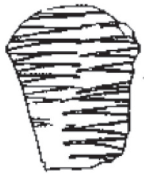
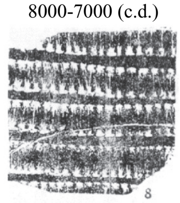
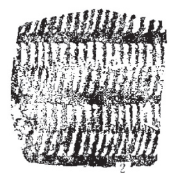


Fig. 4. Pottery shapes, forms, and decorations from the West Liao basin, Jilin, eastern Heilongjiang, eastern Liaodong, and the Primorye (dates are BCE).

2016) and perhaps in facilitating the dispersal of millet farming.

Lack of archaeological data from North Korea makes it difficult to test Yan's (1993) Yalu model. However, the cultural influence of the West Liao basin was less strong in the Liaodong region, or else included common features of a different nature, compared to those noticed in Jilin and Heilongjiang. Therefore, the dispersal of millets to the Korean peninsula probably followed a separate route over the Liaodong peninsula. Millets at the Wangjiacun (3550–3350 BCE) site suggest contact with the West Liao basin, but, by contrast, stone tools, jade, pottery and figurines all showed stronger local traditions in Liaodong. Connections with the West Liao basin were even weaker in eastern Liaodong and the Korean peninsula. On current evidence, therefore, the Manchuria model of the direct expansion of millet farming from the Liao river area across Jilin and Heilongjiang to the Russian Far East is most consistent with the archaeological data (Table 3).

Type of Artifacts	West Liao valley (Eastern Inner Mongolia and Western Liaoning)	Jilin	Eastern Heilongjiang	Liaodong (Eastern Liaoning)	Primorye
		 Jingu 2500-2000			
Horizontal/vertical zigzag or punctured-dot zigzag patterns	 Xinglongwa 6200-5200	 Aobaoshan 8000-7000 (c.d.)			
	 Zhaobaogou 5200-4200	 Yaojingzi 5050-4550	 Zhenxing 5500-4500 (c.d.)	 Lower Beiwutun 4705-4335	

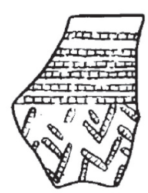
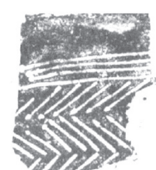
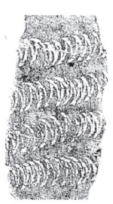
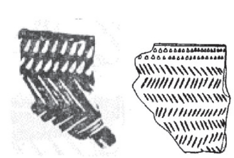
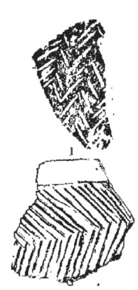
Type of Artifacts	West Liao valley (Eastern Inner Mongolia and Western Liaoning)	Jilin	Eastern Heilongjiang	Liaodong (Eastern Liaoning)	Primorye
	 Niuheliang 3779-2920	 Lower Zuojiashan pre-5000 to 3000	 Zhenxing 5500-4500 (c.d.)	 Lower Houwa 4370-4040	
	 Haminmangha 3600-3100	 Yuanbaogou 4670-3980		 Lower Guojiacun 3780-3530	
					

Fig. 4. (*continued*)

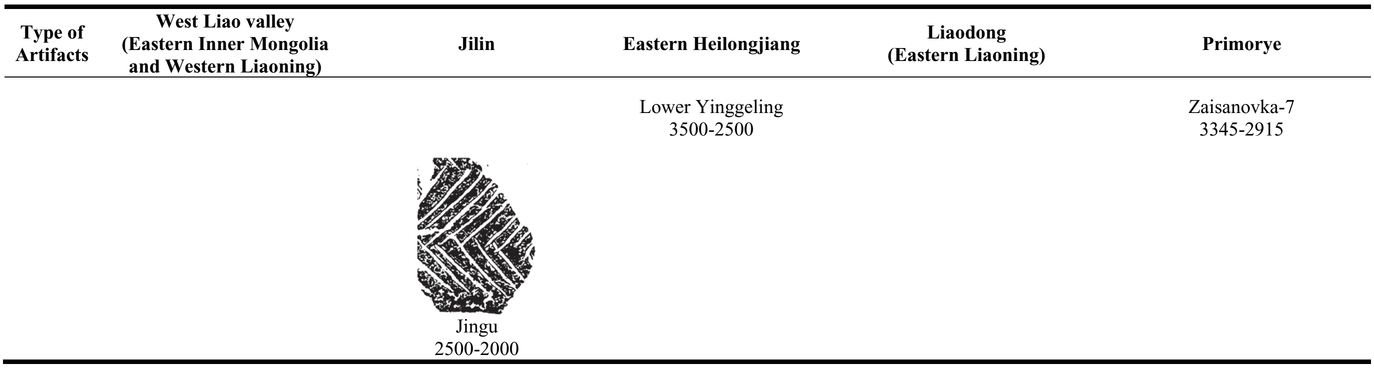


Fig. 4. (*continued*)

