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Kushan Period rice in the Amu Darya Basin: Evidence for prehistoric exchange along the southern Himalaya

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Abstract The origins and prehistoric spread of rice agriculture between East and West Asia are hot topics in the current archaeological community. In this study, we present the results from a preliminary archaeobotanical study at the Khalchayan site in Uzbekistan, where we recovered the oldest securely dated rice thus far identified in Central Asia. We directly dated the rice grains to 1714–1756 cal yr BP (Kushan period), and morphologically compared them with other contemporaneous cultivated rice remains from China and India. The morphological results showed that the rice remains found at Khalchayan are more similar to cultivated *japonica* rice from southern China and northwestern India. Integrated archeological and chronological results from the surrounding area show that the rice remains found at Khalchayan likely spread along a southern Himalayan route from southwest China to northern India and finally reached the Amu Darya. The rice remains from Khalchayan are the first directly dated and well-reported rice remains found in Central Asia. By the Islamic period, rice was an important culinary aspect of the culture in Central Asia, but the cultural affinity towards rice only developed over the past two millennia. This study provides new information on the spread of rice agriculture globally, especially in arid-semiarid inland regions.

Keywords Rice, Central Asia, Khalchayan site, Agriculture spread, Seed morphology, Civilization exchange, Silk Road

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1. Introduction

The exchange of agricultural crops and cultivation techniques across the Old World began in the Middle Holocene, and was the most significant event in the development of human society. The relatively restricted area where people were cultivating plants during the Early Holocene, specifically in a few rich regions of eastern China and the Fertile Crescent of southwest Asia, gradually expanded outward after thousands of years of independent development. Rapid and extensive interaction between these centers of agricultural origin began after 5000 a BP (Jones et al., 2011;

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Zinkina et al., 2019). Western-derived technologies, such as bronze smelting, wheeled carriages, sheep (*Ovis aries*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*), entered the East Asian region along the northern route through the Inner Asian Mountain Corridor. Broomcorn (*Panicum miliaceum*) and foxtail millet (*Setaria italic*), as well as peaches (*Prunus persica*) originated in East Asia, and entered Central Asia and Europe along the same path. This exchange promoted the rapid development of Old World civilization and is known as the early globalization process (Amzallag, 2009; Fan et al., 2012; Miller et al., 2016; Stevens et al., 2016; Zhou et al., 2016).

Agricultural spread is the most highly cited and evident indicator of this early globalization process. Crops from different parts of Asia that had been cultivated for thousands of years were supplemented with local crops through the process of diffusion, thus forming a more diverse agricultural system. In addition, this exchange increased productivity and environmental adaptability and resulted in a more resilient response to environmental stressors, such as drought or epizootics (Zhao, 1998; Jiang and Liu, 2006; Fuller et al., 2009; Fuller, 2011a; Zhao, 2015). Additionally, the dispersal of these crops led to the production of new varieties through hybridization with local related and wild species, in some cases, leading to specific landraces that were better adapted to the local climate environment (Fuller and Rowlands, 2009; Gross and Zhao, 2014). Therefore, early globalization research elucidates the timing and path of agricultural spreading, which helps us to understand both the development of local agricultural systems, the productivity level, and crop evolution in different regions of Eurasia, as well as providing strong evidence for communication between the early urban centers of antiquity.

Rice has long been the most important food in East and South Asia, it is also historically an important crop in Central Asia, although very little is known about its origins in Central Asia (Spengler, 2019). This crop is divided into two major cultivated varieties, *japonica* (*Oryza sativa* ssp. *japonica*) and *indica* (*O. sativa* spp. *indica*). The origin, domestication and spread of these two varieties are among the most heavily debated topics in agricultural archaeological research (Fuller and Rowlands, 2009; Jones et al., 2011; Zheng et al., 2016). The current evidence shows that the progenitor of all Asian rice is *O. rufipogon*, and that it first evolved traits of domestication in the lower Yangtze region of China and spread to surrounding areas by 8000 a BP (Wu, 1998; An, 1999; Huang and Zhang, 2002; Qin, 2012; Lu, 2017). Thereafter, domesticated *japonica* gradually spread to northern, northwestern, and southwestern China, during the Holocene climatic optimum (Zhang J P et al., 2010, 2012; Jin et al., 2014; He et al., 2017; Deng et al., 2018b). *Indica* rice evolved traits of domestication on the Ganges Plain at some point before 4000 a BP; most scholars believe the traits of domestication introgressed into the Indian rice population through hybridization with eastern Chinese rice varieties (Stevens et al., 2016). There is an ongoing debate over how eastern Chinese rice spread to northwestern India by four millennia ago (Spengler, 2019). Domesticated Indian rice then gradually spread to the northwest and southeast of the Ganges Plain, southern parts of India, Sri Lanka, and southeast Asia (Fuller, 2011a; Gross and Zhao, 2014; Castillo et al., 2016).

Despite the cultural significance of rice in Central Asia today, notably as pilof, the national dish of Uzbekistan, there is currently no evidence showing that rice entered Central Asia or West Asia from East Asia thousands of years ago. In this study, we present a preliminary analysis of the agricultural system, noting that rice was cultivated during the Kushan period at the Khalchayan site in the Amu Darya region (Uzbekistan). We also discuss the timing and route of the spread of rice agriculture from East to Central Asia.

