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A Sui-Tang dynasty woman's crown: analyzing form, glass and class

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Abstract

A woman's crown made of fine gilt bronze with refined glass inlay work was excavated from a Sui-Tang tomb called Kunlun M2 in Xi'an, Shaanxi Province, China. Very few female crowns and crown ornaments have been excavated in China thus far, and there has been a lack of systematic research into the technologies used to manufacture them. Importantly, this paper uses the M2 crown to investigate its surface inlays and overall shape, then conducts a comparative analysis of women's crown ornaments of the same type, providing a reference for study of the crown. Non-invasive and micro-destructive analysis including optical microscopy (OM), optical coherence tomography (OCT), micro X-ray fluorescence imagery (XRF), and Raman spectroscopy were applied. These identified the crown's inlays as potash-lime glass, composed mainly of the raw materials: vein quartz or quartzite with potassium nitrate as flux. The inlays were sintered before embedding into gilt copper wire filigree. In comparison to the composition proportions in other ancient potash-lime glass, there is no specific percentage of the raw materials in Chinese potash-lime glass, where the ingredients were likely determined by the experience of the craftsman. Compared with existing research on other crowns and their inlays, this study speculates that the crown dates from the Sui dynasty (581–618) or early Tang dynasty (618–649), was made locally by Chinese craftsmen and belonged to the wife of a high official.

Keywords: Potash-lime glass, Filigree glass, Kunlun M2 crown, Sui-Tang dynasty crown, Sui-Tang dynasty jewellery

Introduction

In January 2007, the Xi'an Kunlun Industry Company found two tombs at their premises in an eastern suburb of Xi'an. That month, the Xi'an Institute of Cultural Relics Protection and Archaeology conducted a rescue excavation of the tombs. A large number of crown ornaments were discovered in the M2 tomb. Archaeological investigation and research classify M2 as a typical tomb of the Sui dynasty (581–618) to early Tang (618–649) dynasty, with such ritual female crowns belonging to the late Sui and early Tang periods. There is a lack of archaeological information, such as an epitaph tablet, to further identify the Kunlun M2 crown, but scientific research can explore the intrinsic chemical character of the crown's decorative elements and manufacturing techniques used, as well as placing it in the context of technological developments and exchange, and social significance in the Sui-Tang period (Fig. 1).

The crown was made using filigree inlay, a technique that originated in China in the Warring States Period (475–221 BCE), when it was called *jin yin cuo* (金银错 'gold and silver inlay') and involved painting gold and silver onto the surface of bronze artworks. By the Sui and Tang dynasties, filigree inlay technique was mature, with the development of high level techniques for making fine gold and silver thread [1, 2]. Examples of exquisite ornamented female crowns include that of Sui dynasty Empress Xiao (566–648, wife of Emperor Yang) [3], and the Tang dynasty 'phoenix crown' found in the 736 tomb of the royal family member Li Chui [4] (Fig. 2). Tang dynasty women's crowns were also recorded in the incised line drawings on the interiors of the stone sarcophagi in the Qianling tombs of Crown Prince Zhanghuai [5] and Crown Prince Yide [6], dating from 706. The

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Fig. 1 Extant components of the Kunlun M2 Crown (Photo: Du Jingnan)

filigree technique in the Kunlun M2 crown is not as elegant as these, however. This suggests that the owner of this crown was not of the highest status, though without epitaph tablets or other identifying information extant in the tomb, her precise status is difficult to ascertain. This paper analyses the physical evidence of the inlay materials and the way these were combined with the base metal to unlock more historical information about the crown, and compare it to other crowns and crown ornaments. Thus, we can combine the inlays' physical and chemical information together with the typology of the crown to identify the status of crown's owner more accurately, while shedding new light on the inlay techniques of the Sui-Tang period [7].

Nondestructive analysis methodology

Due to the Kunlun M2 Crown's rarity, elite character and significance as a nationally important Chinese cultural relic, destructive methods of analysis were not permitted. Accordingly, OM, OCT, microfocus XRF and Raman spectroscopy were used to analyze the ornament samples of the Kunlun M2 crown, OCT was used for the first time in China for high-resolution imaging of inlays, and microfocus XRF (not commonly used in archaeological analysis), with its highly focused beams of light, allowed precise control of the areas to be tested and accurate data to be obtained in seconds. The parts that were analyzed are shown in Fig. 3.

Description of samples

Figure 1 shows five parts of the Kunlun M2 crown after conservation. The main color on the headpiece is green coated with gold and colourful, elegant, and sumptuous decorations. BB-1 and BB-2, called *bo bin* (broad sideburns), were distributed on both sides of the head, lower than the ears simulating sideburns or streamers (Fig. 4a) [8]. Granulated bronze beads at the periphery of these elements began to evolve under the influence of Sasania (Persia) during the Northern and Southern Dynasties (386–589), and became typical inclusions in crown designs of the Sui-Tang period, reaching a peak in the Tang Dynasty [9] (Fig. 4c) [10]. Apricot leaf-shaped ornaments, XY-2, XY-3, XY-6, XY-8, would have hung at the back of the crown; these are called *bao dian* (filigree inlay) (Fig. 4c) [11]. Typically, the size and materials of *bo bin* and the number of *bao dian* represent the class

Fig. 2 Li Chui's crown in the Shaanxi Provincial Institute of Archaeology (Photo: Liu Xingchen)

of the person who wore the crown [10]. In Fig. 4b, there is a flower bouquet-shaped decoration called *bu yao* (an ornament that quivers when the wearer walks) [12]. The *bo bin*, *bao dian*, and *bu yao* together could form a floral female crown popular in the Sui-Tang dynasty [8]. (*Bu yao* quivering pieces, were also found in Kunlun M2, but are not analyzed in-depth in this article). In total, the excavation of M2 revealed two *bo bin*, eight *bao dian*, and the remains of at least four *bu yao* pieces, indicating that the Kunlun crown belonged to a high-class woman [13, 14]. Crowns of the highest rank consist of twelve *bao dian*, so the owner of the Kunlun M2 crown, with eight *bao dian*, could be the wife of a second-grade official (not less than an Imperial Chief Secretary or an Imperial General) [3, 15].

Each part of the headpiece has extensive inlays with granulated metal beads surrounding them. The inlay materials and their associated manufacture technology are little known due to the small number of Sui-Tang female crowns or headwear discovered so far, and because most of these are too rare and precious to be subjected to destructive analysis. Of known crowns, the Kunlun crown is most similar in type to that of Sui dynasty Empress Xiao (566–648, wife of Emperor Yang) excavated in Yangzhou, Jiangsu Province in 2012, and the earliest empress' crown discovered thus far. Both the M2 Kunlun crown and Empress Xiao's crown are made of gilt bronze, with multiple inlays, *bo bin*, *bu yao*, and *bao dian*, as well as coherent beads at their periphery (Fig. 5).

Instrumental techniques

The discovery of the Kunlun M2 crown has enabled the conduct of the analytical experiments in this study to observe and analyze the inlays, using OM, OCT, XRF, and Raman with the following test conditions:

OM

The microscope used in this experiment was a Primotech from ZEISS, connected to a tablet computer equipped with Matscope software to obtain relatively clear micrographs.

OCT

Optical coherence tomography (OCT) is the optical analog of ultrasound imaging and is emerging as a powerful imaging technique enabling non-invasive, high resolution, cross-sectional imaging in light transmittable material. Its axial resolution is typically 3–15 μm, and the imaging depth in the air is typically 2 mm. The OCT used in this system is the iHR320 produced by Jobin Yvon of France, connected to the Symphony CCD detector and computer. The Symphony controller adopts thermoelectric cooling (STE) for the CCD detector, enabling the target temperature of CCD chip to reach 70℃, and making the dark current of the detector very low to improve the SNR of the system. The light source is 1 W high-power LED produced by Shenzhen Yongxin Co., Ltd. The central wavelength is about 860 nm and the half-width is about 35 nm. The core components of OCT are diffraction grating and planar CCD. When 1200 g/mm grating is selected, the spectrometer resolution is 0062 nm, and the minimum integration time of CCD(H1024xV256) is 1 ms.

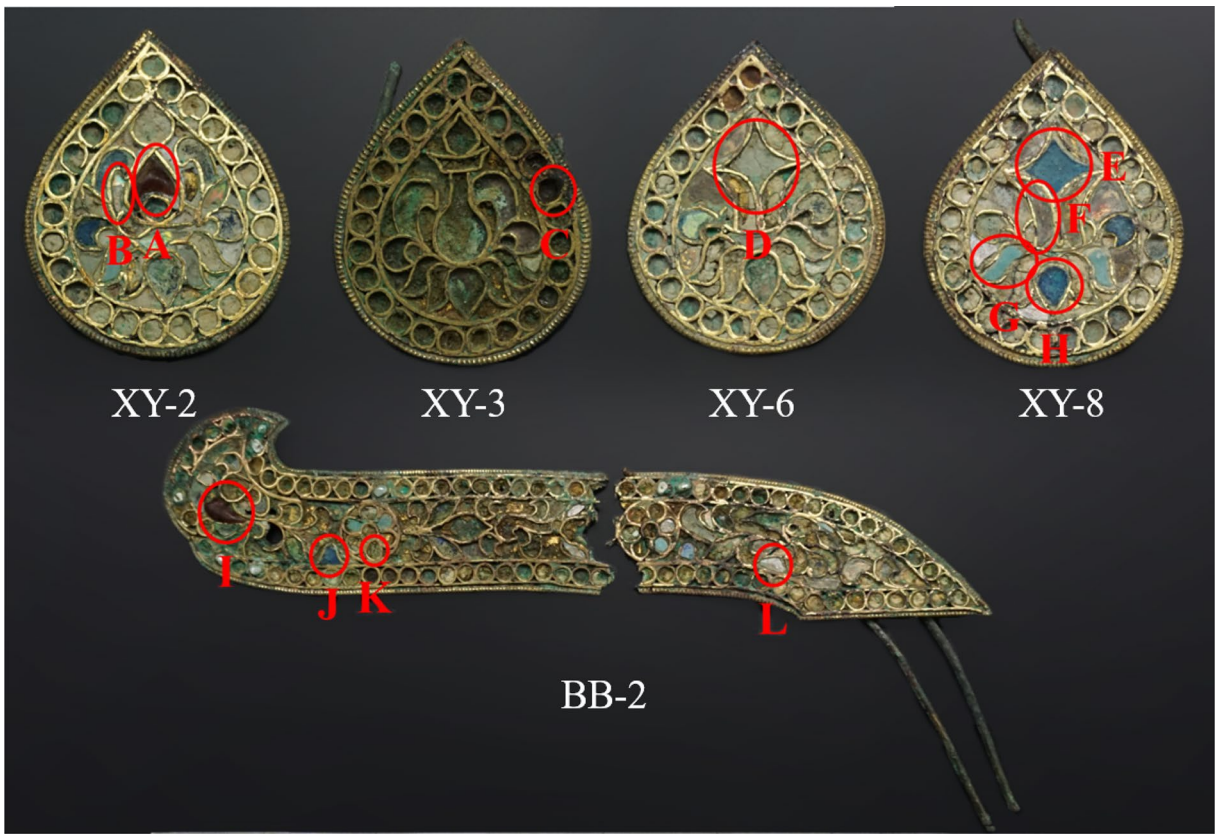


Fig. 3 Ornaments of the Sui-Tang crown excavated from Kunlun M2, Xi'an, Shaanxi, China. **A**–**L** represent the test points. (Photo: Du Jingnan)

