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The dissemination of Chinese potash-rich faience: investigation of faience beads from the Wupu cemetery, Xinjiang

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Abstract

The Wupu cemetery, located in the Yizhou District, Hami City, Xinjiang Province, and in the eastern part of the southern foothills of the Tianshan Mountains, is remains from the late Bronze Age. In this study, four faience beads excavated from the Wupu cemetery were examined by stereomicroscopy, synchrotron radiation micro-CT, and electron microprobe analysis. The appearance and compositions of these faience beads are presented and discussed. The results show that these tubular faience beads, glazed by the application glazing method, are all potash-rich faience, consistent with the faience produced locally in China. The faience products from the Central Plains were disseminated to the Hami region of Xinjiang Province during the Western Zhou dynasty (1046 BC–771 BC), reflecting the spread of such faience to the west with the Zhou people mastering the technique of making potash-rich faience.

Keywords Potash-rich faience, Xinjiang, Western Zhou Dynasty

Introduction

The production and distribution of faience

Faience is an early decorative object made from quartz grains as the body, which was covered with glaze and fired at temperatures approaching 1000 °C [1]. The types of faience objects range from small tube beads to large tiles. The production of faience was first developed in Mesopotamia and Egypt [2–4], and from which it spread westwards and northwards to Europe and northern grasslands, and from these sites eastwards to the east and south of Asia. Faience in the Indus Valley first appeared at the beginning of the 3rd millennium BC but began to decline in the 2nd millennium BC [5].

The earliest faience beads in China were dated from 1661 to 1546BC, and found in the Adunqiaolu site in Wenquan County, northwestern Xinjiang [6, 7]. Thereafter, faience in the Central plains lasted mainly from the Western Zhou (1046–771BC) to the Warring States period (475–221BC). It emerged in the Western Zhou, flourished during the Spring and Autumn period (770–476BC), declined from the Warring States to the Qin dynasty, and nearly disappeared in the Han dynasty (206BC–220AD) [8].

Composition characteristics of faience beads produced in different places

The flux composition of faience products is an important characteristic to distinguish the provenance. According to previous studies, the early production of faience in West Asia and Egypt used lime, natural soaking soda ash, and soda-rich plant ash as fluxes, resulting in Na_2O/K_2O ratios much greater than 1 for the majority of the finished faience [9]. Later, on the way to the north and west, Europeans mastered the technique of faience production and substituted the raw materials used with locally accessible

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materials [10]. In Western Europe, mineral evaporite and plant ash have been used as faience fluxes [11], producing faience characterized by high sodium and mixed alkali [12].

In China, the first-appeared faience had high sodium and mixed alkalies, such as the Adunqiaolu site (nineteenth–fifteenth centuries BC) [7, 13], the Tianshanbeilu in Hami (1500–1400BC) [14], and the Ya'er cemetery (1050–910BC) [15]. Scholars tend to believe this technique began in Eurasian steppes and then may have spread from Xinjiang to the Yellow River basin through the Hexi Corridor [16]. Potash-rich faience began to appear in China in the 1st millennium BC, such as at the Dahekou site in Shanxi, the Peng State site in Shanxi, and the Yuguo cemetery in Shaanxi, all of which are in the Yellow River basin. Potash-rich faience is often thought to be of indigenous Chinese production because of their compositional characteristics different from those provenances which already known. However, the route and mode of the technique dissemination are still unknown (Fig. 1).

Research aim

This study presents a synthetic analysis of four faience beads excavated from the Wupu cemetery and compared them with the faience beads excavated from other Chinese sites of the same period. We focus on exploring the dissemination routes and modes of Chinese indigenous faience beads during the Western Zhou period and providing insights into the study of this particular faience production during the middle and late Western Zhou.

Materials and research methods

The Wupu cemetery in Hami, Xinjiang (Fig. 2) was discovered in 1978 and has undergone several excavations ever since. This site was excavated with a wide variety of materials for decorations, with beadwork such as agate beads, turquoise tube beads, glass beads and faience beads currently detected. Four faience beads from the