2. Materials and methods

2.1 Research area

Khalchayan (38°17′37″N, 7°58′44″E) is located in the Surkhan Darya region of southeastern Uzbekistan (Figure 1), which is one of the famous archaeological sites in the Amu Darya region. The Surkhan River is the primary tributary of the Amu Darya, with a length of 175 km and a drainage area of approximately 13500 km^2. The average temperature in January is 3°C, and that in July is 30°C; annual precipitation in the plain area is 130–360 mm, and that in the piedmont area is 440–620 mm (Yuan, 2004). The earliest archaeological activities in the area date back to 1925. In the 1960s and 1970s, archaeologists in the former Soviet Union carried out a great deal of archaeological work in the area and found a large number of settlements belonging to multiple historical periods (Pugachenkova, 1966).

The Khalchayan site is a city site in the Surkhan Darya region with an age of 2400–1650 a BP, corresponding to the Bactria and Kushan periods (Pugachenkova, 1966). The site was discovered by Soviet archaeologists in 1959 and was excavated several times between 1959 and 1963. The site is 2.5 km long from north to south and 1.5 km wide from east to west. The interior is divided into two mounded areas, Hanakatepa and Karabagtepa. Hanakatepa includes the palace (X-1), the West District (X-2), and the Southwest District (X-3); Karabagtepa is located to the east of Hanakatepa (Pugachenkova, 1966). The palace area contains 4 cultural layers, and the related relics mainly include pottery, pottery fragments, charcoal, animal bones, etc. The pottery types are not complicated, but the features are very distinctive. In addition, the relics include a large number of coins, clay sculptures, and murals from approximately 2050 a BP. The character

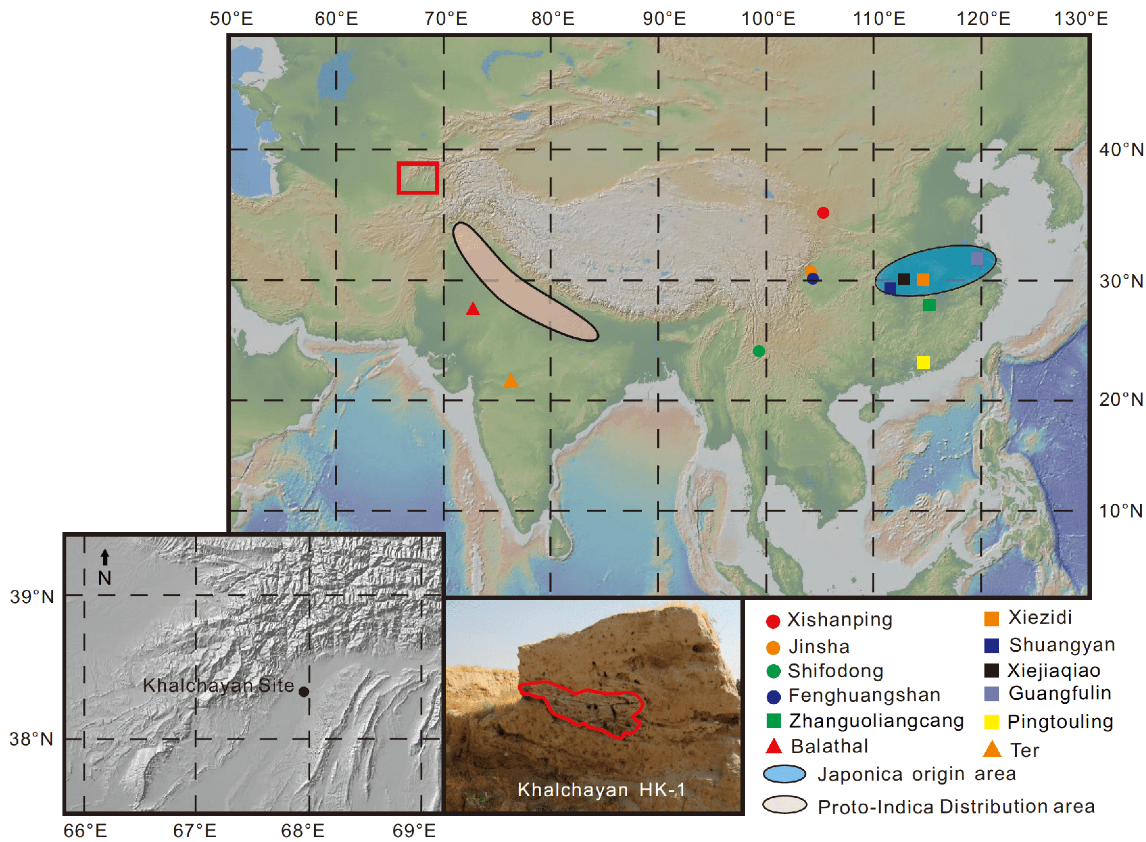

Figure 1 Research area, the Khalchayan site, an ash pit, and contrasting site location.

depicted in the sculptures is very similar to the character Heraios depicted on an early Kushan coin (Pugachenkova, 1971; Pugachenkova, 1966).