2.2. Genetic evidence

2.2.1. Research history

Only a few Neolithic and Palaeometal sites from the Primoyre have produced human skeletal remains. Approximately 35 individuals are known from the Middle Neolithic Boisman 2 site (Popov et al., 2014; Popov and Tabarev, 2016). Artificial cranial modification has been identified at this site (McKenzie and Popov, 2016), a custom which

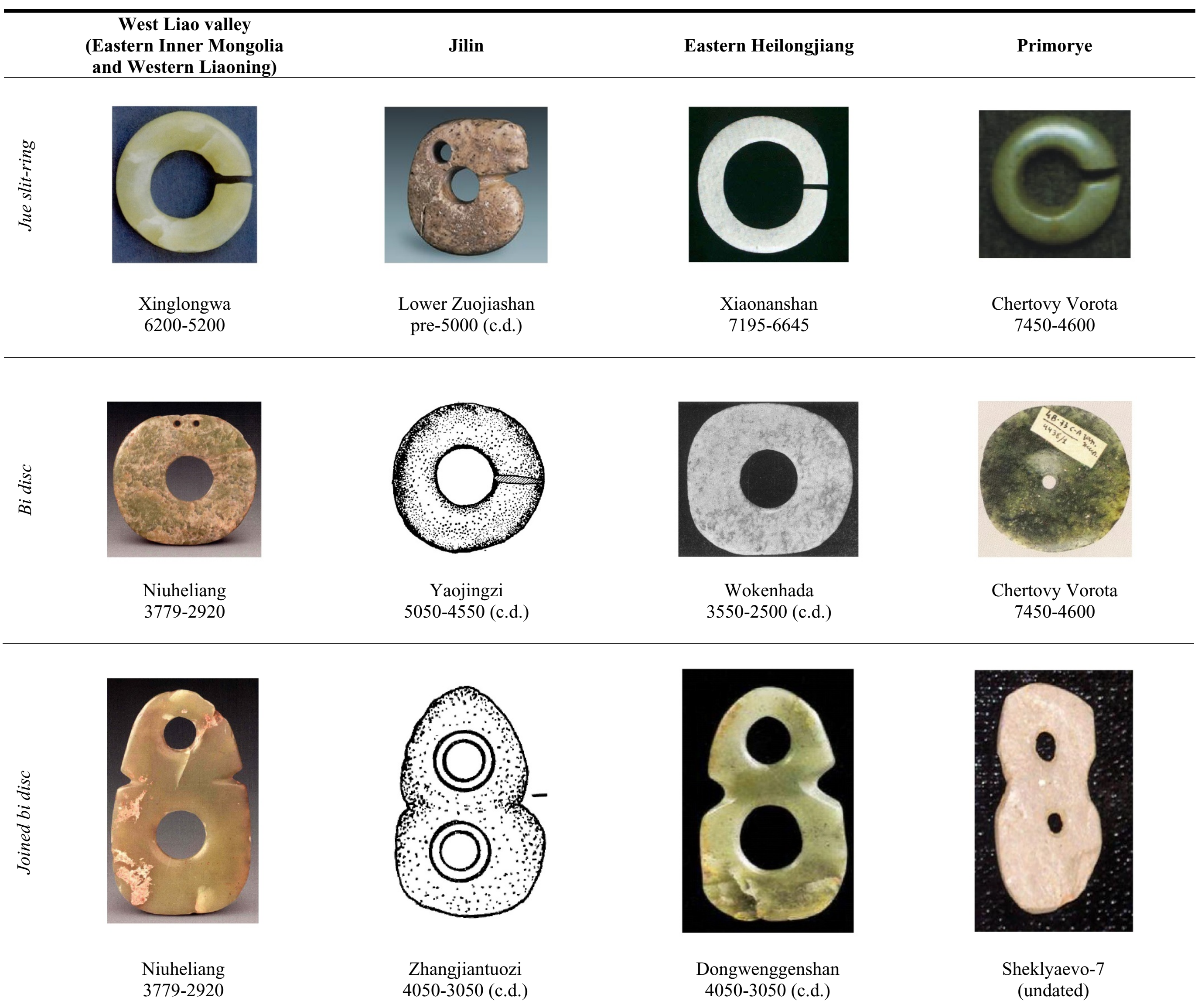


Fig. 5. Jade artifacts found in the West Liao basin, western Jilin and eastern Heilongjiang, and the Primorye (dates are BCE, c.d. = cross-dated with sites for which radiocarbon dates are available).

Table 3
Presence (+) of comparable data (millets, stone tools, painted pots, residential burials) in Northeast China and the Primorye. See Supplementary Table 1 for details of dating.

Region	Site and dates (BCE)	Millets	Stone tools		Jade						Pottery				Residential burials
			Constricted hoes	axe	*huan* ring	Dragon	*bi* disc	*jue* slit-ring	Joined jade	Tube beads	Human/animal figurines	Zigzag pattern	Straight-walled flat bottomed jar	Painted pots	
Liaoning	Xinglonggou (6050−5550)	+	+	+	+		+	+				+	+		+
	Chahai (6490–5910)		+	+				+		+		+	+		+
	Hutougou (3550–3050)				+		+		+	+				+	
	Niuheliang (3779–2920)		+	+	+	+	+	+	+	+	+	+	+	+	
	Weijiawopu (4500–4000)	+	+	+								+	+	+	
	Haminmangha (3600−3100)	+	+	+	+		+		+			+	+	+	
Jilin	Dazhuxian (4050–3050)		+	+									+		
	Aobaoshan (8000–7000)		+	+	+					+	+	+	+		
	Zhangjiantuozi (4050–3050)								+		+				
	Yaojingzitun Beigang (5000)				+					+		+			
	Zuojiashan (5000–2500)	+		+		+					+	+	+		
	Yuanbaogou (4670–3980)			+							+	+	+	+	
	Houtaomuga IV (3500–2950)	+		+								+	+	+	
	Jingu (2500–2000)		+	+									+		
Heilongjiang	Upper Xinkailiu (4260–4000)			+							+		+		
	Tengjiagang (6000–5730; 3700–3350)			+	+		+				+				
	Wokenhada (3550–2500)						+			+			+		+
	Yabuli (4500–3500)		+	+	+		+		+			+	+		
	Angangxi (2500–2000)														