Fig. 2 Map showing the location of Wupu cemetery

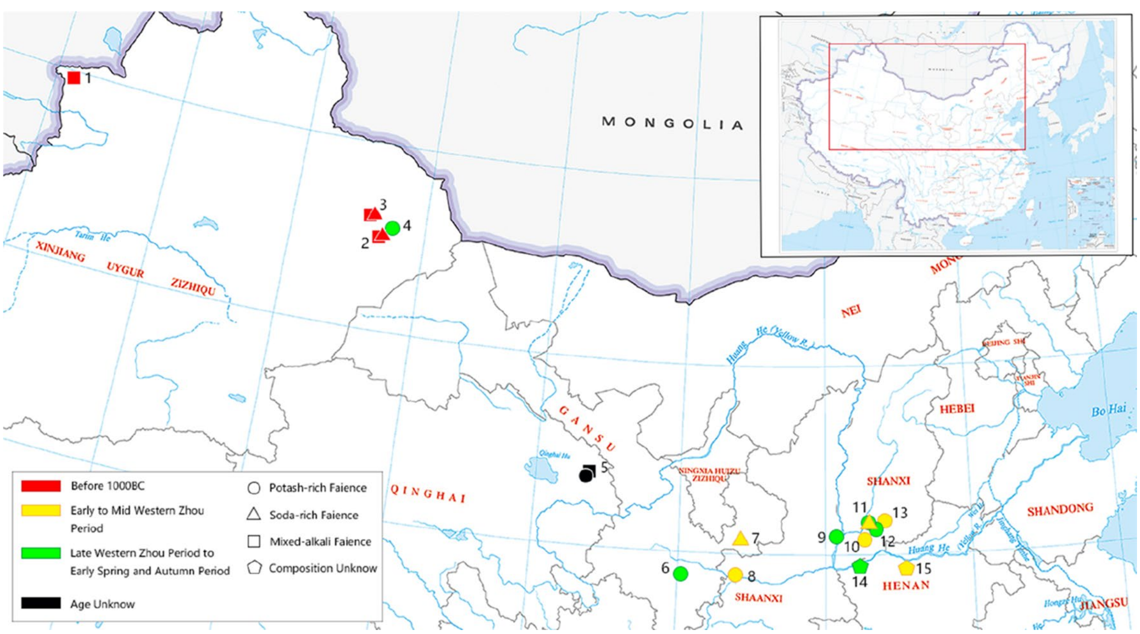

Fig. 1 Map showing the location of key sites mentioned in this study (1. Adunqiaolu site, Xinjiang 6, 7; 2. Ya'er cemetery, Xinjiang 15; 3. Tianshanbeilu site, Xinjiang 14; 4. Wupu cemetery, Xinjiang; 5. Shangsunjiazhai site, Qinghai 14; 6. Dapuzishan cemetery, Gansu 49; 7.Yujiawan site, Gansu 52; 8. Yuguo cemetery, Shaanxi 18; 9. Liangdaigou site, Shannxi 23; 10. Peng State site, Shanxi; 11. Tianma-Qucun site, Shanxi 23; 12 Yangshe cemetery, Shanxi 23; 13. Dahekou site, Shanxi 48; 14. Guo State site, Henan 17; 15. Western Zhou cemetery at Zhongzhou Road, Henan 18)

Fig. 3 The Wupu cemetery 78HWM1:1 single-eared pottery pots①

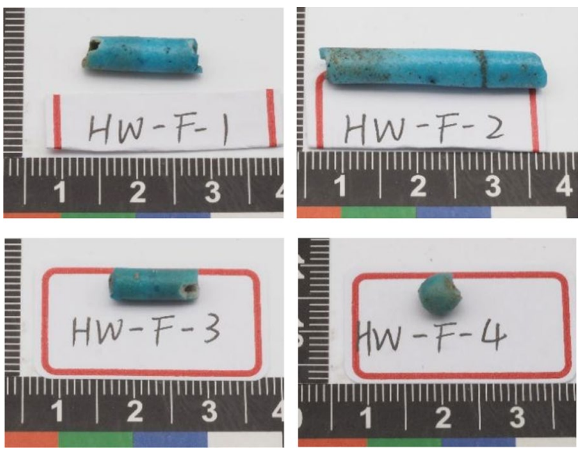

Fig. 4 Faience beads excavated from the Wupu cemetery

Wupu cemetery were investigated in this study. Dating of other textile items such as plant and woolen clothing excavated from the tombs indicates that most of these remains were from the mid to late Western Zhou period, with a few from the early Western Zhou. The four faience beads in this study were all excavated from the Wupu cemetery, two (HW-F-3 and HW-F-4) of which were from burial 78HWM1, and no remains were suitable for dating at this time. A single-eared pottery pot (Fig. 3) was also excavated from the same tomb where the studied faience beads were unearthed in the Wupu Cemetery, and it is similar to the single-eared pottery pots dated to 800–500BC from the Ya'er cemetery in Hami. A similar object was also excavated from M75 in the Yanbulake cemetery. Based on the similar forms of these pottery and other burial relics dating results from the Wupu site, the studied faience beads were probably produced from the mid-to-late Western Zhou dynasty to the Spring and Autumn Period, no earlier than 1000BC.

Of the four faience beads from the Wupu cemetery (Fig. 4), HW-F-4 is an ovoid bead, while the other three are all tubular beads, and they all have varying degrees of fragmentation and weathering. In cross-section, all four beads have a white body covered with a blue-green glaze. Details are summarized in Table 1.