2.2 Experimental method

The flotation work was carried out at the Khalchayan site after excavation. The flotation samples came from the Khalchayan HK-1 ash pit (Figure 1), corresponding to the palace area in Hanakatepa. The material obtained by flotation was air-dried in the shade, and associated work, such as sorting, classification, and identification, were carried out in the Key Laboratory of Vertebrate Evolution and Human Origin of the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences. The intact plant seed remains were collected from the flotation samples and identified using a Leica M205 C stereomicroscope.

The rice remains were subjected to 225 kV three-dimensional (3D) fossil micro-CT (225-3D-μCT) scanning (Developed by the Institute of High-Energy Physics, Chinese Academy of Sciences) (Wang et al., 2017; Sun et al., 2018). The scanning parameters were set as follows: voltage 140 kV, current 120/100 μA, 360-degree rotation scan, step 0.5 degrees, 4 scans per angle, scan resolution 6.27 μm (X, Y, Z axis consistent). The raw projection was converted into a tomographic slice in .raw format by using IVPP225kVC-T_Recon software, and each tomogram consisted of 2048×2048 pixels.

The raw tomogram was imported into VGstudio 2.2 software, and the data were saved as a. Tiff format file and imported into Mimics 19.0 software to separate the sample from the pedestal to obtain the 3D structure of the rice remains. Separation was performed with the multiple modification and thresholding function tools in Mimics 19.0.

Additionally, the same kind of carbonized plant seeds were selected from the carbonized plant remains for AMS^{14}C dating, and the samples were sent to the US BETA laboratory for testing. The pretreatment protocol followed the acid-alkali-acid method. The sample was first ground and dispersed in deionized water, then washed with heated HCl to remove carbonate, after which NaOH was used to remove organic acid from the sample. Finally, the sample was washed and neutralized with acid and then dried. The ^{14}C dates were subsequently calibrated by using OxCal v3.10 software and the IntCal13 database (Ramsey, 2009; Reimer et al., 2013).

3. Results

3.1 Dating results

The dating results showed that the age of the ash pit was 3164–2925 cal yr BP (Table 1). The excavator speculated

Table 1 Radiocarbon age of the Khalchayan site

Lab No.	Sample name	Type	δ^{13}C (‰)	Age (a BP)	σ	Calendar calibration (cal yr BP)
BETA-515838	Halecharan 01	*Lithospermum arvense*	−22.5	2900±40	2	3164–2925
BETA-530014	Khalchayan 02	*Oryza sativa*	−24.6	1740±30	2	1714–1756
BETA-533104	Khalchayan 03	*Triticum aestivum*	−24.7	1690±30	2	1632–1534

that the ash pit was formed in the transition between the Yaz-1 and Yaz-2 periods in the middle Iron Age in Central Asia (Dani and Masson, 1992). However, the direct dating results for the rice seeds indicated an age of 1714–1756 cal yr BP, which corresponds to the Kushan period. The AMS^{14}C results of other crop residues were basically the same. Due to the extensive application of AMS^{14}C dating in archaeobotany research, it has been found at many sites that late grain remains and other crop seeds intrude into in early strata (Deng et al., 2019). Because the AMS^{14}C dating results from other crop seeds found in ash pits showed an age of 1632–1534 cal yr BP, we believe that the rice remains found in the ash pit are intrusive, but the possibility of an old carbon effect from weed seed remains cannot be excluded.

3.2 Macrobotanical remains

The botanical remains recovered through flotation include both local native plants and food crops. A total of 10 types of plants were identified among the 198 seeds. The identified food crops included 2 rice (*Oryza sativa*), 3 barley (*Hordeum vulgare*), 5 wheat (*Triticum aestvum*), and 20 foxtail millet (*Setaria italica*) specimens. The other identified remains included 1 grape pip fragment (*Vitis vinifera*), 8 flax (*Linum usitatissimum*), 1 lentil (*Lens culinaris*), and 2 pea (*Pisum sativum*) specimens. The other identified plants included *Chenopodium* sp., *Polygonum* sp., *Lithospermum arvense*, *Alhagi sparsifolia*, and *Galium aparine* (Figure 2).

3.3 Rice morphology

We took measurements of the length, width, and thickness from the rice specimens and photographed them under the microscope, the rice was scanned with a 225 Micro CT using Mimics research 19.0 software to reconstruct a high-resolution 3D model and then remeasured accurately based on the 3D reconstruction result. Since one of the rice specimens (Khalchayan 02) was damaged during the scanning process, its length was measured manually.

4. Discussion

4.1 Comparison of rice morphology at the Khalchayan site and others

Many archaeobotanists have debated whether *japonica* rice and *indica* rice can be morphologically differentiated. Approaches have been proposed, which include as the use of grain morphology, phytolith morphology, and ancient DNA analyses. Currently, there is considerable debate about the accuracy of these different methods (Kato and Kosaka, 1930; Yang et al., 2006; Ma et al., 2017). Because there were only 2 rice specimens found at the Khalchayan site, we could not make any clear conclusions regarding the morphology of the broader population that these grain came from. However, acknowledging the limitations of morphological methods, and recognizing the large area of overlap between the two subspecies, we felt that it was worth cautiously presenting the morphology.