	Lower Yinggeling (3500–2500)		+	+							+				
Primorye	Krounovka-1 II-III horizons (2720–2690)	+		+								+	+		
	Bogolyubovka-1 (2710–1940)	+		+								+	+		
	Sheklyaevo-7 (2530–2450)	+										+			
	Gvozdevo-4 (2230–2150)	+									+	+			
	Zaisanovka-7 (2550)	+	+									+	+		
	Novoselishche-4 (1850–1150)	+									+	+	+		
	Vodopadnoe-7 (2523–2361)	+		+								+	+		
	Rettikhovka-Geologicheskaya (1440–1330)	+										+	+		

complicates biodistance analyses based on cranial metrics. The Devil's Gate site is discussed below. Cherepakha 13 is a recently discovered Yankovsky culture cemetery near Vladivostok dated to ca. 1200 cal BCE (Kuzmin et al., 2018). A stable isotope analysis of human skeletons from this site found results consistent with millet consumption (Kuzmin et al., 2018), but no biodistance or archaeogenetic analyses have yet been conducted. Finally, a burial from Zaisanovka 7 was also assigned to the Yankovsky culture and cross-dated to the first millennium BC (Komoto and Obata, 2005). A preliminary cranial metric analysis of this skull found similarities with prehistoric Northeast Asian populations but a significant distance from Jōmon and south Chinese samples (Nakahashi, 2007).

2.2.2. The Yalu vs. Manchuria models

Our recent palaeogenomic study of north China found highly stable but distinct genetic profiles in the Yellow and Amur river regions dating back to 4000 and 5500 BCE, respectively (Ning, 2018a, 2018b). However, the geographically intermediate West Liao region showed genetic profiles which varied over time and with subsistence strategy. In the West Liao basin, we can assume a basal Amur-like genetic profile which shows an increasing degree of admixture with the Yellow River genome over time as reliance on millet increased in the Late Neolithic. The subsequent spread of animal pastoralism in the Bronze Age Upper Xiajiadian culture led to a restoration of genetic similarities with the Amur region (Ning, 2018a, 2018b).