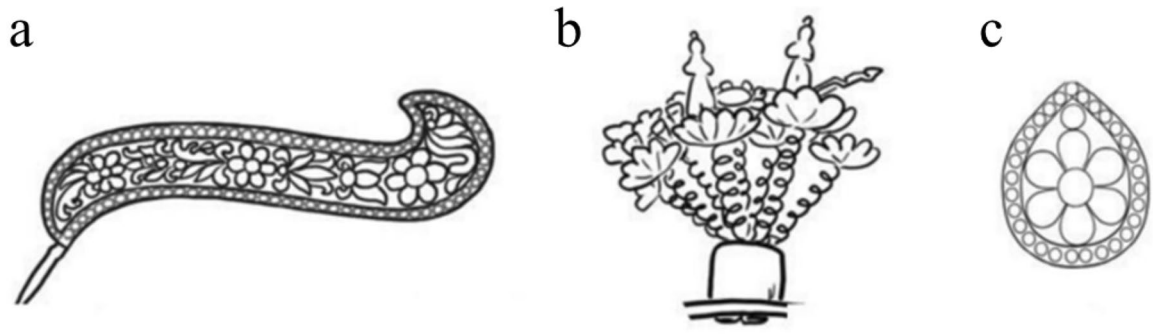


Fig. 4 Typical ornaments on Sui-Tang female crowns [8]: **a** *bo bin* (博鬓), **b** *bu yao* (步摇), **c** *bao dian* (宝钿). (Drawings: Wang Fei)

Fig. 5 Left: crown of Sui dynasty Empress Xiao [16]; right: reconstructed replica of Empress Xiao's crown. (Photos: Tian Jin)

Microfocus XRF

The microfocus X-ray fluorescence spectrometer used was a model artax-400, made by BRUKER, Germany. The range of elements analyzed was 11Na—92U (the content of sodium was not measured in the actual experiment, as the error margin would have been too large), and the spatial resolution was 0.2–1.5 mm, better than 159 eV. During the experiment, there was an Rh target, helium purge, and the beam spot diameter was 1 μm.

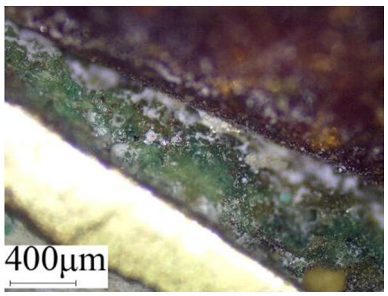
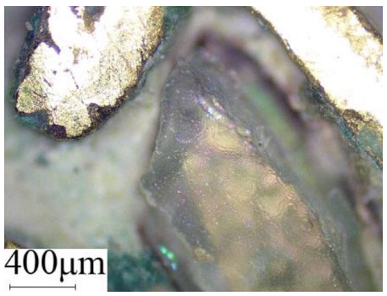
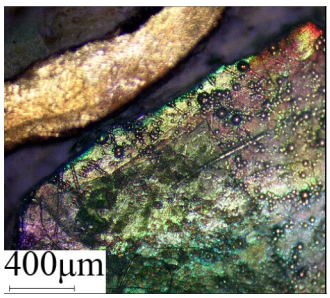
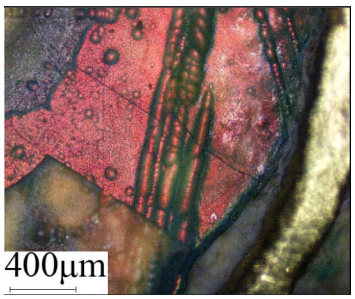
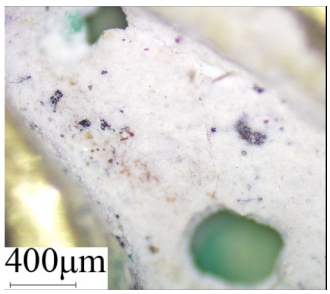
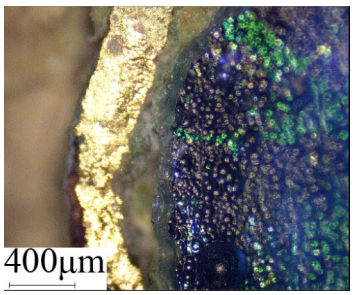
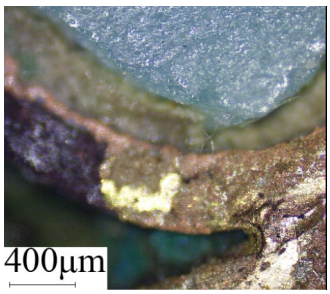
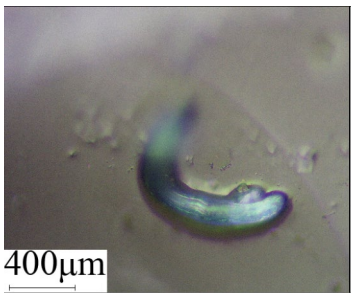
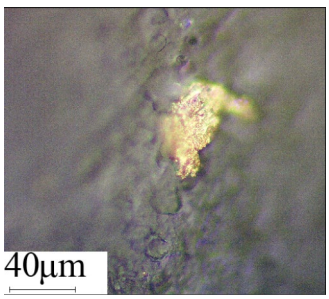
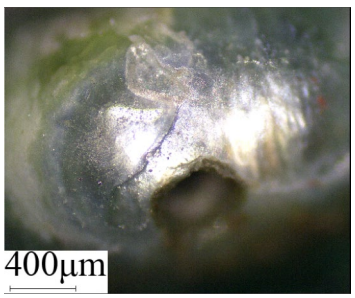
Raman spectroscopy

This experiment was tested using laser microscopy with a confocal Raman spectrometer (model In Via, Reinshaw, Co., Ltd.). The excitation wavelength of the Ar ion laser source is 532 nm, the spectral range is 200–1060 nm, and the spectral resolution is 0.5–1 cm. During the experiment, the temperature generally required is between 18 and 30 ℃, with the humidity below 50%.

Results

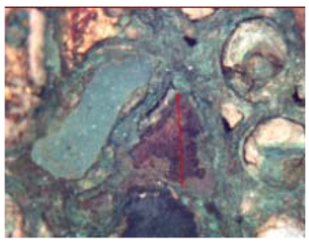
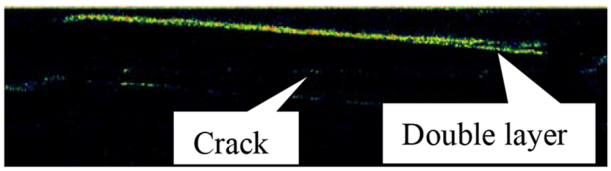
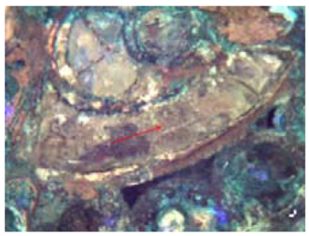
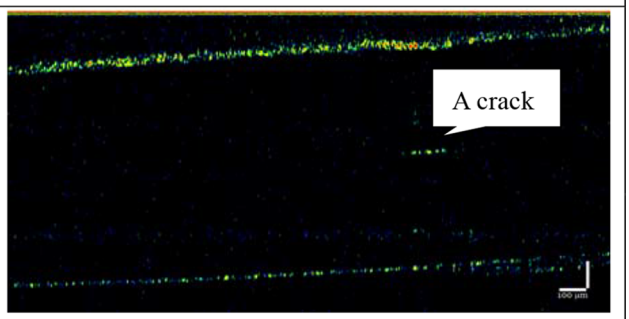
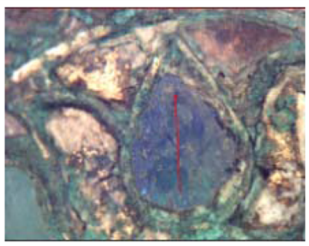
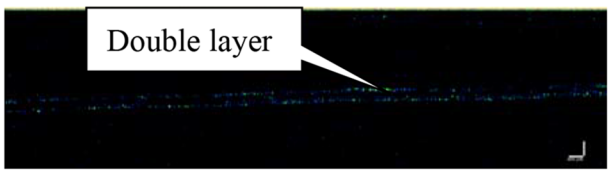
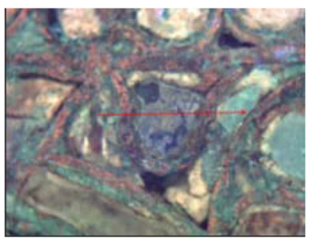
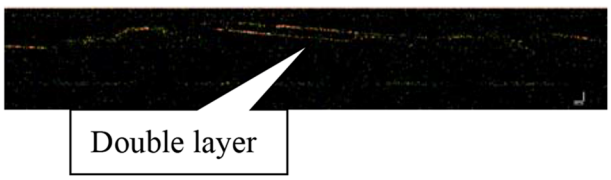
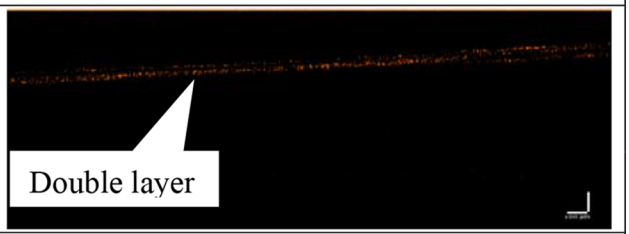
Micrographs of the Kunlun M2 crown headpieces (Table 1)