Rice morphology is one of the most widely used indicators for distinguishing *indica* and *japonica* today. In general *indica* varieties are longer than *japonica*; however, there are short-grained landraces of *japonica* and hybrids of both. The commonly used method is based on the rice length-width ratio (L/W), but there are many differing views on what, if any, standards are reliable (You, 1976; Zheng et al., 2004; Fuller et al., 2007). Thus, there is no agreed-upon conclusion about whether it is necessary to restore the specimens to a fresh state through empirical formulas (Zhang and Pei, 2000; Ma et al., 2017). Because the current approach for studying the morphological changes in rice during the carbonization process is still not perfect, this paper uses the original data from the rice remains according to the revised standards of the International Rice Research Institute (IRRI) for modern specimens. The data were discriminated such that an aspect ratio >2.2 corresponded to *indica* rice and an aspect ratio <2.0 to *japonica* rice to determine the type of the unearthed rice at the site (Castillo, 2013; Castillo et al., 2016).

The morphological measurements of rice from Khalchayan show that the two grains of rice were 4.10–4.29 mm long, 2.13–2.51 mm wide, and 1.62–1.79 mm thick, with an aspect ratio of 1.71–1.93. According to the standards of previous studies on ancient and modern specimens, the rice from the Khalchayan site presents a more similar shape to *japonica* rice (Figure 3).

Rice specimens from northwest, southwest, and south China and central and northwestern India that were contemporaneous to those from the Khalchayan site were selected for comparison with modern *japonica* and *indica* rice from South Asia and the rice specimens from the Khalchayan site (Figure 3; Table 2) (Zhou, 1981; Kan, 1983; Xu, 1998; Li et al., 2007a; Jiang et al., 2011; Xiang et al., 2012, 2013,

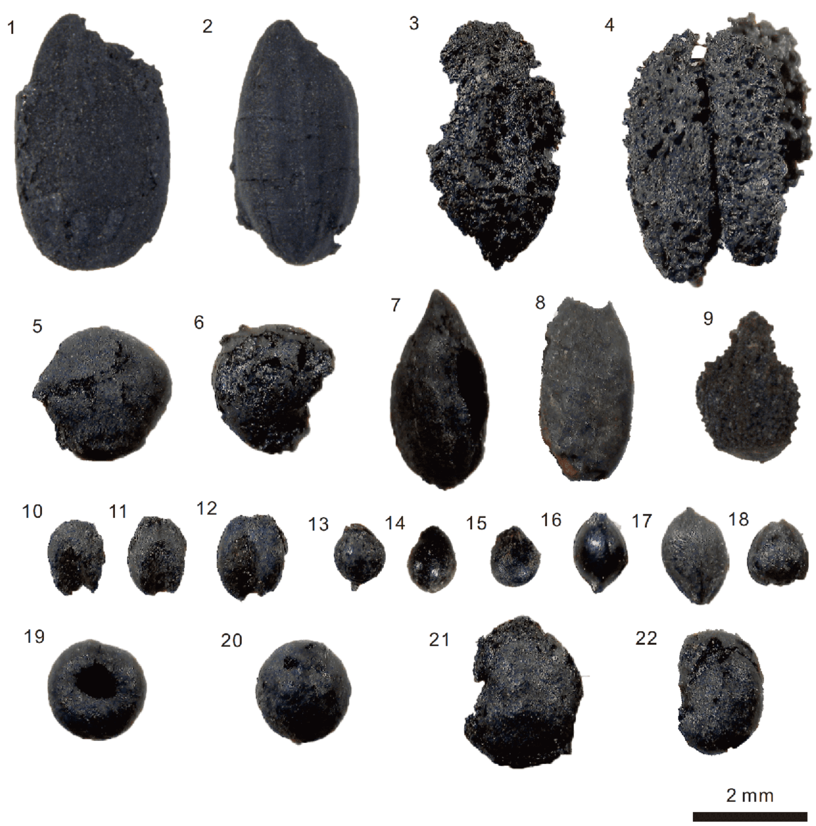

Figure 2 Macrobotanical remains from the Khalchayan site. 1–2, *Oryza sativa*; 3, *Hordeum vulgare*; 4, *Triticum aestvum*; 5, *Pisum sativum*; 6, *Lens culinaris*; 7–8, *Linum usitatissimum*; 9, *Lithospermum arvense*; 10–12, *Setaria italica*; 13–15, *Chenopodium* sp.; 16–18, *Polygonum* sp.; 19–20, *Galium aparine*; 21–22, *Alhagi sparsifolia*.