Examination conditions:

1. Stereomicroscope: The stereomicroscope model is KF-7700 produced by Japan HIROX. The working conditions included a Halogen cold light source, MX-5040RZF lens, and 2.01 million dynamic pixels. Beads were observed at 50×–100× magnification.
2. Synchrotron radiation micro-CT (SR-μCT): Shanghai Synchrotron Radiation Facility (SSRF) beamline station BL13W. The distance between the sample and the detector was 10 cm. The maximal photon flux density was observed to appear at the X-ray energy of 27 keV. The charge-coupled device detector had a spatial resolution of 9 μm.
3. Electron microprobe analysis (EPMA): JXA-8230, JEOL. The beam spot of 3 μm in diameter and operating voltage of 20 keV were used. The glassy material inside the faience body was analyzed in a vacuum and the measurements were averaged to represent the compositions.

Results

Results of stereomicroscope observations

Stereomicroscope observations show that all four faience beads have white dense bodies with blue-green glaze, which have many small bubble pits on the surface. Sample HW-F-2 has a groove around its surface, which may

Table 1 Overview of some of the faience beads excavated from the Wupu cemetery

Sample	Date	Features of appearance	Shape	Analysis
HW-F-1	800B.C.–500B.C	Blue-green, opaque	Tubular beads	Stereomicroscopy, SR-μCT, EPMA
HW-F-2	800B.C.–500B.C	Blue-green, opaque, grooved surface	Tubular beads	Stereomicroscopy, SR-μCT, EPMA
HW-F-3	800B.C.–500B.C	Blue-green, opaque, with a few white weathered layers on the surface	Tubular beads	Stereomicroscopy, SR-μCT, EPMA
HW-F-4	800B.C.–500B.C	Blue-green, opaque, with a few white weathered layers on the surface	Ovoid beads	Stereomicroscopy

have resulted from the incomplete truncation of the faience tube during manufacture (Fig. 5).

Results of synchrotron radiation micro-CT analysis

Synchrotron radiation micro-CT for the observational examination of remains is feasible because heavy elements in the remains have a higher absorption of X-rays and appear brighter in CT sections. The obtained images can be used to identify the density and chemical composition of faience and their variations from the body to glaze, which could help reveal the possible glazing methods.

In the three CT images, HW-F-1 and HW-F-2 are the cross-sections of the sample, and HW-F-3 is the longitudinal section of the sample. As shown in the microscopic CT images (Fig. 6), each faience bead has a dense body with small granules of unfused quartz and rounded bubbles inside, a clear demarcation between body and glaze, and a thick and uniform glaze layer. The glazing method is likely to be the application glazing method. The inner wall of the body is straight and regular, suggesting it should have been molded by the core-forming method.

Results of the electron microprobe analysis

As a traditional minimal-damage method, only limited samples from the remains could be analyzed. As samples HW-F-1, 2 and 3 were taken from sections where the edges were about to fall off and sample HW-F-4 was smoother and more intact, to protect the remains to the maximum, samples HW-F-1, HW-F-2, and HW-F-3 were selected for EPMA analysis, and the internal parts of the bodies were analyzed to minimize the effects of weathering. The composition of the Corning glass specimens was examined and validated prior to sample testing using the electron microprobe to ensure that the test data are quantitatively accurate and reliable.

Three to five spot analyses were performed on each sample and the data were averaged (Table 2). Before normalization, the analyzed total contents of 97–100 wt% agree well with the expected analytical total contents from 98 to 102 wt %, suggesting little or minor weathering on samples andreliable analyticalresults of this test. The data obtained show small differences in fluxes between the three samples, which have SiO_2 content between 72.75 and 76.35%, Na_2O content of 1.39–2.39% and K_2O content of 11.92–12.32%, with Na_2O/K_2O ratios