Table 1 Micrographs of the Kunlun M2 crown headpieces

	XY-2 A Gilt copper wire filigree and brown inlay		XY-2 B Gilt copper wire filigree and transparent inlay
	XY-2 01 Gilt copper wire filigree and blue inlay		XY-2 02 Gilt copper wire filigree and yellow inlay
	XY-2 03 Gilt copper wire filigree and inlay adhesive		XY-8 H Gilt copper wire filigree and blue inlay
	XY-8 G Gilt copper wire filigree and turquoise inlay		BB-2 04 Inlay impurities
	BB-2 05 Inlay impurities		BB-2 06 Pearl-like inlay

OCT results of the Kunlun M2 crown inlays (Table 2)

Table 2 OCT results of the Kunlun M2 crown inlays

No.	Sample	OCT
XY-2		
A		
	Semi-transparent brown inlay	Surface coat and cracks inside
XY-2		
B		
	Transparent inlay	No surface coat but cracks inside
XY-8		
H		
	Opaque blue inlay	Surface coat
BB-2		
J		
	Opaque dark blue inlay	Uneven surface
BB-2		
L		
	Opaque white inlay	Surface coat

Focal XRF of Kunlun M2 crown inlays (Table 3)

Table 3 Chemical composition analysis using micro focal XRF

Sample	Type	Color	Dynasty	Place	Concentration (Wt-%)																
					Si	Al	Ca	K	Cu	Fe	S	Pb	Mn	Ti	Cr	Sr	Os	As	Pd	Rb	Ni	Au
XY2-A	insertC	Brown	Late Sui C	Xi'an C	34.82	0.00	1.92	1.22	33.49	0.24	23.71	0.00	0.00	0.00	0.00	0.00	1.24	2.24	0.62	0.50	0.00	0.00
XY8-E	insertC	Dark blue	Late Sui C	Xi'an C	89.69	0.00	5.84	3.87	0.13	0.34	0.00	0.07	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00	1.08	0.00
XY8-F	insertC	Brown	Late Sui C	Xi'an C	78.86	0.00	10.32	7.46	0.02	0.50	2.22	0.00	0.51	0.07	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
XY8-G	insertC	Green	Late Sui C	Xi'an C	88.55	0.00	6.62	3.78	0.36	0.29	0.00	0.32	0.02	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
XY8-H	insertC	Blue	Late Sui C	Xi'an C	95.77	0.00	2.59	0.33	0.26	0.83	0.00	0.09	0.01	0.10	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
BB-K	insertC	Yellow	Late Sui C	Xi'an C	33.17	0.00	8.30	1.58	7.10	0.17	45.19	0.00	0.00	0.00	0.13	0.00	0.22	0.28	0.25	0.00	0.00	3.61
BB-J	insertC	Blue	Late Sui C	Xi'an C	95.03	0.00	3.33	0.84	0.18	0.47	0.00	0.07	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB-3	insertC	Green	Late Sui C	Xi'an C	89.43	0.00	5.49	3.02	0.73	0.24	0.00	1.05	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00
BB-I	insertC	Yellow	Late Sui C	Xi'an C	66.78	0.00	21.47	7.46	0.11	1.18	2.72	0.00	0.06	0.16	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.00

Raman spectrum of XY-8 of the Kunlun M2 crown (Fig. 6)

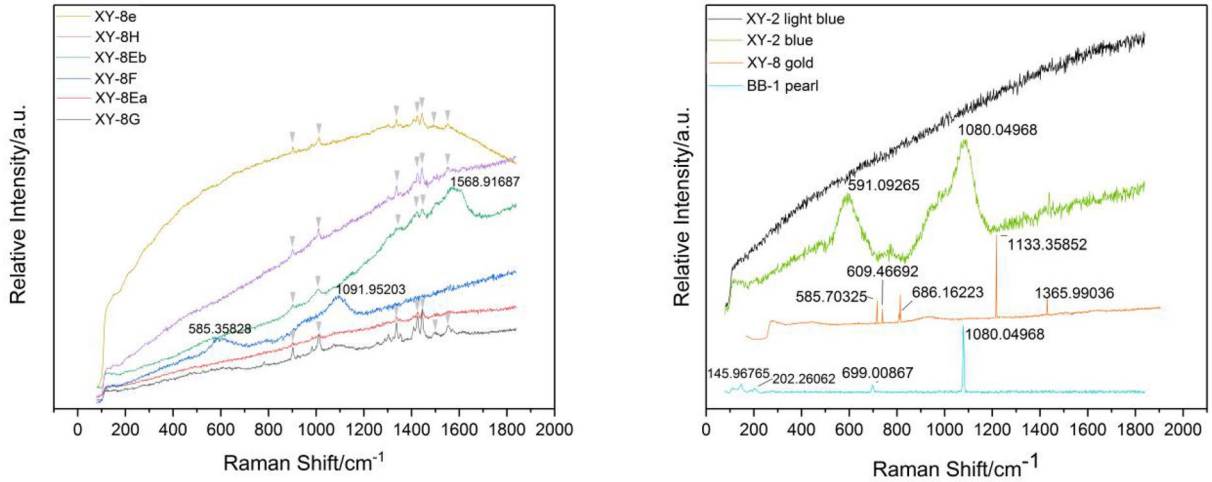


Fig. 6 **a**, **b** The Raman spectrum XY-8 of the Kunlun M2 crown. XY-8e is the Raman spectrum of the base metal. Other XY-8 measurements are for parts of the glass inlays, and the inverted grey triangles represent the corresponding peaks of the six measurements

Principal component analysis (PCA) of Chinese potash-lime glass

The chemical composition of Chinese potash-lime glass is shown in the Appendix. Its PCA is as follows: (Fig. 7)

Discussion

This study is the first to analyze glass inlays in a crown. These tests can contribute to knowledge more widely about glassware and help with the study of crowns and other inlaid objects.

Characterization of the decorative pieces

Surface topographical features

A magnification of 50, reveals numerous bubbles and cracks in the inlaid decorative materials (XY-2 01, XY-2 02, XY-8 H), and these contain obvious impurities (BB-2 04, BB-2 05). Inside the gilded copper forming the frames of the decoration there is an unknown white substance that seems to be binding material for the inlays (XY-2 A, XY-2 B, XY-2 03, XY-8 G). Pearls form a circular decoration around the edges of the headpieces, (BB-2 pearl). The inlays are colorful but the inlay workmanship on the headpieces overall is not finely executed, with the individual inlay frames uneven in width and lacking uniformity of shape (XY-2 01, XY-2 02). There is a conchoidal fracture on the transparent inlay of XY-2B. In BB-2 05 there is an uncommon characteristic, where it appears that gold foil is embedded within the inlaid decorative material; possibly an accidental inclusion of gold foil that has fallen into the raw material of the inlay. Other impurities are also evident in the inlays (BB-2 04).

All surface topographical features reveal rough workmanship, and the inlaid materials are in an amorphous state, full of bubbles. To understand the techniques and materials used to make the inlays, OCT was used to observe the internal features of the inlays. The results are shown in Table 2s.

Optical coherence tomography (OCT) features

OCT is a well-used tool for the inspection of reverse glass painting (Hinterglasmalerei, 玻璃版画) paintings, faience, jade and porcelain in the field of Heritage

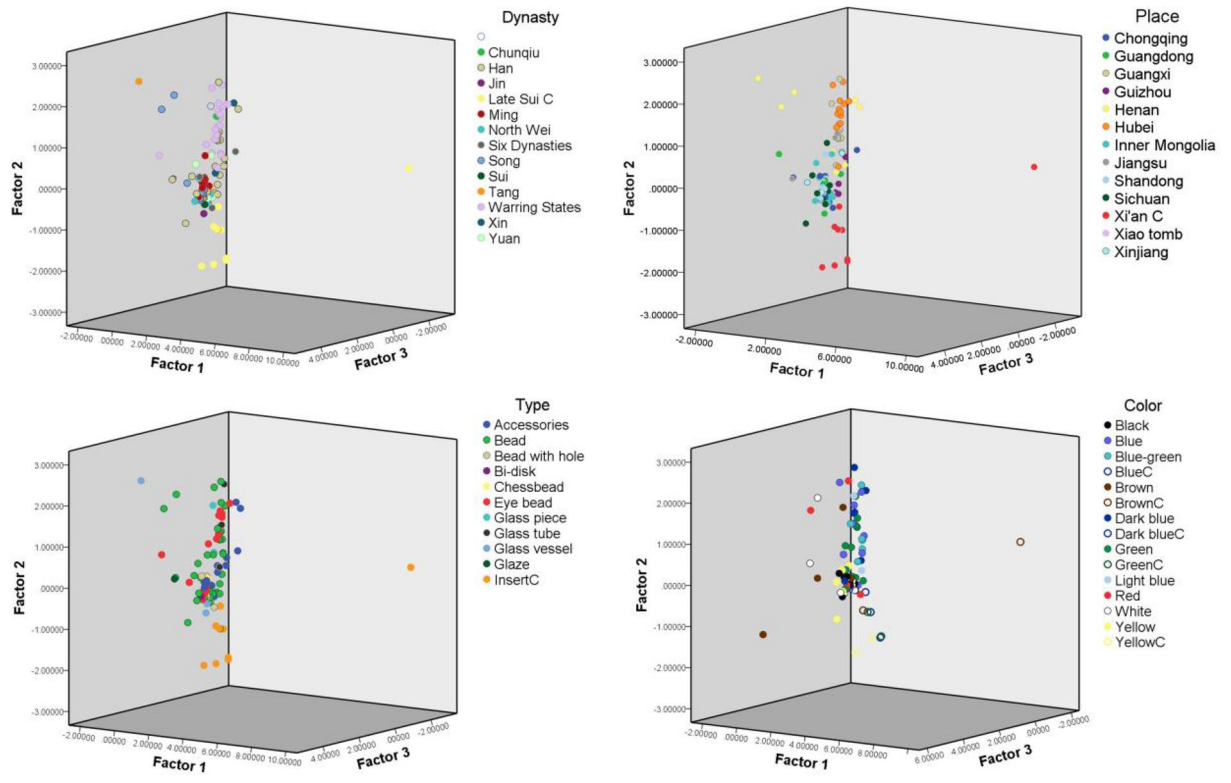


Fig. 7 PCA is used in these potash-lime glass decorations to obtain statistical models that make significantly visible the samples' chemical components and their proportional differences. (The 4 Categories—Dynasty, Place, Type and Color which were selected are the four parameters that are most likely to affect the potash-lime-glass glass composition. Dynasty and place are dependent on the samples' sites, type is the archaeological type of the sample, color is the physical color of the glassware)

Research [17–22], as it is a fast non-contact and non-invasive technique for the examination of objects that consist of transparent or semi-transparent materials [23]. In this study, the refractive index and Thickness of glass material cannot be measured, but "surface coat" can be seen in nearly all samples. This may have been caused by weathering and could have affected the composition of the materials, therefore the surface coats were removed to exclude disturbance to the analysis. The OCT image of sample B, reveals damage to the inlay in the form of a crack (see Table 2-B). Due to the lack of comparable OCT data from other ancient glass artifacts from the Sui-Tang dynasty, it is not possible to ascertain its relative quality and sophistication of craftsmanship.