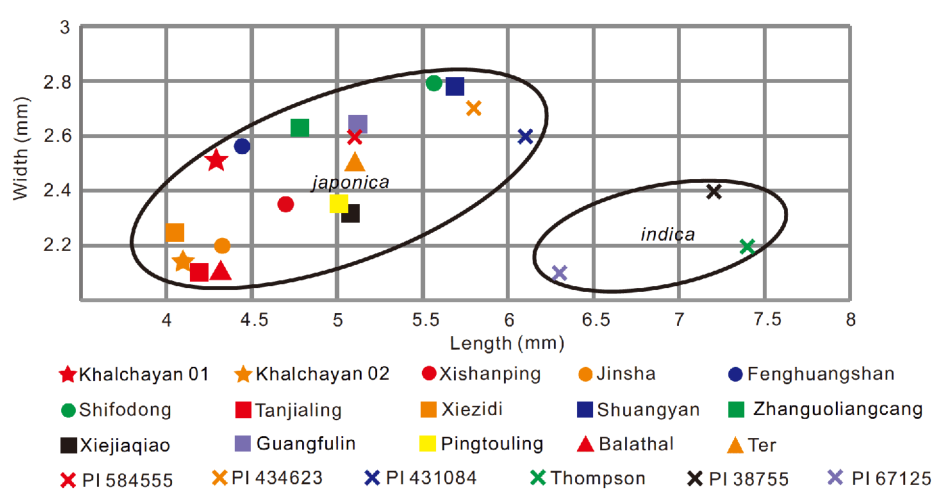

Figure 3 Comparison of morphological data from ancient rice and modern rice in China and South Asia.

2015; Deng et al., 2013; Tang et al., 2014; Castillo, 2013; Castillo et al., 2016). The results showed that the rice remains from Khalchayan presented an aspect ratio consistent with that of *japonica* from India and China, but the average length and width values were lower than most those of the rice remains from China and India from the same period. The Khalchayan site data were closest to those from the Balathal site, northwestern India and some sites in China. Compared with modern cultivated rice from south Asia, the rice remains at Khalchayan were similar to modern cultivated *japonica* rice, but the grain size was significantly smaller, and the Khalchayan remains showed obvious

Table 2 Statistics of the morphological data of ancient and modern rice in China and South Asia

Sample Name	*L* (mm)	*W* (mm)	*L*/*W*	Age (a BP)	Location	Type
Khalchayan 01	4.29	2.51	1.71	1740±30	Uzbekistan	*japonica*
Khalchayan 02	4.1	2.13	1.93	1740±30	Uzbekistan	*japonica*
Xishanping	4.69	2.35	2.00	5070–4300	Gansu, China	*japonica*
Jinsha	4.34	2.2	1.97	3200	Sichuan, China	*japonica*
Fenghuangshan	4.45	2.55	1.75	3000	Sichuan, China	*japonica*
Shifuodong	5.56	2.79	1.99	2925±110	Yunnan, China	*japonica*
Tanjialing	4.24	2.16	2.28	5000–4000	Hubei, China	*japonica*
Xiezidi	4.03	2.25	1.79	4200–3900	Hubei, China	*japonica*
Shuangyan	5.68	2.78	2.04	3000	Hunan, China	*japonica*
Zhanguoliangcang	4.78	2.63	1.82	2500	Jiangxi, China	*japonica*
Xiejiaqiao	5.08	2.32	2.19	2133	Hubei, China	*japonica*
Guangfulin	5.12	2.64	1.94	2500	Shanghai, China	*japonica*
Pingtouling	5.01	2.35	2.13	4000	Guangzhou, China	*japonica*
Balathal	4.3	2.1	2	2090±30	India	*japonica*
Ter	5.1	2.5	2.1	2250±39	India	*japonica*
PI 584555	5.1	2.6	1.96	modern	Nepal	*japonica*
PI 434623	5.8	2.7	2.15	modern	Bhutan	*japonica*
PI 431084	6.1	2.6	2.35	modern	Myanmar	*japonica*
Thompson	7.4	2.2	3.36	modern	Thailand	*indica*
PI 38755	7.2	2.4	3.00	modern	India	*indica*
PI 67125	6.3	2.1	3.00	modern	India	*indica*

morphological differences from modern cultivated *indica* rice from South Asia.

4.2 The path of the transmission of rice at the Khalchayan site

Over the past decade, a variety of new methods such as phytolith, starch, and C, N isotope analyses of animal bone have been widely used for the investigation of agricultural origins and transmission, leading to many impressive achievements (Lu, 2017). However, as the most traditional and intuitive research method, the evaluation of macrofossil remains of carbonized plants at archaeological sites still provides the most direct and credible evidence. However, due to the selective preservation of large subfossils, even in arid and semiarid regions, even though a large number of phytoliths may be found at a site, carbonized rice seeds may still be rare (Li et al., 2007a); therefore, the combination of macrofossil remain analysis with other methods, such as phytolith analysis, can greatly improve the reliability of the conclusions that are reached (Chen et al., 2012; Li et al., 2016; Xia et al., 2017; Deng et al., 2018a; Wang et al., 2018). Although only 2 carbonized rice grains were found at the Khalchayan site, these specimens represent the oldest securely dated of rice remains in Central Asia and are significant for studying the spread of rice to Central and West Asia.