Long-term genetic continuity in the Amur basin was also documented by Siska et al. (2017) who used their results to argue against population replacement by exogenous farmers. However, this last conclusion is problematic for several reasons. Firstly, Siska et al. (2017) only compared the genomes of two hunter–gatherers from the Russian Far East with present-day populations, while the genomic structure of Neolithic millet farmers in that region is still unknown. Whether the Neolithic millet farmers' genomes are also similar to the hunter–-gatherers from the Devil's Gate site awaits further research. Secondly, the two Devil's Gate individuals were dated to 5726–5622 BCE, predating the first evidence of millet farming in the region by around two millennia. Thirdly, Siska and colleagues do not take into account the possibility that the incoming farmers may have shared an Amur-like genetic profile with the local populations. Our genomic study of a 5500-year-old individual from the Haminmangha site in the West Liao basin showed that this individual lies in the Amur cluster, which is genetically continuous with present day Tungusic populations and shares a large proportion of her genetic features with the two Devil's Gate individuals (Ning, 2018a, 2018b). This raises the possibility that genetic admixture between millet farmers and hunter–gatherers could have occurred, but that the admixture of two similar genomes resulted in few genetic changes. For this reason, the genetic evidence cannot currently exclude the possibility that the dispersal of millet farming from the West Liao River basin into the Russian Far East might have been accompanied by demic diffusion.

Current genetic data are insufficient to test Yan's Yalu model because of the lack of ancient DNA data from Liaodong and the Korean peninsula. In sum, we cannot confirm either the Yalu or Manchuria models based on currently available genetic data. Further studies on ancient genomic data from the West Liao River basin, Liaodong, the Russian Far East as well as the Korean peninsula will serve as a key to understand agricultural dispersals in Northeast Asia.

2.3. Linguistic evidence

Robbeets (2017b) has proposed to connect the dispersal of millet agriculture to the Russian Far East with the split of the Tungusic branch from the Altaic language family and its spread to the Primorye. The estimated location of the Altaic homeland in the West Liao River basin, the location of the Tungusic homeland in the southern Primorye, and the separation date between Tungusic and Turko-Mongolic inferred at 3300 BCE are suggestive of this connection (Robbeets, 2020). Linguistic evidence suggests that millet farmers speaking an ancestral form of Tungusic spread beyond the West Liao River basin, moved eastward, and reached the Primorye around 3300 BCE via an inland route distantly removed from the Liaodong peninsula and the coastal areas of the Yellow Sea. The indications come from the topology of the Transeurasian family tree and the transfer of maritime borrowings from coastal languages into the ancestral Tungusic language. This evidence is explained below.

2.3.1. Family tree

Robbeets and Bouckaert (2018) tested the probability of different hypotheses with regard to the position of the Tungusic branch within the Transeurasian family tree. The hypothesis that Tungusic forms a separate entity with Mongolo-Turkic received overwhelmingly more support than the hypothesis in which Tungusic clusters with Japano-Koreanic (Fig. 6). This suggests that the dispersal of Tungusic-speaking populations took a route that was radically separated from the dispersal of Japano-Koreanic-speaking populations. Given the evidence to situate Japano-Koreanic on the Liaodong peninsula (Robbeets, 2017, 2020), from where Koreanic entered Korea across the Yalu river and Japonic crossed the Yellow Sea to enter mid-west Korea from the Liaodong and Shandong peninsulas, it is unlikely that the Tungusic speakers followed a similar southern route along the Liaodong peninsula.