Material composition

After examining the optical characterization of the inlays, their composition was analyzed using micro focal XRF and Raman.

Elemental composition

Table 3 summarizes the analysis of the composition of the decorations on the M2 crown using micro focal XRF. The test results of XY2-A and BB-K were affected by the base metal. Most of the Silicon (Si) content ranges from 66.78 to 95.770 wt%, the content of only XY2-A and BB-K are lower than 34.82wt% and 33.117wt% respectively, potassium (K) content ranges from 0.33 to 7.46, most calcium (Ca) content ranges from 1.92 to 10.32, and only BB-L shows 21.47wt% which is several times that of other decorations, with ferrum (Fe) content ranges from 0.17 to 1.18 wt%. It is important to note that aluminum (Al), magnesium (Mg), and sodium (Na) are not present in these samples, while sulfur (S) abounds in XY2-A and BB-K and there is a small quantity in XY-F and BB-I.

This chemical composition as a whole indicates that the inlays are potash-lime glass. Soda lime silicate glass which was introduced to China from the West has been made and applied in Inner China since the Tang Dynasty. Na_2CO_3, $NaNO_3$ and $CaCO_3$ are more common minerals in Western glass and some domestic Chinese glass [24–34]. High potassium content is not typical of Western glass but is characteristic of Central and Southeast Asian glass [35, 36], with research work demonstrating that the ratio of silicon to potassium of China's potassium glass is higher than Central and Southeast Asian countries [34, 37]. The inlaid glass sample in this paper has elemental characteristics consistent with domestic Chinese glass [24, 38–41].

According to modern glass scientific research, potassium silicate glass has the characteristics of higher chemical stability, is not easily crystallized, and has material enhancements making it suitable for the manufacture of more complex glassware of exquisite appearance [42, 43].

The high amount of silicon and lack of aluminum indicate the use of raw material excluding arenaceous quartz and sandstone, and probably including vein quartz or quartzite. Arenaceous quartz contains a small number of impurities such as Al_2O_3, K_2O, Fe_2O_3, Fe_2O_3, Cr_2O_3, and TiO_2, all of which can be used to colour glassand affect its transparency. Sandstone is a kind of clastic sedimentary rock formed by cementing quartz particles and cementing material under high pressure. The cementing material can be divided into clay sandstone (containing more Al_2O_3), arkose sandstone (containing more K_2O), and calcareous sandstone (containing more CaO). The appearance of sandstone is mostly yellowish and reddish, and red when iron staining is strong. The variation range of SiO_2 content is 65–95%.

Vein quartz is an igneous rock with a hard texture and sedimentary crystalline properties. Its appearance is pure white and translucent with a greasy luster. It fractures like a shell and has a SiO_2 content of up to 99%. Quartzite is a metamorphic rock, which is formed by the recrystallization of quartz grains by the metamorphic process of siliceous sandstone. Its SiO_2 content is more than 97%, it is hard and not easy to crush, and is a good raw material for manufacturing ceramics and advanced glass products.

The presence of K and absence of Mg might indicate the use of saltpeter (potassium nitrate) as a fluxing agent rather than plant ash, with Ca being the stabilizer of the admixture. According to Fuxi Gan's "Development of glass technology in ancient China", on the Northern Song dynasty period (960–1127), to further improve the physical properties of glass, saltpeter (KNO_3) was generally used as a flux, so that K_2O replaced part of the PbO, and changed lead silicate glass to potassium and lead silicate glass [43].

Based on archaeological typology, the "bead circle line" (Fig. 3) on the objects from this experiment belong to the late Sui or early Tang dynasty [44]. The elemental composition of the glass supports this dating. Saltpeter, straw ash, and potash fertilizer are discovered as the source of most potassium elements used to make potassium calcium silicate glass in ancient China. It is not clear whether saltpeter was used in the production of glass in Sui Dynasty, but there was certainly no use of straw ash or potash fertilizer in the raw material of Kunlun M2 woman's crown.

Composition of the inlays

In Fig. 6a, XY-8e is the Raman spectrum of the base metal of XY-8, with peaks of 902.571 cm^{-1}, 1012.21 cm^{-1}, 1336.94 cm^{-1}, 1444.15 cm^{-1}, and 1554.36 cm^{-1}. The grey inverted triangles indicate that all Raman spectra have the similar peaks compared to XY-8e, at around 900 cm^{-1}, 1100 cm^{-1}, 1300 cm^{-1}, 1335 cm^{-1}, 1420 cm^{-1},

1445 cm^{-1}, 1551 cm^{-1}. The base metal has a significant effect on the Raman test results of glass inlays, so the possible molecular structure of the glass inlays' composition is still unknown.

In Fig. 6b, the Raman spectrum peaks of blue glass in the sample XY-2 are 591.093 cm^{-1} and 1080.050 cm^{-1}, the Raman spectrum peaks of the gold foil of the sample XY-8 are 585.703 cm^{-1}, 609.467 cm^{-1}, 686.162 cm^{-1}, 1133.359 cm^{-1}, 1365.990 cm^{-1} and the Raman spectrum peaks of a pearl-like inlay on sample BB-1 are 145.968 cm^{-1}, 202.261 cm^{-1}, 699.009 cm^{-1}, 1080.050 cm^{-1}. The main composition of this inlay is calcium carbonate, which means it is highly possible that BB-2 06 is pearl.

Comparison of Chinese ancient potash-lime glass

This study has analyzed the glass inlays of the Kunlun M2 crown and shown that they are all potash-lime glass. Chinese potassium glass was not common in the Sui and Tang dynasties [45] and has not been systematically studied. To discover what role these potash-lime-glass decorations played in ancient China, this investigation has collected most of the representative data and compared these with the data of the glass inlays of the Kunlun M2 crown using the PCA method. The primary data is shown in Appendix and the PCA results are shown in Fig. 7.

In Fig. 7 the samples were grouped into four categories, by dynasty, excavation location, type, and color, respectively, to understand how the ratio of materials in the samples was affected. The elemental components of the glassware samples have significant regional characteristics. This could be because the ratios of materials used in local glass handicraft industries varied by production time, relic type, and their appearance of color, but were consistent by excavation place. Therefore, potash-lime glass was hypothesized to have been made locally, and the ratio of the raw material would have been decided by the local craftsmen based on experience. Unlike bronzeware, ceramics, or other mature industries in ancient China, glass manufacturing was not yet fully developed, especially potassium glass. K_2O–CaO–SiO_2 glass appeared around the Spring and Autumn period to early Warring State period (800–400 BC), mostly in the form of faience [46]. Compared with other types of glass, potassium glass has a higher softening temperature, superior toughness, and higher strength, so it is also called hard glass and is suitable for decoration making. In the Spring and Autumn period, the bronze Sword of Goujian has blue glass inlay decorations consisting of K_2O–CaO–SiO_2 glass [24, 47]. The glass was inlaid in the sword handle together with kallaite (turquoise), suggesting that K_2O–CaO–SiO_2 glass could have been one of the most valuable items indicating high honor at that time when the production of glass was probably very rare. During the historical development of glass manufacture, the value of the potash-lime glass became less as time progressed. In the Sui-Tang dynasty, the royal family used potassium glass imported from the West, but hardly used domestic Chinese potash-lime glass [2]. The Kunlun M2 crown uses potash-lime glass inlay indicating that its owner was a woman of high, but not royal, social status. According to An Jiayao's "A Brief History of Glasswares in China", Western glass came to China in the Han dynasty (202 BCE–220 CE) [24], and from then on Western glass gradually became a symbol of the highest status and power [2]. Domestic potash-lime glass in China, by comparison, can be taken to represent the "second highest class" up until the Song dynasty (960 AD) when the glass industry was no longer under government control [2]. Exquisite domestic glassware was produced during the Sui and Tang dynasties, marking a peak of Chinese glass manufacturing [2]. Most of that domestic glass was crystal glass with a high lead content, used exclusively for vessels. After the Song dynasty, glass manufacturing in China moved from government-controlled palace workshops and temple workshops to the private sector. After that time, the value of glass began to plummet and it was no longer valued by the upper classes [2].

In the late Sui to early Tang dynasty the glass inlays in the Kunlun M2 woman's crown, were dyed to imitate crown jewels. A, E and G look similar to amber, sapphire, and kallaite, respectively. Although the overall shape of the crown has been destroyed, and the value of the domestic glass can be assessed as lower than that of precious stone, this confirms that the crown belonged to a woman of significant social status above that of an ordinary person.

Glass filigree-embedding

Two significant examples of glass inlaid products are the Spring and Autumn period bronze swords that belonged to King Fuchai of Wu and King Goujian of Yue, respectively (Fig. 8). Through scientific and technological analysis, it was found that the glass on the two sword hilts was potassium calcium silicate glass, like the Kunlun M2 crown [47].

Other examples of crowns with glass dating from the sixth and seventh centuries make significant use of the filigree technique. The seventh century Sui dynasty tomb of Shi Wushe (buried on 22 January 610), excavated in Guyuan City, Ningxia Province contained a bronze "strip" and "apricot leaf" ornaments (see Fig. 9). Shi Wushe was the Right General leading the cavalry. His ancestors came from a Sogdian city (in the present-day Republic of Tajikistan) [48]. One of the ornaments is very similar to the apricot leaf ornaments of the Kunlun M2 crown.