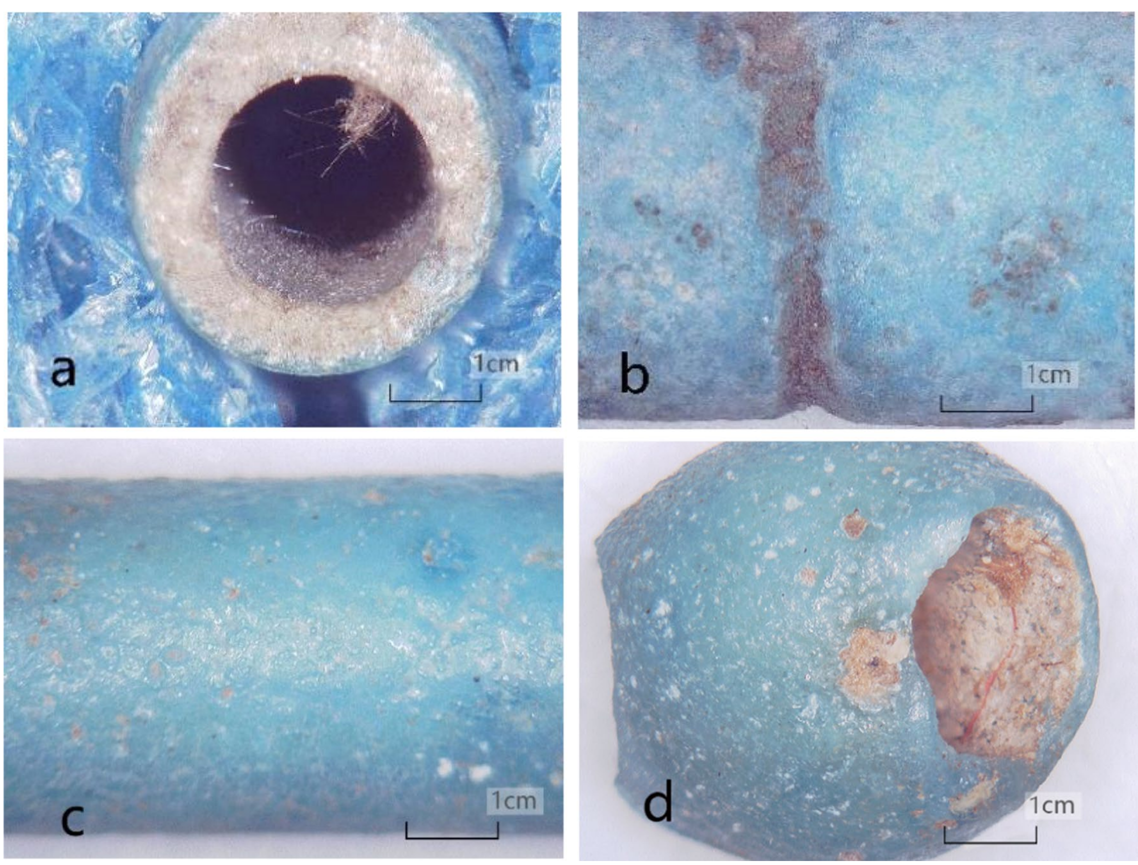

Fig. 5 Results of stereomicroscopic observation (**a** HW-F-1, **b** HW-F-2, **c** HW-F-3, **d** HW-F-4)

of 0.12–0.19. These chemical characteristics indicate the samples are potash-rich faience.

Discussion

Production process

Typologically, the ovoid-shaped form of Sample HW-F-4 has been excavated in many other regions of China. For example, the Peng State cemetery, the Dahekou site, and the Tianma-Qucun site in Shanxi all have ovoid faience beads similar to Sample HW-F-4 from the Wupu site. Tubular faience beads are found in tombs from around the Western Zhou period, including the Sanmenxia Guo State site in Henan and the Yuguo cemetery in Shaanxi [17, 18]. Shortland suggests that tubular faience was first produced in the Northern Caucasus [19]. Prior to this study, tubular faience beads from 1700BC–1500/1400BC were excavated in the Tianshanbeilu and the Saensayi Cemetery in Xinjiang Province, while those from the Central Plains did not occur until 1040BC–950/910BC in the Shanxi-Shaanxi region [14]. Among them, both contemporaneous tubular beads and oval beads are present in Shanxi Peng State Cemetery (Fig. 7), Shanxi Dahekou site, Shanxi Tianma-Qucun site (Fig. 8), Qinghai Shangsunjiazhai site (Fig. 9) and other sites, similar to the combination of beaded ornaments of Wupu Cemetery. The similarity in faience form and the combination of beads

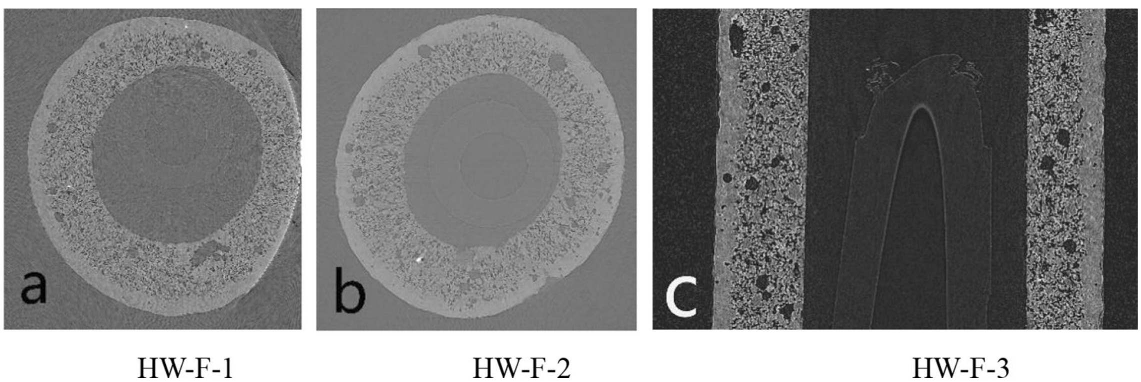

Fig. 6 Morphology of the sample bead sections under micro-CT (**a** HW-F-1, **b** HW-F-2, **c** HW-F-3)