After the domestication of *japonica* rice along the middle and lower Yangtze, the crop spread westward in two directions, roughly northwest and southwest, expansion during the Holocene Climate Optimum. At approximately 8000–7000 a BP, rice rapidly spread northwards to reach the Xihe site in Zhangqiu, the Yuezhuang site in Changqing, Shandong, the Zhuzhai site in Zhengzhou, Henan, and the Tanghu site in Xinzheng and continued to spread towards the northwest to Guanzhong Plain and the Hehuang area in Gansu (Zhang J P et al., 2010, 2012; Jin et al., 2014). Thereafter, rice was dispersed southwards from 5000–4000 a BP along two routes. One route passed through Tianshui in Gansu, Sichuan, Yungui, and other low-altitude areas into Indochina via the Tibet-Burma corridor (He et al., 2017); the other passed through Fujian, Taiwan, and finally reached Luzon island in the Philippines (He et al., 2017; Deng et al., 2018b).

Although Indian rice cultivation began as early as 5000 a BP, genetic studies have shown that the domesticated traits of *japonica* and *indica* are controlled by the same alleles, which originated in *japonica*. The most widely accepted scenario for how this occurred involves two independently developing processes of cultivation, one in eastern China and one in northern India. The cultivated rice in eastern China evolved to lose its mechanical seed-dispersal mechanism, rachises that shatter upon ripening. The cultivated rice in India did not evolve the same trait. However, eventually, East Asian rice dispersed to northern India, where the two subspecies hybridized and the tough-rachis trait from *japonica* gradually infiltrated the proto-*indica* rice population, thus establishing the subspecies of domesticated *indica*. The currently accepted model indicates that modern Indian cultivated rice evolved through hybridization and not as an independent selection for non-shattering florets (Figure 4) (Fuller et al., 2010; Fuller, 2011b; Gross and Zhao, 2014). However, the specific timing and path of the domestication of japonica rice from the southwestern part of China on the Indus Plain are still not clear (Castillo, 2013; Castillo et al., 2016).

Rice is an annual herb that prefers a warm and humid climate, and it is usually grown in standing water. Because it requires a great deal of water, the planting of rice in areas that are relatively dry and receive less precipitation requires certain water management techniques (Fuller, 2011a). In northern and inland areas, due to the lower precipitation rates, rice cultivation usually requires large-scale irrigation to ensure an adequate water supply. The westernmost part of the rice distribution in the prehistoric area of China includes the Xishanping and Qingyang sites in southwestern Gansu (Zhang and Wang, 2000; Li et al., 2007a). These sites are located at the boundary between the monsoon zone and the non-monsoon zone. The climate in the piedmont zone is warmer and more humid than in the surrounding area. Annual precipitation in this area today is roughly 574 mm per annum (Li et al., 2007a).

The Surkhan Darya region, where the Khalchayan site is located, has an arid continental climate; the modern annual precipitation is only 155 mm yr^{-1}, and the region is hot in the summer and cold in the winter. Global climate change during the late Holocene has resulted in a cooling and drying process. The hydrothermal conditions in the region could not support rice cultivation without irrigation. Other studies have shown that the local agropastoral populations in the mountainous areas of Central Asia incorporated domesticated crops with different seasonal precipitation needs into their economy by 4000 a BP. Archaeobotanists believe that these early farmers primarily lived in river valleys and began to use surface water on alluvial fans to support small-scale irrigation and the cultivation of wheat and barley (Miller, 1999; Spengler et al., 2014). Additionally, on the southern Misrian Plain, in the Margiana region, a complex agricultural system was present by the time of the Dahestan culture. People had established a canal system that was as long as 50 to 60 km, similar to Geoksiur farming, which used small channels leading from mountain streams or river deltas. Similar strategies can be found during the Chalcolithic and Iron Ages in the Bactria region (Dani and Masson, 1992). In South Asia, the rice cultivation method gradually changed from “dry rice” to “wet rice” cultivation, and rice spread from northern India to the Deccan Plateau of southern India, and Sri Lanka by 3000 a BP (Fuller, 2011a). In addition, domesticated cotton (another water demanding crop) was grown locally in Transoxania after 1600 a BP (Brite et al., 2017). It is clear that the local irrigation system was able to support highly water-demanding crops that required long growing seasons and significant labor investment. These requirments need to be considered when discussing the cultivation of rice at the Khalchayan site at 1714–1756 a BP, in an arid region of Central Asia.

The earliest direct dates for rice in South Asia come from 8350 a BP (Saraswat, 2005; Tewari et al., 2006), but many scholars believe that these archaeobotanical remains represent the foraging of wild rice. The earliest good evidence for cultivated rice in India date to 4950–4550 a BP, corresponding to the early Harappan period (Fuller, 2011a). By 4000 a BP, rice was widely distributed across northwestern India, in the upstream region of the Ganges and in Pakistan (Fuller et al., 2010; Fuller, 2011a; Fuller, 2011b). At 3850 a BP, domesticated *japonica*-like rice has been recovered from late Harrapan period sites in the Swat Valley of Pakistan, and roughly contemporaneous finds come from Balochistan in the northwestern part of Pakistan (Fuller, 2006; Fuller et al., 2010; Castillo, 2013; Castillo et al., 2016). At the same time, some crops of Chinese origin appeared in the northwestern part of South Asia, including broomcorn millet, apricots (*Prunus armeniaca*), peaches, and hemp (*Cannabis sativa*) (Fuller, 2011b). These plant remains have been used to argue for a ‘Chinese Horizon’ in northern India by four millennia ago, and this cultural diffusion may have influenced Central Asia through the southern Himalaya as well.