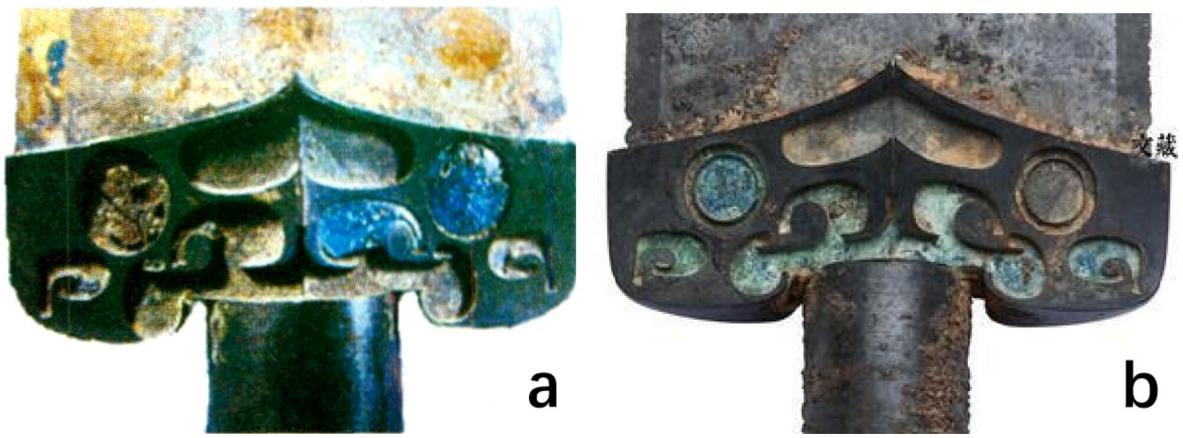


Fig. 8 **a** Hilt of King Goujian's sword. (Photo: Gan Fuxi). **b** Hilt of King Fuchai's sword. (Photo: Suzhou Museum)

Chen Zhonghui believes that the ornament was made with enamel technology. First, copper wire was used to make cell borders on the copper base, then the vitrified powder was placed in the cells, to be calcined with the copper forming a glass enamel. Historically, this technique, sometimes called "glass coating" inlay technology [49] was used widely from the Warring States period to the Han dynasty. In the sixth century, filigree enamel was also used on gold ornaments, such as those in the tomb of the Eastern Wei dynasty Ru Ru Princess (c.550) located north of Da Zhong Ying village, Hebei Province, and in the Northern Qi dynasty tomb of Lou Rui (c.577) in Taiyuan City (Fig. 10); Western countries also have enamel ornaments [50]. According to the archaeological record, pearls, carnelians, sapphires, emeralds, clamshells, and glass were inlaid in the gold ornament of Lou Rui's tomb, while pearls, gemstones, and amber were inlaid in the gold ornament of Ru Ru Princess's tomb. None of these glass inlays were tested for composition, however [48] in the case of the glass of Kunlun M2 crown, the base of gilded bronze is pure copper and the inlays are potash-lime glass. Comparison of the Kunlun M2 crown with the two swords of Wu and Yue, and since potassium glass is harder than other glass, it can be inferred that potash-lime glass may have been considered more suitable for inlaying. The glass transition temperature of the potash-lime glass is about 1200 ℃, which is higher than the melting temperature of copper which is 1083.4 ℃, and much higher than the firing temperature of enamel which is around 800 ℃. Therefore, the inlays of the Kunlun M2 crown apricot leaf ornaments must have been sintered first and then embedded inside the copper wire filigree. This is also indicated in Table 1 (XY-2A, XY-2B, XY-8H, XY-8G), where the edge of the glass inlays are not smooth, the glass was cut roughly with a conchoidal fracture, and not well matched to the filigree. There is also a white substance in the gap between the glass and filigree. Infrared spectroscopy, Transmission X-ray diffraction were used to analyze the composition of the white substance, but only SiO_2 was found.

Comparison with other crowns

Dating back to the Han Dynasty, crowns were first developed only for men to confirm their high status [53], while

Fig. 9 The bronze strip and "apricot leaf" ornaments of Shi Wushe's tomb, Guyuan City, Ningxia Province [48]. (Photo: Luo Feng)

Fig. 10 Left: gold ornament of Lou Rui's tomb in Taiyuan City [51]. (Photo: Taiyuan Institute of Cultural Relics and Archaeology); right: gold ornament of Ru Ru Princess's tomb [52]. (Photo: Zhu Quansheng)

women use the number of *bu yao* and *bao dian* to distinguish status levels [8, 13]. The full coverage ceremonial crown originated during the Northern and Southern Dynasties (420–589), and only could be worn by an empress or empress dowager, while others could only use hair accessories such as *bao dian* (宝钿, gem filigree inlay) and hair clasps. The earliest complete female crown was recorded in the Northern Wei period relief sculpture of the Longmen Grottoes Binyang Middle Cave [54] (Fig. 11).

In the Longmen relief, there are three crowns but only two of them are have *bo bin*. *Bo bin* can be seen at the bottom of the crown of Northern Wei Empress Wenzhao and the presumed Queen Mother Hu, where the tops of the crowns resemble a lotus in full bloom and there seem to be three circular ornaments hanging from the forehead, believed by archaeologists to be leaf-shaped decorations [54].

There is a further crown with similar apricot leaf ornaments to that of Kunlun M2 crown, unearthed from the Northern Wei Dynasty tomb M1 in Chen Village, Datong, Shanxi Province. M1 is a well-preserved, high-level, and large-scale brick chamber fresco-lined tomb, however, due to the lack of epitaph tablets, it is impossible to know the identity of the tomb owner [57]. As the leaf ornaments were the only parts recovered from M1 by archaeologists, it is also difficult to determine whether or not these ornaments originally belonged to a complete crown (Fig. 12).

Unearthed Sui and Tang dynasty, crowns or their parts with similar components to the Kunlun M2 crown are recorded in Table 4.

Fig. 11 Left: Empress Wenzhao, detail of Empress Wenzhao's Buddha Worship, relief sculpture, Binyang Middle Cave, Longmen Grottoes. Northern Wei dynasty [55]. (Photo: YOYO); right: Drawing of larger section showing three people wearing crowns [56]. (Drawing: Longmen Cultural Relics Depository)

Empress Xiao's crown reveals the whole scheme of a ceremonial crown in the Sui dynasty, combining *bo bin* and *bao dian* with *bu yao* (Fig. 5) to form a typical ceremonial crown that influenced the form of female ritual crowns until the Ming Dynasty (1368–1644). Together with Xiao's crown, about ten other crowns or their components have been excavated.

Xiao's crown has similar components to the Kunlun M2 crown (Fig. 5; Table 4), but the inlays of its *bo bin* have not yet been studied. Another is the Tang dynasty crown of Lady Pei who was the wife of Yan Shiwei (magistrate of Lanxi county in Zhejiang Provence) (Table 4) [58]. Yan Shiwei and his wife Lady Pei were buried in their hometown Chang'an (present-day Xi'an) on May 20 (Chinese lunar calendar) in 691. Zhang Zhengyuan identified its glass ornaments as being of two types—one is $PbO–SiO_2$, the other is $Na_2O–CaO–SiO_2$ [58, 59], although there are no glass inlays.

Comparing the number of *bao dian* in the crowns of Empress Xiao and Lady Pei, with the Kunlun M2 crown, they have twelve, six, and eight respectively, Considering the location where the M2 crown was unearthed, the owner of the M2 crown while not a royal family member, was not inferior to Lady Pei.

To date, no analysis of the inlay composition in the above crowns has been conducted, therefore systematic comparison is not possible. Future clarification of the inlays' chemical composition might enable the establishment of a classification system for Sui and Tang dynasty female ceremonial crowns. Therefore, even if only fragments of crowns can be found, important elements of the owner's personal information can be restored.

Conclusion

Application of OCT in glass observation

Unlike XRF, Raman detection, OCT is not a common analytical method used in archaeological research. OCT has lower environmental requirements, shorter time, simpler and cheaper instruments than CT, but for translucent and transparent materials, it works very well. In this paper, OCT could expose the cross-sectional information of glass in a nondestructive way, showing both the surface coating layers of the glass and the cracks inside.

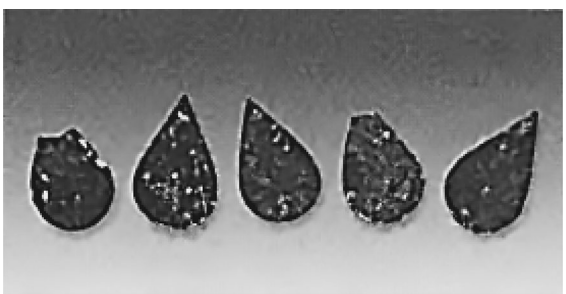


Fig. 12 Bronze apricot leaf ornaments of M1, Chen village, Datong city, Shanxi Province, Northern Wei Dynasty [57]. (Photo: Gao Feng)

Craftsmanship of the glass on Kunlun M2 crown

The inlays in the Kunlun M2 crown are potash-lime glass, belonging to the $K_2O–CaO–SiO_2$ system, and, as such, are Chinese domestic glass. This composition is not common in Sui and Tang dynasty domestic lead crystal glass. There is an undefined layer on the surface of each glass inlay, which could be a weathered layer. According to the elemental composition of the glass inlays, the raw materials of the glass might include potassium nitrate and vein quartz or quartzite. The glass inlays use lapidary techniques to cut the glass into shape and then use some additional substance to adhere them in the filigree. The whole process is fairly rough, especially on the edges of the glass and filigree.

The social status of glass products in the Sui-Tang dynasty

Glass technology was generally underdeveloped in China until it reached a peak during the Sui and Tang dynasties when glass manufacture was under government control. Potash-lime glass is one type of historical domestic Chinese glass. The ratio of chemicals comprising the glass is unique to the area and the workshop in which it was produced. It is not related to the advance of time, the particular colors, or the shape of objects. To date, no systematic data have been developed on the properties of glass at that time, nor have there been studies on the effects on the properties of glass according to the chemical distribution ratio, as is the case with historical bronze and ceramic wares. During the Sui and Tang dynasties, glass was generally used by people of the ruling class, but as the domestic glass had a lower status than imported glass, it was generally used by officials, not the royal family.