Table 2 Electron microprobe composition data results (wt %)

	SiO_2	Al_2O_3	CaO	Na_2O	MgO	K_2O	FeO	CuO	TiO_2	MnO	SrO	Cr_2O_3
HW-F-2	76.35	1.85	0.62	2.36	0.49	12.28	0.28	3.95	0.03	0.02	0.23	0.00
HW-F-1	76.03	7.57	0.12	1.39	0.09	11.92	0.14	2.08	0.12	0.01	0.18	0.01
HW-F-3	72.75	6.85	0.83	2.39	0.06	12.32	0.07	2.62	0.01	0.02	0.18	0.00

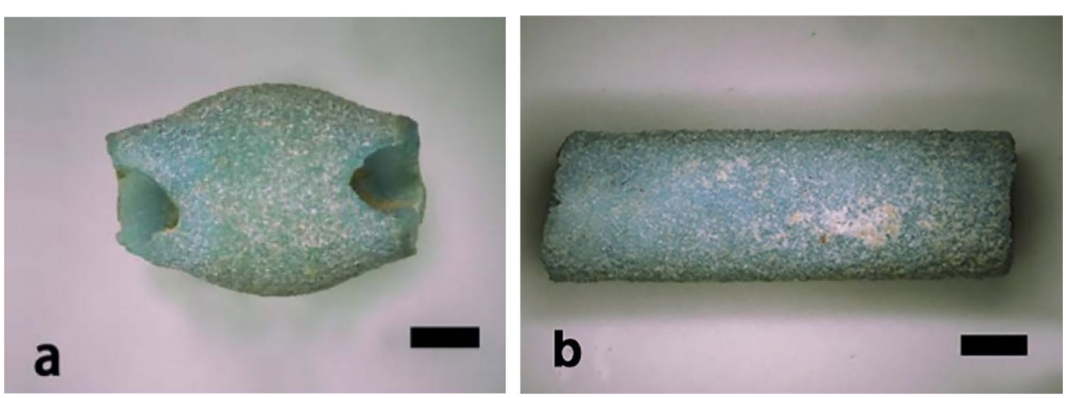

Fig. 7 Ovoid and tubular faience bead from the Peng State cemetery, Shanxi [22]

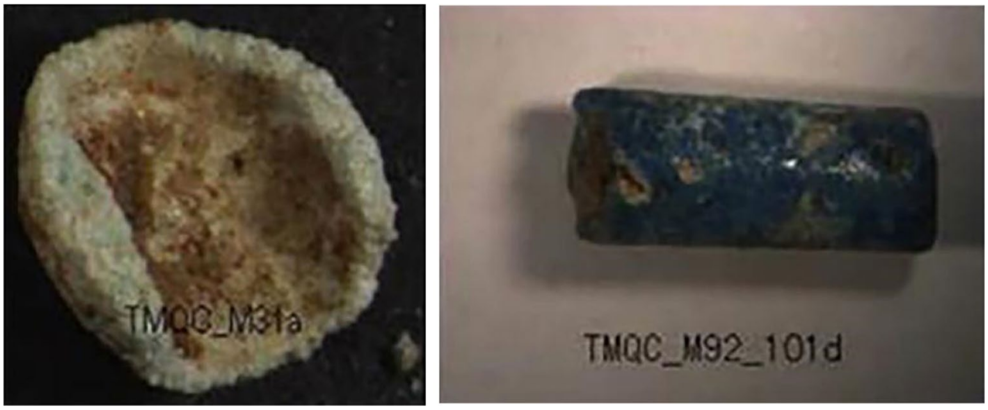

Fig.8 Ovoid and tubular faience bead from the Tianma-Qucun cemetery, Shanxi [23]

Fig. 9 Ovoid and tubular faience beads from the Shangsunjiazhai cemetery, Qinghai [14]

indicate the connection between the Central Plains and Xinjiang.

In terms of the molding process, the SR-μCT results show that HW-F-3 has a vertical uniform inner wall, indicating that the faience beads should have been molded by the core-forming method. The grooves surrounding the tubular bead on the surface of HW-F-2 may have been made by artificial pressure with a tool after the glaze was fired. It is possible that a long, thin tube of faience was made and cut into short sections after or during firing. HW-F-2's grooves may be the result of an incomplete cut.

In terms of the glazing process, the internal morphology of the three small faience bead ornaments (HW-F-1, HW-F-2, and HW-F-3) excavated from the Wupu site revealed by SR-μCT shows a dense body with a thick and uniform glaze layer and a clear boundary between the body and glaze. For the efflorescence glazing method and cementation glazing method, the boundary between the carcass and the glaze layer is not clear due to the infiltration between the glaze layer and the body [20]. Therefore, the glazing method for the studied beads with clear body-glaze boundary was likely to be the application glazing method [21]. The irregular bubble pits in the glaze of the samples are unevenly distributed, which may be a reduction glaze phenomenon, and they also represent the traces of direct application glazing.