As, we noted above, ancient rice has never been recovered in China west of the sites of Xishanping (Li et al., 2007b) and Qingyang (Zhang and Wang, 2000), both in southwestern Gansu, and archaeobotanical rice has not been found in the Hexi Corridor (An et al., 2010; Zhang D J et al., 2010; Zhou et al., 2011; Dong et al., 2017). Therefore, there is a huge geographic gap in the range of rice distribution, between northwest China and Central Asia. Combined with the densely distributed rice remains in the southern Himalayas and southeast Asia and the above morphological analysis, we believe it is more likely that the rice remains at the Khalchayan site illustrate a dispersal of the crop from northwestern India. Therefore, rice likely spread across the southern Himalaya into Central Aisa.

Some researchers have suggested that ‘exotic’ crops found at early sites may have presented some relationship with power or prestige or been used in religious worship (Long et al., 2018). However, due to the small number of rice grains found at the Khalchayan site, we cannot say much about their role in the economy or if they were considered a prestige

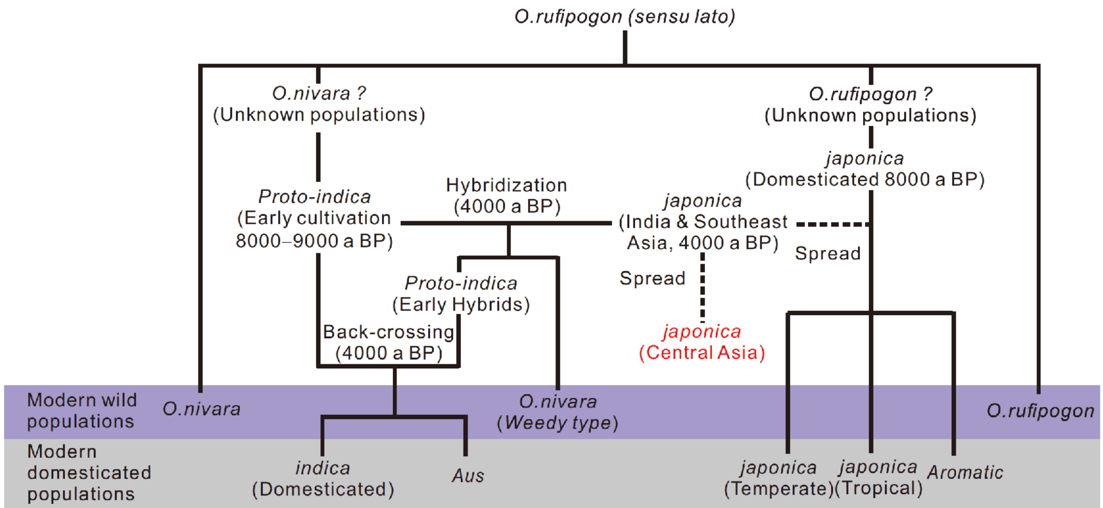

Figure 4 Schematic diagram of rice evolution (Garris et al., 2005; Fuller et al., 2010; Fuller, 2011b; Castillo et al., 2016; Fuller et al., 2011).

good. It is worth noting that they were recovered from a domestic ash pit rather than a ritual context, and that they were associated with a palace.

Ancient DNA studies on rice remains from sites in India illustrate that the grains more closely relate to *japonica*, but that they clearly poses some *indica* components (Castillo, 2013; Castillo et al., 2016). Genetic results of studies on ancient grains from southeast Asia and Thailand also showed that the locally cultivated rice was *japonica*-like but, in those cases, without any *indica* components (Castillo et al., 2016). The *indica* rice currently cultivated in southeast Asia is a product of the early domesticated *indica* rice introduced from India. Therefore, when rice appeared at Khalchayan, *indica* rice may not have been widely planted in the Indus and Ganges Rivers or may still have been undergoing hybridization and domestication. Based on current archaeological findings, it appears likely that rice in Central Asia spread northwestern South Asia, from where it spread northward from northwestern India and Pakistan to the Amu Darya (Figure 5).

Many scholars have noted that there is early evidence for exchange between people in the Indus Valley, across the Iranian Plataue, and in southern Central Asia (Spengler et al., 2019; Dani and Masson, 1992; Harmatta, 1992). Attesting to these southern crop dispersals, cotton, a fiber crop originating in South Asia, was recovered from royal tombs in the northern part of the Iranian Plataue, as early as 6000 a BP (Moulherat et al., 2002; Brite and Marston, 2013). Archaeobotanical evidence for locally grown cotton in Central Asia appears after 1600 a BP, probably originally constrained by its northern dispersal due to environmental conditions (Brite et al., 2017). a large number of handicrafts produced in the There are many other archaeological lines of evidence for cultural connections between people in the Indus Valley, southern Central Asia, and China (Lahiri, 1990). All of these data, combined with the lack of early rice in other parts of Central Asia (Miller, 1999; Fuller, 2011a; Spengler et al., 2013, 2014; Miller et al., 2016; Stevens et al., 2016) support a southern Himalayan dispersal route.