Defining the Kunlun M2 crown

The shapes of the crown's elements are very similar to those of Empress Xiao of the Sui dynasty and Lady Pei of the Tang dynasty. The base metal of all three is gilded bronze, though the inlays are different. Although the excavated parts of the Kunlun M2 crown are damaged, the extant materials used to make the crown, to some certain extent, indicate the owner's social status. Following the previous analysis, the crown was most likely made by the royal workshop for a female owner of an official family, holding high social rank in the late Sui or early Tang dynasty.

Table 4 Unearthed ceremonial crowns with *bao dian*, *bo bin* or *bu yao* from the Sui-Tang dynasty

Tomb	Date	Objects	Owner	Image	Number of *bao dian*
Southern suburbs of Ningxia Guyuan Sui Shi Wushe tomb	610	*Bao dian* and part of *bi ji* (蔽髻) "ornaments for making fake chignon"	Shi Wushe, Sui dynasty General	(See Fig. 9)	1
M2 of Cao village, Yangzhou City, Jiangsu province	648	A set of a complete ritual crown with two *bo bin*, six hairpin	Empress Xiao of Sui	  (Photos: Yang Junchang)	12
Tang tomb of Yan Shiwei and his wife, Lady Pei in Majiagou, Xi'an, Shaanxi	706	A set of a complete ritual crown with six *bao dian*, humanoid, avian, and floral ornaments	Lady Pei (wife of Yan Shiwei, a magsitrate in Taizhou)	 [58] (Photo: Yang Junkai)	6
Kunlun M2		Kunlun M2 crown	Unknown	(See Fig. 1)	8

Appendix

Sample	Type	Color	Dynasty	Place	Si	Al	Ca	K	Cu	Fe	S	Pb	Mn	Ti	Cr	Sr	Os
XY2-1	InsertC	Brown	Late Sui C	Xi'an C	34.82	0.00	1.92	1.22	33.49	0.24	23.71	0.00	0.00	0.00	0.00	0.00	1.24
XY8-1	InsertC	Dark blue	Late Sui C	Xi'an C	89.69	0.00	5.84	3.87	0.13	0.34	0.00	0.07	0.02	0.03	0.00	0.01	0.00
XY8-2	InsertC	Brown	Late Sui C	Xi'an C	78.86	0.00	10.32	7.46	0.02	0.50	2.22	0.00	0.51	0.07	0.01	0.01	0.00
XY8-3	InsertC	Green	Late Sui C	Xi'an C	88.55	0.00	6.62	3.78	0.36	0.29	0.00	0.32	0.02	0.04	0.01	0.01	0.01
XY8-4	InsertC	Blue	Late Sui C	Xi'an C	95.77	0.00	2.59	0.33	0.26	0.83	0.00	0.09	0.01	0.10	0.01	0.01	0.00
BB-1	InsertC	Yellow	Late Sui C	Xi'an C	33.17	0.00	8.30	1.58	7.10	0.17	45.19	0.00	0.00	0.00	0.13	0.00	0.22
BB-2	InsertC	Blue	Late Sui C	Xi'an C	95.03	0.00	3.33	0.84	0.18	0.47	0.00	0.07	0.02	0.05	0.00	0.00	0.00
BB-3	InsertC	Green	Late Sui C	Xi'an C	89.43	0.00	5.49	3.02	0.73	0.24	0.00	1.05	0.00	0.00	0.00	0.01	0.02
BB-5	InsertC	Yellow	Late Sui C	Xi'an C	66.78	0.00	21.47	7.46	0.11	1.18	2.72	0.00	0.06	0.16	0.02	0.02	0.00
Tang Xiaoling-1	Bead		Tang	Xiao Tomb	89.26	0.00	6.24	3.72	0.04	0.45	0.00	0.13	0.06	0.07	0.01	0.01	0.00
Tang Xiaoling-2	Bead		Tang	Xiao Tomb	89.13	9.37	1.43	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Tang Xiaoling-3	Bead		Tang	Xiao Tomb	80.72	10.62	5.05	2.84	0.04	0.39	0.00	0.23	0.05	0.05	0.00	0.00	0.00
Tang Xiaoling-4	Bead		Tang	Xiao Tomb	81.28	11.38	4.16	2.39	0.01	0.18	0.00	0.55	0.01	0.03	0.01	0.00	0.00
Tang Xiaoling-5	Bead		Tang	Xiao Tomb	81.75	10.69	3.43	3.11	0.02	0.22	0.00	0.06	0.67	0.05	0.01	0.00	0.00
GD02	Bead	Dark blue	Han	Guang-dong	81.68	3.70	1.03	10.39	0.03	1.44	0.00	0.14	1.33	0.15	0.00	0.00	0.00
GD05	Glass vessel		Jin	Guang-dong	80.33	1.87	11.68	4.13	0.02	1.13	0.47	0.00	0.03	0.10	0.06	0.00	0.00
GD04	Acces-sories (hairpin)		Ming	Guang-dong	66.25	5.51	10.54	16.39	0.68	0.30	0.07	0.04	0.00	0.22	0.00	0.00	0.00
GD03	Acces-sories (hairpin)		Ming	Guang-dong	65.93	5.60	10.58	16.45	0.67	0.32	0.17	0.01	0.00	0.21	0.04	0.00	0.00
GZH-1B	Bead	Light blue	Han	Guizhou	84.68	5.55	1.05	5.37	1.52	0.76	0.36	0.00	0.60	0.11	0.01	0.00	0.00
GZH-1C	Bead	Green	Han	Guizhou	88.18	4.11	1.38	2.09	2.84	0.86	0.37	0.00	0.03	0.10	0.02	0.00	0.00
GZH-10	Bead		Han	Guizhou	88.01	4.80	1.74	2.58	0.13	1.92	0.37	0.00	0.23	0.17	0.00	0.00	0.00
44-18-35A	Bead	Yellow	Han	Sichuan	61.93	1.48	9.98	14.29	0.00	0.40	0.00	11.80	0.00	0.05	0.00	0.00	0.00
44-18-35B	Bead	White	Han	Sichuan	73.87	3.44	7.04	9.75	0.01	1.07	4.06	0.36	0.00	0.17	0.00	0.00	0.00
44-18-35C	Bead	Dark blue	Han	Sichuan	63.73	5.27	10.85	12.66	0.02	0.84	5.14	0.00	0.00	0.03	0.05	0.00	0.00
44-18-36B	Bead	Yellow	Han	Sichuan	59.11	3.78	24.94	3.50	0.10	0.64	5.91	1.53	0.02	0.00	0.00	0.00	0.00
44-18-40	Bead (olive shape)	Brown	Tang	Sichuan	70.26	4.42	8.12	11.52	0.02	0.79	4.16	0.42	0.03	0.09	0.01	0.00	0.00
44-18-37	Bead (olive shape)	Light blue	Tang	Sichuan	69.35	2.25	13.80	11.61	0.01	0.57	0.91	0.34	0.05	0.03	0.01	0.00	0.00
44-18-38	Acces-sories (bracelet)	Green	Ming	Sichuan	74.66	4.07	5.74	9.26	1.13	3.83	0.73	0.38	0.11	0.10	0.00	0.00	0.00
43-1-65	Accesso-ries		Ming	Sichuan	64.40	2.27	15.23	16.49	0.05	0.92	0.40	0.09	0.00	0.07	0.00	0.00	0.00
44-18-43	Glass vessel	Green	Sui	Sichuan	75.32	1.15	7.76	14.79	0.12	0.23	0.16	0.24	0.04	0.00	0.19	0.00	0.00
44-18-42	Acces-sories (hairpin)		Ming	Sichuan	67.42	2.28	11.36	17.31	0.03	0.57	0.85	0.10	0.01	0.04	0.01	0.00	0.00

Sample	Type	Color	Dynasty	Place	Si	Al	Ca	K	Cu	Fe	S	Pb	Mn	Ti	Cr	Sr	Os
C26	Accessories (bracelet)		Han	Guangxi	73.83	1.75	3.47	17.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WJ-05	Bead	Yellow	North Wei	Inner Mongolia	74.72	6.66	7.00	5.05	0.12	2.36	1.42	0.00	0.10	0.29	0.04	0.00	0.00
WJ-06-B	Bead	Black	North Wei	Inner Mongolia	70.39	11.54	6.37	2.95	0.03	3.95	1.18	0.00	0.92	0.31	0.00	0.00	0.00
WJ-07-A	Bead	White	North Wei	Inner Mongolia	72.41	3.73	12.15	1.44	0.00	2.48	2.40	0.00	0.09	0.24	0.03	0.00	0.00
WJ-03-A	Bead	White	North Wei	Inner Mongolia	82.90	4.25	6.36	2.75	0.00	1.11	1.05	0.00	0.07	0.11	0.03	0.00	0.00
WJ-03-B	Bead	Black	North Wei	Inner Mongolia	82.17	4.37	5.36	2.28	0.03	1.94	1.09	0.00	0.78	0.14	0.00	0.00	0.00
WJ-02	Bead (hexagonal stick)		Yuan	Inner Mongolia	78.04	1.93	8.60	5.03	0.04	4.66	0.88	0.00	0.09	0.09	0.03	0.00	0.00
WJ-08-B	Bead	White	Yuan	Inner Mongolia	76.11	4.11	8.10	6.14	0.05	0.28	1.91	0.00	0.00	0.03	0.00	0.00	0.00
WJ-10	Bead (rhombus)	Blue	Yuan	Inner Mongolia	62.20	8.43	6.09	15.38	1.87	2.01	1.58	0.00	0.05	0.12	0.00	0.00	0.00
WJ-12	Accessories (hairpin)	Blue	Yuan	Inner Mongolia	83.18	3.70	5.60	3.50	0.72	1.11	1.67	0.00	0.02	0.08	0.00	0.00	0.00
WJ-01	Bead (hexagonal stick)		Yuan	Inner Mongolia	57.44	4.86	7.03	18.65	3.33	4.81	2.03	0.00	0.09	0.09	0.00	0.00	0.00
BS01	Chessbead	White	Ming	Shandong	72.33	9.94	5.95	10.89	0.00	0.36	0.19	0.00	0.00	0.34	0.00	0.00	0.00
BS02	Chessbead	Yellow	Ming	Shandong	69.70	6.41	8.36	14.52	0.41	0.15	0.13	0.00	0.00	0.21	0.04	0.00	0.00
BS03	Accessories (hairpin)	Black	Ming	Shandong	71.59	8.57	7.65	5.13	1.44	0.44	4.27	0.00	0.00	0.26	0.05	0.00	0.00
BS04	Bead (umbrella)	Green	Ming	Shandong	63.29	9.34	8.23	16.23	1.07	0.72	0.58	0.00	0.00	0.26	0.00	0.00	0.00
BS05	Accessories (hairpin)	White	Ming	Shandong	69.14	9.98	8.60	11.30	0.00	0.44	0.33	0.00	0.03	0.18	0.00	0.00	0.00
BS06	Accessories (hairpin)	Black	Ming	Shandong	78.23	8.79	5.74	4.50	0.00	0.61	1.82	0.00	0.00	0.30	0.00	0.00	0.00
BS07	Bi-disk	Yellow	Ming	Shandong	72.02	9.17	10.67	3.56	0.00	0.69	3.09	0.00	0.00	0.38	0.00	0.00	0.00
CQ05	Accessories (earrings)	Blue	Six Dynasties	Chongqing	81.50	3.00	1.20	4.80	0.10	3.00	2.40	0.00	3.40	0.50	0.00	0.00	0.00
CQ09	Bead	Brown	Six Dynasties	Chongqing	45.50	19.30	14.20	4.20	0.10	1.90	11.10	0.00	0.00	0.30	0.00	0.00	0.00
CQ10	Bead with hole	Blue	Six Dynasties	Chongqing	76.60	4.30	9.70	4.50	1.10	1.20	1.50	0.00	0.10	0.20	0.00	0.00	0.00