Composition characteristics and raw material

The excavated Chinese faience was mainly from the Western Zhou to the Spring and Autumn period and was mainly composed of SiO_2. The Na_2O contents are very low, and most Na_2O/K_2O ratios are much lower than 1, showing an obvious high potassium characteristic [9]. In contrast, faience from Western Europe has Na_2O/K_2O ratios around 1 or just below 1, and the sodium contents are usually much higher than those of the potash-rich faience excavated in China. The Chinese faience has distinct compositional characteristics from the Egyptian and Mesopotamian Plain's faience. Lin studied the different compositional characteristics of faience and concluded that a minimum total alkali content above 4% was required to minimize element loss due to weathering, 6–7% would be preferred for accuracy. Therefore, faience with a Na_2O/K_2O ratio above 1.5 can be considered soda-rich, while faience with Na_2O/K_2O ratio between 0.5 and 1.5 or slightly higher can be classified as mixed-alkali faience. Potash-rich faience is defined by a total alkali content above 7% and a Na_2O/K_2O ratio below 0.4 [14]. The EPMA data in this study show that faience beads are potash-rich with K_2O contents above 10% and Na_2O contents below 3%.

Based on this feature, it is speculated that in the mid-1st millennium BC, China had already used local raw materials to make faience that was characterized by the use of high-potassium fluxes. Some scholars have suggested that this high-potassium flux may have derived from the ashes of the Chenopodiaceae family of halophytic plants, such as Salsola [24]. However, the low Ca and Mg contents of the faience samples in this study and the complex compositions of the plant ashes with their high impurity contents indicate that purer minerals were more likely to be the flux [24], given that it was uncertain whether clarifiers were used in the treatment of plant ashes. Of these, soil nitrate and saltpeter (KNO_3 being the main component) are more likely to have been used as fluxes for potash-rich faience. Saltpeter ores are widely distributed in Xinjiang, Shanxi, Shandong, and Sichuan in China. In addition to mineral resources, Brill suggests that precipitated salts from toilets could also be sources of saltpeter [25]. Saline alkaline land and northern rural walls in China commonly have white precipitates, where soil nitrate is more easily accessible and the processing and purification are simply boiling and precipitation.

The glaze of these faience beads is green. Copper is often considered to be the coloring agent for blue-green faience. The presence of CuO in our analytical results suggests that the coloring agent used must contain copper because Cu^{2+} would have appeared blue-green during the firing at high temperatures [26, 27]. The use of this coloring agent could have been related to the development of copper smelting [28] and also to the fact that it was originally used as a substitute for precious natural stones such as turquoise for decoration, which was consistent with the indigenous Chinese aesthetics.

Modes of dissemination of potash-rich faience

Cultural exchanges between Xinjiang and the Central Plains have existed since ancient times. Since twenty-first century BC [29], the agricultural civilization represented by painted pottery has spread westwards many times, from the Shaanxi-Gansu region to Xinjiang through the Hexi Corridor. For instance, the amphora diamond grid painted pottery jars in the remains of the Tianshanbeilu in Hami, Xinjiang, are examples of the painted pottery forms of the Machang civilization in the Gansu-Qinghai region [30, 31]. In addition, the costume remains from the Wupu site show similarities to the costume combinations of the Shang and Zhou people, with a strong influence from the Central Plains [32]. The hooked thunder pattern and hooked pattern (a kind of decorative pattern) on the fabric of the Yanghai cemetery in Xinjiang are similar to the clouded thunder pattern and hooked thunder pattern that were prevalent during the Shang and Western Zhou dynasties in Central Plains [33, 34], indicating the influence of the Central Plains civilization on the Xinjiang region during the Shang and Zhou periods. At the same time, culture spread from west to east, with weapons, horse tools, decoration and other bronze and even iron tools from the Eurasian steppe through Xinjiang and influencing the Shaanxi-Gansu region [31, 35, 36]. Cultural exchanges in the Xinjiang region have been characterized by great diversity and complexity. Eastern cultures, represented by painted pottery, entered Xinjiang, interacted with cultures from the west, and continued advancing westwards. These cultural exchanges presented the rich cultural heritage in Xinjiang and laid the foundation for the Silk Road in later times [37–39].

The faience in this study dates from roughly 800BC to 500BC, between the late Western Zhou and Spring and Autumn periods. During the same period, Central Asia was in the early stage of the Persian Empire, when the nomadic people of the Eurasian steppe had already migrated eastwards. The frequent migration of nomads across the vast steppes also played a significant role in ancient ethnic exchanges. The cultural exchange between the people of Central Asia and the native Chinese people became more frequent and diverse [40]. The development of the faience-making technique in Xinjiang was influenced by a combination of factors, with Egypt, West Asia, and Europe all playing a role in its development, whereas the role of the central Chinese region (Central Plains) cannot be ignored.