The Kushan Empire was established in 1920 a BP by yabghu Kujūla Kadphises I in the northwestern mountains of the Indus Valley and then gradually expanded to the west and north to eventually reach the Aral Sea, the Amu Darya, and Afghanistan at 1823–1810 a BP Coins from the Kushan period have been excavated from sites in the Khorazam and across the Iranian Plateau (Dani et al., 1994). Imperial expansion and political unrest may have further fueled the dispersal of crops across Inner Asia.

4.3 Farming and cuisine at Khalchayan

In addition to the rice remains, carbonized wheat, 2-row barley, peas, flax, lentils, grapes, and other crops were recovered at the site. These crops, originating in the Fertile Crescent or broadly in the western Mediterranean, but were also widely cultivated in the southern Central Asia by 4000 a BP (Miller, 1999; Frachetti et al., 2010; Spengler et al., 2014; Miller et al., 2016). A dynamic agricultural tradition appears to have spread north into Central Asia along the mountain foothills, with a set of well-established crops. The presence of an East Asian millet further illustrates how complex the farming system would have been, with long-season and short-season crops, and water-demanding and drought-tolerant crops. While the cuisine in southern Cenrtal Asia was probably based on bread, the rice that we present in this paper may represent the earliest evidence of what will become a culinary shift towards a cuisine based on rice, wheat porridge, baked dough (Naan), and bean porridge (Askarov, 1973). Considering the traditional cooking methods of Central Asia, it can be inferred that the current dietary

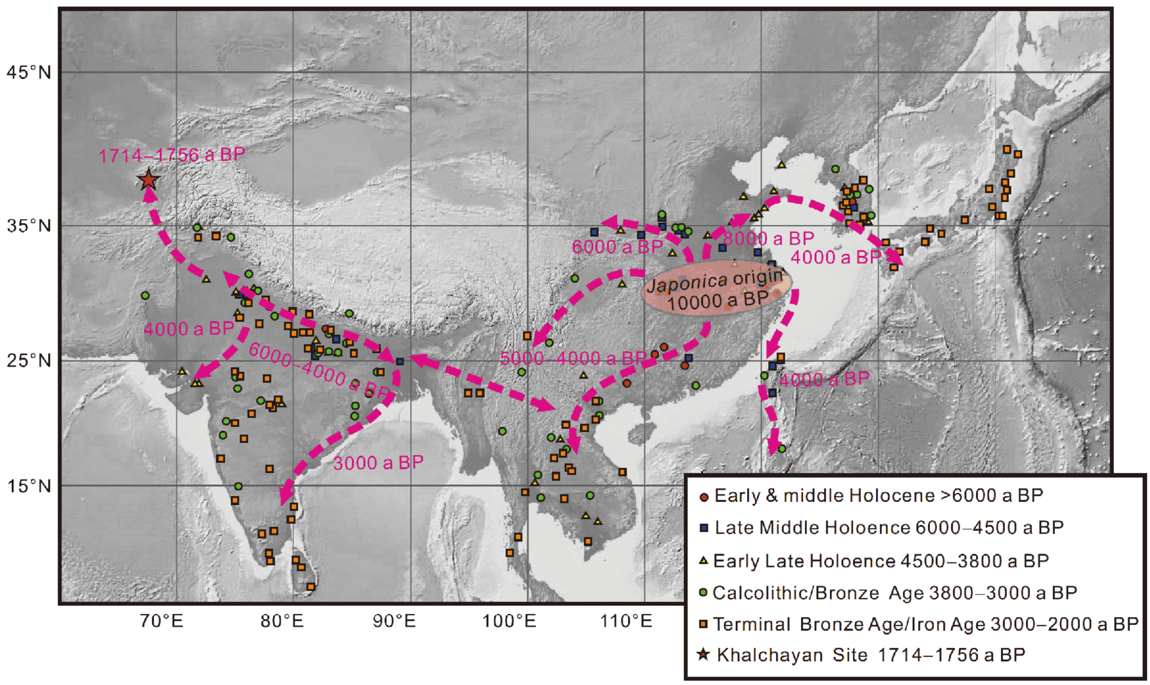

Figure 5 The spread of rice in East Asia, South Asia, and Central Asia.

system in Central Asia, in which naan, pilaf, and open-fire cooked meat are the main foods, began to form around two millennia ago and then was gradually adopted in the surrounding areas.

5. Conclusion

Rice agriculture in the Amu Darya region of Central Asia began during the Kushan period, at least 1714–1756 cal yr BP. The rice grains that we report in this paper, morphologically look more like a *japonica* type, and appear to have been dispersed from southwest China to the Indus River Basin and then to the Amu Darya region through a southern Himalayan route. Rice, together with wheat, two-row barley, peas, lentils, millet, grapes, and other crops formed a diverse agricultural system in Central Asia. The corresponding cuisine may also have adjusted immediately. The current dietary system of Central Asia based on naan, pilaf, and meat/dairy products began to form around two millennia ago. The processes of agricultural globalization and crop exchange between early farming cultures, provided an important foundation for the development and prosperity of early Central Asia peoples.

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