Sample	Type	Color	Dynasty	Place	Si	Al	Ca	K	Cu	Fe	S	Pb	Mn	Ti	Cr	Sr	Os
CQ11	Bead with hole	White	Six Dynasties	Chongqing	83.40	2.10	7.40	3.60	0.00	0.80	1.70	0.00	0.00	0.10	0.00	0.00	0.00
CQ12	Bead with hole	Brown	Six Dynasties	Chongqing	78.30	3.90	7.80	4.60	0.10	1.50	2.40	0.00	0.00	0.10	0.00	0.00	0.00
CQ15	Bead with hole	Red	Six Dynasties	Chongqing	88.20	2.10	7.00	1.90	0.00	0.10	0.70	0.00	0.00	0.00	0.00	0.00	0.00
CQ17	Bead with hole	Black	Six Dynasties	Chongqing	75.10	4.30	7.90	5.00	0.10	2.20	4.10	0.00	0.20	0.10	0.00	0.00	0.00
CQ18	Bead with hole	Green	Six Dynasties	Chongqing	76.60	13.10	2.20	4.40	0.80	1.30	0.70	0.00	0.00	0.40	0.00	0.00	0.00
CQ19	Bead with hole	Black	Six Dynasties	Chongqing	78.10	12.20	3.00	2.60	0.10	1.50	1.40	0.00	0.10	0.60	0.00	0.00	0.00
CQ20	Bead with hole	Yellow	Six Dynasties	Chongqing	76.10	12.30	2.30	2.00	0.10	1.10	3.00	0.50	0.10	0.50	0.00	0.00	0.00
XZHM06-08	Glass piece	Brown		Guangxi	60.04	9.54	4.21	15.95	2.81	2.14	0.00	0.00	0.14	0.57	0.00	0.00	0.00
HBWKI-27	Eye bead	Blue	Warring States	Hubei	67.46	6.84	3.62	11.67	5.07	1.79	0.00	0.00	0.14	0.25	0.03	0.00	0.00
HBWKI-30-A	Glass tube	Dark blue	Warring States	Hubei	70.33	6.69	3.80	12.75	2.52	1.33	0.00	0.00	0.10	0.24	0.03	0.00	0.00
HBWKI-30-A	Glass tube	Dark blue	Warring States	Hubei	70.04	3.98	3.64	13.44	3.26	1.43	0.00	0.00	0.09	0.30	0.04	0.00	0.00
HBWKI-36	Bead	Green	Warring States	Hubei	76.42	4.65	2.89	8.18	2.34	1.41	0.00	0.00	0.07	0.25	0.00	0.00	0.00
HBWKI-48	Bead	Blue	Warring States	Hubei	59.74	15.87	3.15	7.57	4.41	4.29	0.00	0.00	0.10	0.40	0.04	0.00	0.00
HBWKI-57	Glass tube	Dark blue	Warring States	Hubei	69.16	3.16	4.22	15.00	2.10	1.28	0.00	0.00	0.09	0.14	0.09	0.00	0.00
HBXKI-T9	Eye bead	Blue	Warring States	Hubei	72.41	3.79	2.81	9.82	4.38	0.98	0.00	0.00	0.00	0.08	0.00	0.00	0.00
HBXKI-T10	Bead	Blue-green	Warring States	Hubei	66.45	8.32	4.19	11.68	3.74	3.02	0.00	0.00	0.23	0.29	0.00	0.00	0.00
Lgd4	Glass tube	Blue	Warring States	Hubei	72.73	1.07	1.66	15.63	1.52	0.40	0.34	0.52	0.00	0.00	0.00	0.00	0.00
HNLY-09c	Glass piece	Green	Warring States	Henan	78.50	7.38	4.04	1.84	2.45	3.04	0.05	0.00	0.00	0.15	0.00	0.00	0.00
HNLY-12	Glass vessel		Tang	Henan	38.00	7.81	2.85	3.60	4.50	0.47	0.00	26.90	0.03	0.03	0.00	0.00	0.00
HNLY-14a	Bead	Red	Song	Henan	47.00	3.78	3.27	8.73	1.95	2.47	0.79	22.30	0.03	0.04	0.00	0.00	0.00
HNLY-14b	Bead	White	Song	Henan	51.30	8.09	10.40	3.24	0.08	0.92	1.10	16.50	0.00	0.06	0.00	0.00	0.00
HNLY-07	Accessories (earrings)	Dark blue	Han	Henan	72.20	3.88	1.53	11.50	0.08	3.48	0.00	0.00	4.51	0.00	0.00	0.00	0.00
HNZZ-55	Accessories (earrings)	Blue-green	Xin	Henan	72.30	3.95	3.82	7.98	0.24	3.82	0.00	0.89	2.76	0.00	0.00	0.00	0.00
HNZZ-64	Accessories (earrings)	Blue-green	Han	Henan	84.20	3.67	3.46	2.55	0.07	2.10	0.00	0.00	1.82	0.00	0.00	0.00	0.00
HNZZ-73	Accessories (earrings)	Blue-green	Xin	Henan	84.00	4.04	4.31	1.65	0.21	2.57	0.00	0.00	0.66	0.00	0.00	0.00	0.00

Sample	Type	Color	Dynasty	Place	Si	Al	Ca	K	Cu	Fe	S	Pb	Mn	Ti	Cr	Sr	Os
GZH-7	Accessories (earrings)	Light blue	Han	Guizhou	77.32	5.15	1.38	9.33	0.06	3.01	0.00	0.00	2.16	0.00	0.00	0.00	0.00
XJ-5A	Bead	Blue-green	Warring States	Xinjiang	77.92	1.63	1.97	15.60	0.91	0.57	0.00	0.01	0.01	0.12	0.00	0.00	0.00
XJ-5B	Bead	Blue-green	Warring States	Xinjiang	78.71	1.63	2.36	14.18	1.19	0.43	0.00	0.01	0.02	0.06	0.00	0.00	0.00
HB-3	Bead	Light blue	Warring States	Hubei	71.26	6.83	2.37	10.71	2.64	1.19	0.00	0.98	0.11	0.16	0.00	0.00	0.00
SC-QT	Eye bead		Warring States	Sichuan	70.86	14.34	5.35	0.84	2.63	1.26	0.00	0.76	0.11	1.26	0.00	0.00	0.00
XJ-42A1	Eye bead	Red	Song	Xinjiang	71.63	6.50	9.25	4.04	3.79	2.48	0.00	0.66	0.08	0.33	0.00	0.00	0.00
XJ-42A2	Eye bead	Black	Song	Xinjiang	73.12	5.89	12.52	3.91	0.37	2.51	0.00	0.02	0.10	0.48	0.00	0.00	0.00
XJ-42A3	Eye bead	White	Song	Xinjiang	73.22	6.05	11.42	3.87	0.28	2.29	0.00	0.65	0.07	0.30	0.00	0.00	0.00
XJ-42A4	Eye bead	Green	Song	Xinjiang	73.63	5.24	9.86	4.30	2.08	2.03	0.00	1.46	0.10	0.28	0.00	0.00	0.00
XJ-42A5	Eye bead	Yellow	Song	Xinjiang	66.17	4.86	9.35	3.81	0.53	1.57	0.00	13.07	0.06	0.16	0.00	0.00	0.00
XJ-42A6	Eye bead	Green	Song	Xinjiang	70.66	6.06	10.44	3.85	2.54	2.89	0.00	2.51	0.08	0.29	0.00	0.00	0.00
GD01-1	Eye bead	White	Warring States	Guangdong	54.41	14.37	2.03	2.98	0.13	2.72	0.00	11.82	0.01	0.01	0.00	0.00	0.00
GD01-2	Eye bead	Blue	Warring States	Guangdong	49.95	9.01	2.87	1.81	0.06	1.43	0.00	18.58	0.00		0.00	0.00	0.00
XZHM-06-01	Bead	Green	Han	Guangxi	75.56	2.98	1.56	16.64	0.00	0.55	0.00	0.00	0.06	0.20	0.00	0.00	0.00
XZHM-06-02	Bead	Blue	Han	Guangxi	72.24	4.92	1.98	14.32	0.24	1.81	0.00	0.00	1.31	0.32	0.00	0.00	0.00
XZHM-06-02B	Bead	Blue	Han	Guangxi	75.44	3.81	1.18	14.55	0.03	1.45	0.00	0.00	1.06	0.24	0.00	0.00	0.00
FMLM26-2	Bead	Green	Han	Guangxi	76.68	2.64	1.46	15.28	0.00	0.54	0.00	0.00	0.05	0.20	0.00	0.00	0.00
XZHM-06-08	Bead	Red	Han	Guangxi	58.87	2.64	4.80	22.82	3.71	1.63	0.00	0.00	0.16	0.54	0.00	0.00	0.00
JZLM5-15	Bead	Green	Han	Guangxi	75.20	3.97	2.33	13.33	1.02	0.61	0.00	0.00	0.06	0.12	0.00	0.00	0.00
JS-TB-1	Eye bead		Warring States	Jiangsu	72.04	3.23	4.48	12.54	2.87	1.10	0.00	0.00	0.13	0.19	0.00	0.00	0.00
JS-TB-2	Eye bead		Warring States	Jiangsu	73.28	4.54	4.94	11.22	1.67	1.18	0.00	0.00	0.10	0.23	0.00	0.00	0.00
JS-TB-3	Eye bead		Warring States	Jiangsu	71.36	3.45	4.61	13.16	2.90	1.12	0.00	0.00	0.12	0.21	0.00	0.00	0.00
HB-TB-1	Eye bead		Warring States	Hubei	71.58	3.81	4.13	13.31	3.62	1.13	0.00	0.00	0.16	4.13	0.00	0.00	0.00
HB-TB-2	Eye bead		Warring States	Hubei	69.44	4.10	4.39	14.33	3.68	1.15	0.00	0.00	0.22	4.39	0.00	0.00	0.00
HB-TB-3	Eye bead		Warring States	Hubei	69.48	4.15	4.32	14.10	3.69	1.16	0.00	0.00	0.21	4.32	0.00	0.00	0.00
HB-EB-3	Eye bead		Chunqiu	Hubei	71.23	5.63	4.23	12.16	2.47	0.11	0.00	0.00	0.11	4.23	0.00	0.00	0.00
JS-BB	Glaze	Brown	Han	Jiangsu	36.86	0.00	13.41	1.23	0.00	35.07	7.44	0.74	0.00	3.78	0.01	0.00	0.00