Influenced by Mesopotamia and Egypt or Caucasus faience products, a local Chinese faience system began to sprout, and it began to spread in turn to the west after the localization of the production techniques. According to previous research, most of the potash-rich faience from the Western Zhou period was found in Gansu, Shaanxi, and Shanxi provinces, i.e. mainly in the Central Plains. During the reign of King Cheng of Zhou (1043BC–1021BC), the establishment of the Eastern Capital of Luoyi in Luoyang (Henan) as a new political center led to economic and cultural development. Henan became the center of development in the Central Plains, where superb production techniques flourished. The production and use of faience are one of the manifestations of this prosperity. Faience beads were excavated from the Western Zhou cemetery at No. 816 Zhongzhou Road, Luoyang, which date from the time of King Mu (977BC–922BC) [18]. Faience beads from the cemetery site of Guo State in Sanmenxia, northwest of Luoyang, date mainly from the ninth to the seventh century BC, which was an important vassal state of the Western Zhou period. However, due to sample breakage and element loss, faience from both sites was impossible to identify its original composition.

Furthermore, during the Western Zhou period, the Zhou dynasty expanded its territory through many wars [41]. King Zhao of Zhou waged several wars against the state of Chu to the south [42], and the losses in the wars also led to a decline in the state's power [43]. According to available excavations, no potash-rich faience has been unearthed in the south of the middle and lower reaches of the Yangtze River, which might have resulted from a weaker control of this region due to the loss of expansion to the south during the Western Zhou. In contrast, interactions between the Zhou and the many tribes of the northwest were more frequent. The tombs of the Central Plains during the Western Zhou period show the characteristics of the various tribes of the northwest tribes. The bronze ritual vessels excavated at Liangdai village in Shaanxi incorporate features from other surrounding tribes [44]. Bronze mirrors were excavated from the tombs of the State of Guo in Henan and are thought to have been first introduced to the Shang dynasty from west of Central Asia through the Hexi Corridor [45]. The exchange of civilizations was a two-way street, with the Zhou incorporating features learned from the surrounding tribes of the northwest into their own civilization, as well as bringing the technology and products of the Central Plains to the northwestern tribes.

Historical records show that, during the Zhaomu period (966BC–922BC), the growing power of Quanrong hindered the interaction between the Zhou people and other countries in the northwest. As a result, King Mu of Zhou made three expeditions to the west to restore interaction with other countries in the northwest. It is recorded in many historical books, such as *Guoyu Zhouyu* (The State Language of the Zhou), and is considered to be a historical fact. Among these, *the Biography of Mu Tianzi* is part of the *Zhushujinian* (Bamboo Book of Chronicles), written by historians of the state of Jin during the Spring and Autumn period and historians of the state of Wei during the Warring States period, and was discovered in a tomb in Ji County, Henan, during the Western Jin period. In recent times, Hu Yinglin's *Sibuzhenge* (The Four Correct Errors), and Liang Qichao's *the Authenticity of Ancient Books and Their Dating* have all concluded that *the Biography of Mu Tianzi* is real [46]. The route of the third expedition is detailed in *the Biography of Mu Tianzi*. King Mu of Zhou stayed in Yuguo (Shanxi Province) and crossed parts of Gansu, Qinghai, and Xinjiang [47]. According to previous archaeological excavations and scientific research, potash-rich faience has been excavated from several locations along the route, mostly dating from the mid-late Western Zhou period to the early Spring and Autumn Period, which is consistent with the period influenced by the Western Zhou. In addition to the Luoyang sites mentioned above, faience beads were unearthed along this route

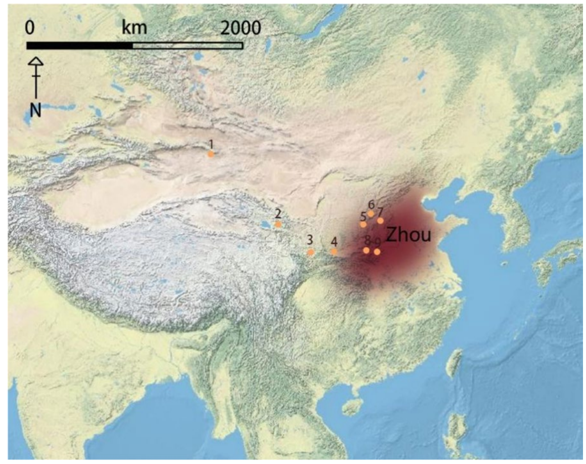

Fig. 10 Map showing the location of key sites mentioned in this part (1. Wupu cemetery, Xinjiang; 2. Shangsunjiazhai site, Qinghai 14; 3. Dapuzishan cemetery, Gansu 49; 4. Yuguo cemetery, Shaanxi 18; 5. Peng State site, Shanxi 23; 6. Tianma-Qucun site, Shanxi 23; 7. Dahekou site, Shanxi 48; 8. Guo State site, Henan 17; 9. Western Zhou cemetery at Zhongzhou Road, Henan 18)