2.3.2. Maritime borrowings in proto-Tungusic

The observation that maritime vocabulary can be reconstructed to proto-Japono-Koreanic, while it is missing from proto-Tungusic, also supports an inland dispersal hypothesis. Robbeets (2017b) argued that proto-Japono-Koreanic was spoken on the Bohai coast and the Liaodong peninsula, based on the cultural reconstruction of maritime and coastal vocabulary to the ancestral proto-Japono-Koreanic language (pJK), e.g., pJK **pʊnə* 'boat', pJK **poko* 'swellfish, *Takifugu chinensis*', pJK **keni* 'crab, *Portunus trituberculatus*'. Such maritime reconstructions cannot be reconstructed for proto-Tungusic. Moreover, proto-Tungusic borrowed basic maritime vocabulary, such as the words for '(warm) wind (from the sea)' and 'whale', from the ancestor of the Nivkh language (Janhunen, 2016; see also examples (1) and (2) below). Given that the word in the first example is morphologically complex in Nivkh, *i.e.,* derived from the simplex root *la* 'wind', while the Tungusic parallel is not segmentable, the direction of the borrowing is verifiably from ancestral Nivkh into ancestral Tungusic. This suggests that the speakers of Tungusic did not acquire coastal or maritime vocabulary on their way from the West Liao basin to the Primorye. It can be assumed that they only became familiar with maritime vocabulary once they reached the coastal areas of the Primorye, where they came in contact with indigenous populations, some of which spoke an ancestral form of Nivkh. As a result, they borrowed maritime vocabulary from the coastal populations.

(1) Even *laamus* '(warm) wind (from the sea)' < Proto-Tungusic **laamos* ← Proto-Nivkh **lamos* > modern Nivkh *lams* 'eastern wind'.

(2) Proto-Mongolic **kalïmu* 'whale' ← Proto-Tungusic **kalïmV* id. ← Proto-Nivkh **kalïmV* 'whale' > modern Nivkh *kalm* (qalm) '(small) whale'.

3. Evidence for demic versus cultural diffusion

3.1. Archaeology

Both demic and cultural diffusion have been proposed in previous research on millet dispersals to the Russian Far East. However, past research has not attempted to test these explanations and has rarely been explicit about the driving forces behind the dispersal of millet agriculture. The archaeological evidence reviewed here suggests that long-range contacts across Northeast Asia existed from at least the time of the first millet cultivation in the West Liao River area in the sixth millennium BCE. By the fifth millennium BCE, Northeast Chinese jade artifacts had influenced the Neolithic cultures of the Primorye. The spread of jade ornaments may, in some cases, have involved actual migrations. The discovery of 78 *jue*-type slit stone earrings dating to around 5000 BCE at the Kuwano site in Fukui, Japan has been interpreted by Takahashi et al. (1998: 69) as evidence for migrants from China. Without supporting human biological evidence, however, it seems safer to assume that jade was exchanged as part of broad social networks that did not necessarily involve long-range migration.

By the Middle to Late Hongshan (4000−3000 BCE), the archaeology supports more extensive and persistent cross-regional contacts across Northeast China and into Korea and the Primorye. Our understanding of population movements in the Hongshan culture itself is complicated by debates over population density and the role of ritual 'pilgrimage' centres (Barnes and Guo, 1996; Peterson et al., 2010; Drennan et al., 2017). However, the fourth millennium BCE was a period which saw the expansion of agricultural systems in many parts of East Asia. The evidence from the Primorye considered here is consistent with that broad pattern, which Stevens and Fuller (2017) link with a Late Neolithic expansion of peoples and languages. The analyses here are also consistent with Miyamoto's (2014) proposal of population movements from Heilongjiang to the Primorye.

3.2. Genetics

As discussed above, we have found genetic similarities between a Neolithic farmer from the West Liao River and hunter–gatherers from the Russian Far East (Ning, 2018a, 2018b). This documents strong genetic continuity between the two regions but raises the possibility—*contra* Siska et al. (2017)—that millet farming in the Primorye was introduced by population migrations given that the admixture of two populations with similar genetic profiles will result in similar descendants.

The dispersal of millet to the Korean peninsula arguably took a separate route of dispersal (i.e., over Liaodong) than the route to the Primorye. This is indicated by the different nature of the cultural connections between the West Liao River and Liaodong and the Korean peninsula as compared to the connection between the West Liao and the Russian Far East. Indirect genetic evidence for the spread of millet farming to Korea may be provided by analysing the modern genomic data of the region, while recognizing that these can be biased by recent historical changes. Evidence from Y chromosome high throughput sequencing shows that Chinese males experienced a strong population expansion at approximately 4000 BCE, a time which corresponds with Yan's (1993) estimate for the spread of farmers into the Korean peninsula (Yan et al., 2014). This finding could be regarded as support for Yan's (1993) theory.