Sample	Type	Color	Dynasty	Place	As	Pd	Rb	Ni	Ga	Au	Co	Sn	Zn	Cl	P	Ba	Mg	Na
XY2-1	InsertC	Brown	Late Sui C	Xi'an C	2.24	0.62	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XY8-1	InsertC	Dark blue	Late Sui C	Xi'an C	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XY8-2	InsertC	Brown	Late Sui C	Xi'an C	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XY8-3	InsertC	Green	Late Sui C	Xi'an C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XY8-4	InsertC	Blue	Late Sui C	Xi'an C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB-1	InsertC	Yellow	Late Sui C	Xi'an C	0.28	0.25	0.00	0.00	0.00	3.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB-2	InsertC	Blue	Late Sui C	Xi'an C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sample	Type	Color	Dynasty	Place	As	Pd	Rb	Ni	Ga	Au	Co	Sn	Zn	Cl	P	Ba	Mg	Na
BB-3	InsertC	Green	Late Sui C	Xi'an C	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB-5	InsertC	Yellow	Late Sui C	Xi'an C	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tang Xiaoling-1	Bead		Tang	Xiao Tomb	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tang Xiaoling-2	Bead		Tang	Xiao Tomb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tang Xiaoling-3	Bead		Tang	Xiao Tomb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tang Xiaoling-4	Bead		Tang	Xiao Tomb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tang Xiaoling-5	Bead		Tang	Xiao Tomb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD02	Bead	Dark blue	Han	Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00
GD05	Glass vessel		Jin	Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00
GD04	Accessories (hairpin)		Ming	Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD03	Accessories (hairpin)		Ming	Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
GZH-1B	Bead	Light blue	Han	Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GZH-1C	Bead	Green	Han	Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
GZH-10	Bead		Han	Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00
44-18-35A	Bead	Yellow	Han	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
44-18-35B	Bead	White	Han	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.03	0.00	0.00
44-18-35C	Bead	Dark blue	Han	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	1.11	0.00	0.00
44-18-36B	Bead	Yellow	Han	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00
44-18-40	Bead (olive shape)	Brown	Tang	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
44-18-37	Bead (olive shape)	Light blue	Tang	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
44-18-38	Accessories (bracelet)	Green	Ming	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43-1-65	Accessories		Ming	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
44-18-43	Glass vessel	Green	Sui	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44-18-42	Accessories (hairpin)		Ming	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
C26	Accessories (bracelet)		Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00
WJ-05	Bead	Yellow	North Wei	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	1.38	0.85	0.00	0.00	0.00
WJ-06-B	Bead	Black	North Wei	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	1.39	0.00	0.00	0.00
WJ-07-A	Bead	White	North Wei	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	2.54	2.04	0.00	0.00	0.00

Sample	Type	Color	Dynasty	Place	As	Pd	Rb	Ni	Ga	Au	Co	Sn	Zn	Cl	P	Ba	Mg	Na
WJ-03-A	Bead	White	North Wei	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.12	0.00	0.00	0.00
WJ-03-B	Bead	Black	North Wei	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.33	0.00	0.00	0.00
WJ-02	Bead (hexagonal stick)		Yuan	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.58	0.00	0.00	0.00	0.00
WJ-08-B	Bead	White	Yuan	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.73	0.54	0.00	0.00	0.00
WJ-10	Bead (rhombus)	Blue	Yuan	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	15.38	0.48	0.00	0.00	0.00
WJ-12	Accessories (hairpin)	Blue	Yuan	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.42	0.00	0.00	0.00	0.00
WJ-01	Bead (hexagonal stick)		Yuan	Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.67	0.16	0.00	0.00	0.00
BS01	Chessbead	White	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS02	Chessbead	Yellow	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.06	0.00	0.00	0.00
BS03	Accessories (hairpin)	Black	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.57	0.00	0.00	0.00
BS04	Bead (umbrella)	Green	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.18	0.00	0.00	0.00
BS05	Accessories (hairpin)	White	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS06	Accessories (hairpin)	Black	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS07	Bi-disk	Yellow	Ming	Shandong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00
CQ05	Accessories (earrings)	Blue	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CQ09	Bead	Brown	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	0.00	0.00	0.00
CQ10	Bead with hole	Blue	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00
CQ11	Bead with hole	White	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00
CQ12	Bead with hole	Brown	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00
CQ15	Bead with hole	Red	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CQ17	Bead with hole	Black	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00

Sample	Type	Color	Dynasty	Place	As	Pd	Rb	Ni	Ga	Au	Co	Sn	Zn	Cl	P	Ba	Mg	Na
CQ18	Bead with hole	Green	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
CQ19	Bead with hole	Black	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
CQ20	Bead with hole	Yellow	Six Dynasties	Chongqing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00
XZHM06-08	Glass piece	Brown		Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	3.10	0.00
HBWKI-27	Eye bead	Blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.03	0.00	0.43	0.00	1.43	1.10
HBWKI-30-A	Glass tube	Dark blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.08	0.00	0.43	0.00	1.09	0.24
HBWKI-30-A	Glass tube	Dark blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.96	0.00	0.95	1.12
HBWKI-36	Bead	Green	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.15	0.00	0.71	0.00	1.54	0.85
HBWKI-48	Bead	Blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.17	0.00	0.69	0.00	1.48	0.53
HBWKI-57	Glass tube	Dark blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.77	0.00	1.57	1.96
HBXKI-T9	Eye bead	Blue	Warring States	Hubei	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.73	0.00	1.14	1.17
HBXKI-T10	Bead	Blue-green	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	1.19
Lgd4	Glass tube	Blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.09
HNLY-09c	Glass piece	Green	Warring States	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	1.17	0.70
HNLY-12	Glass vessel		Tang	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	13.30	0.00	1.17	0.00
HNLY-14a	Bead	Red	Song	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.76	8.01	0.00	0.60	0.20
HNLY-14b	Bead	White	Song	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.24	4.67	0.00	1.76	1.56
HNLY-07	Accessories (earrings)	Dark blue	Han	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.37	0.00	0.91	0.61
HNZZ-55	Accessories (earrings)	Blue-green	Xin	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.67	0.00	0.65	1.38
HNZZ-64	Accessories (earrings)	Blue-green	Han	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.81	0.00	0.20	0.00
HNZZ-73	Accessories (earrings)	Blue-green	Xin	Henan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.43	0.69
GZH-7	Accessories (earrings)	Light blue	Han	Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.03	0.19	0.00	0.00
XJ-5A	Bead	Blue-green	Warring States	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.36	0.82
XJ-5B	Bead	Blue-green	Warring States	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.47	0.81
HB-3	Bead	Light blue	Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.14	1.75	1.81
SC-QT	Eye bead		Warring States	Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.89
XJ-42A1	Eye bead	Red	Song	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.16	0.00	0.00

Sample	Type	Color	Dynasty	Place	As	Pd	Rb	Ni	Ga	Au	Co	Sn	Zn	Cl	P	Ba	Mg	Na
XJ-42A2	Eye bead	Black	Song	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.06	0.00	0.00
XJ-42A3	Eye bead	White	Song	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.08	0.00	0.00
XJ-42A4	Eye bead	Green	Song	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.05	0.00	0.00
XJ-42A5	Eye bead	Yellow	Song	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.09	0.00	0.00
XJ-42A6	Eye bead	Green	Song	Xinjiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD01-1	Eye bead	White	Warring States	Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	9.87	0.00	0.00
GD01-2	Eye bead	Blue	Warring States	Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	15.82	0.00	0.00
XZHM-06-01	Bead	Green	Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.13	0.57	0.96
XZHM-06-02	Bead	Blue	Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.20	0.90	0.64
XZHM-06-02B	Bead	Blue	Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.19	0.67	0.75
FMLM26-2	Bead	Green	Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42	0.15	0.45	1.12
XZHM-06-08	Bead	Red	Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.12	3.63	0.53
JZLM5-15	Bead	Green	Han	Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.13	0.40	1.71
JS-TB-1	Eye bead		Warring States	Jiangsu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	1.12	1.41
JS-TB-2	Eye bead		Warring States	Jiangsu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	1.22	0.85
JS-TB-3	Eye bead		Warring States	Jiangsu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	1.00	1.02
HB-TB-1	Eye bead		Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.86	1.12
HB-TB-2	Eye bead		Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.90	1.13
HB-TB-3	Eye bead		Warring States	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.88	1.18
HB-EB-3	Eye bead		Chunqiu	Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.85	1.21
JS-BB	Glaze	Brown	Han	Jiangsu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	0.00

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Authors' contributions

DJ: methodology, validation, investigation, data analysis, draft writing, editing and reviewing. TE: manuscript editing and reviewing. YJ, JF: project administration. ZQ: provision of samples. SY: methodology, data analyses. All authors read and approved the final manuscript.

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Availability of data and materials

The data and materials are available from the corresponding author on reasonable request.

Declarations

Competing interests

All authors declare that there are no competing interests.

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