till the Peng State. The faience beads excavated from the Peng State also have high potassium contents. This may indicate a distinct local faience system in the Peng State [23], which is also supported by the high-potassium faience beads found in the Dahekou site not far to the northeast of the Peng State [48]. Potash-rich faience has also been excavated from Dapuzishan cemetery in Gansu [49]. On his return journey, King Mu of Zhou passed through the Hami region of Xinjiang [50], which may have likely influenced the Wupu region.

In conclusion, exchanges between the Western Zhou and the tribes in the northwest were either peaceful and civilized or violent and confrontational, resulting in a political, economic, and cultural clash. The dissemination of potash-rich faience was also a result of this mutual exchange. Through warfare and trade, the techniques and finished products of potash-rich faience spread as far as the Western Zhou forces could reach.

The combination of oval faience and tubular high-potash faience, and ages of the excavated beads discussed earlier, including those from the Shanxi Peng State site, the Shanxi Dahekou site, the Shanxi Tianma-Qucun site, the Shanxi Yangshe Marquis of Jin site, and the Qinghai Shangsunjiazhai site, are similar to those of the faience of the Wupu Cemetery. Except for the Shangsunjiazhai site with controversial ages [51], the remaining sites all belong to the Zhou Dynasty period (Fig. 10). The shapes, combinations, compositions, and eras of the faience unearthed at these sites are highly similar, suggesting that the faience beads were likely related in some ways and were made by the same technique.

The potash-rich faience beads excavated in the Wupu sites have also shed light on the mode of faience bead dissemination. The Wupu site is the only site in Xinjiang where potash-rich faience has been excavated, and the faience forms overlap with those excavated in the Central Plains. This indicates that the finished products rather than the technique of potash-rich faience were imported to the Wupu site because a technique import would have a wider distribution of potash-rich faience. Secondly, *the Biography of Mu Tianzi* mentions that King Mu of Zhou offered rewards along his western expedition and that King Xiao of Zhou (892BC–886BC) rewarded faience beads to Quanrong when Quanrong was defeated and tributed horses for peace. Therefore, it is likely that faience bead ornaments spread to nomads and other northwest tribes as one of the various diplomatic rewards. Meanwhile, the Western Zhou period was economically prosperous with trade markets in larger cities. The faience beads in this study were probably traded by exchange, plundered in war, or rewarded by the Zhou, whereas the technique of potash-rich faience remained in the Zhou reign and did not spread to the nomads and other tribes in the northwest.

Conclusion

Four faience beads excavated from the Wupu site in Hami were studied through microscopic typological observations and compositional analysis. The microscopic morphological observations have revealed these faience beads were small pieces made in bulk using the application glazing method, while the tubular bead was probably cut from a long tube. The molding process would be the core-forming method. The compositional analysis shows that the tubular faience beads are all potash-rich, with a possible flux of saltpeter or soil nitrate, and were locally produced in China, as opposed to the Western mixed-alkali faience and soda-rich faience using mixed alkali plant ash and natural soaking soda as fluxes.

Based on the morphological and compositional characteristics, the faience beads excavated from the Wupu cemetery in Hami are potash-rich faience. This potash-rich faience may have been introduced during the exchange between the Zhou and northwestern tribe peoples during the Western Zhou period when the faience production techniques of the Central Plains were disseminated to various parts of China. The faience beads unearthed in this study were considered imported finished products based on their small quantity, which is consistent with the lack of potash-rich faience-making techniques in the Hami region of Xinjiang as revealed in this study. The potash-faience-making technique was mastered by the Zhou and appeared within the geographical areas that the Zhou could influence through war and trade.

The Hami region was located on the road from Europe and Central Asia to the Central Plains of China, and the results of several archaeological excavations in Hami show a high consistency with other archaeological remains from the surrounding areas. This suggests that, by the middle of the 1st millennium AD, the Central Plains and Xinjiang were already in relatively frequent contact and exchange, influencing each other in terms of production and trade. During the late Western Zhou and Spring and Autumn periods, the manufacturing industries of the Central Plains were well developed, with the rapid development of copper smelting, textiles, and other handicrafts. These exchanges have enriched the living of the local people in Xinjiang.

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Author contributions

WR carried out the research design, HX was a major contributor in writing the manuscript, CS tested the relics samples to obtain data, and WY collected the relics samples. All authors read and approved the final manuscript.

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Availability of data and materials

Will be made available on reasonable request.

Declarations

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

The consent for the publication of details and images in the manuscript are obtained from all participants.

Competing interests

No conflict of interest exists in the submission of this manuscript.

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