In conclusion, current genetic data cannot rule out potential population migrations associated with both the Yalu and Manchuria models. In genetics, populations that share similarities in genetic structure can be viewed as deriving from the same common ancestor, or else as displaying strong genetic exchange. Thus, if two populations share the same material culture but display little or no genetic exchange, their relationship can be explained through cultural rather than biological contact. However, an alternative explanation for the lack of genetic admixture could be the indistinguishable mixing of two populations with similar genetic profiles. This may explain the present case of Neolithic expansions in Northeast Asia.

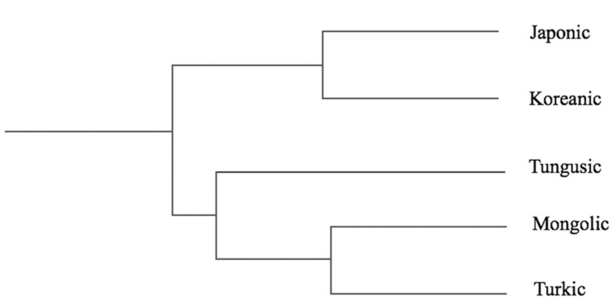


Fig. 6. Classification of the Transeurasian language family by Robbeets and Bouckaert (2018).

3.3. Linguistics

Population migration and cultural diffusion are expected to yield different linguistic outcomes (Thomason and Kaufman, 1988). In the former case, when human populations move into new areas along with their language and culture, language shift is frequently observed: local speakers abandon their own language in favour of the incoming target language. Due to imperfect learning, the abandoned language may leave some traces in the structure of the target language, a phenomenon called 'substratum interference'. Nevertheless, the newly adopted language is genealogically related to the ancestral language of the migrants. By contrast, in the case of cultural diffusion, when certain elements of language and culture move into new areas without the intervention of a migrating population, local speakers frequently maintain their own language but borrow certain words from the model language.

Above, we have associated proto-Nivkh with the language of coastal populations in the Primorye, while we connected proto-Tungusic with the language of incoming farmers who brought millet from Northeast China ca. 3500 BCE. Except for a handful of maritime loanwords (Section 2.3.2), proto-Tungusic borrowed very few words from proto-Nivkh. By contrast, there are several indications of proto-Nivkh substratum interference in proto-Tungusic. The evidence comes from atypical structural features in Tungusic that are likely to have developed through imperfect learning from proto-Nivkh (Robbeets et al., 2017). Among others, these features include the development of a word-initial velar nasal sound in Tungusic, and the development of a distinction between 'we (including the addressee)' and 'we (excluding the addressee)' on first-person plural pronouns, the development of a distinction between alienable and inalienable possession, and the development of marking possessive relations on the head noun instead of the dependent. These linguistic observations suggest a situation of language shift whereby some ancestral speakers of proto-Nivkh abandoned their own language and adopted the proto-Tunguisic target language. Therefore, from a linguistic perspective, population migration is better supported than cultural diffusion.

4. Conclusions

Archaeological evidence shows that millet agriculture arrived in the Primorye province of the Russian Far East from Northeast China by around the middle of the fourth millennium BCE. This dispersal can be considered as part of a broader expansionary phase of agriculture across China and East Asia in the same millennium. The archaeological data analysed here do not support Yan's (1993) theory that millet farming spread first across eastern Liaoning into northern Korea before then moving north to the Primorye. Instead, our results support proposals by Kuzmin (2013) and Miyamoto (2014) that millet farming dispersed directly across Manchuria to the Primorye. Evidence from historical linguistics is consistent with the archaeological record, suggesting that millet farmers speaking an ancestral form of Tungusic spread east from the West Liao River basin and reached the Primorye by an inland route, distantly removed from the Liaodong peninsula and the coastal areas of the Yellow Sea (Fig. 7). These findings are further compatible with the genetic similarities between Neolithic populations in the West Liao region and the Primorye. In contrast to claims by Siska et al. (2017) that population migration was not involved in Neolithic dispersals in the

Fig. 7. Language dispersals associated with millet farming in Neolithic Northeast Asia. Map by M. O'Reilly, MPI-SHH.

Amur basin, our archaeological and linguistic findings support the transfer of culture and language through the intervention of migrating people. The observed genetic continuity between hunter–gatherers and farmers in the Primorye does not exclude genetic admixture of two similar genetic profiles, which would be consistent with Ning's (2018a, 2018b) conclusion that a uniform Amur-like gene pool covered the region between the Liao River and the Primorye before 5000 BCE.

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Author statement

All authors designed this research, collected data and wrote the paper.

Declaration of Competing Interest

None

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