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Technical features of a ninth-century silver vessel of southern China uncovered from Famen Monastery, Shaanxi province

Panpan Tan[1], Junchang Yang[2*] and Xinlai Ren[3]

Abstract

Silver art is an important feature of the Tang dynasty in China and the manufacturing center for silver shifted from north to south after the mid-eighth century CE. The typology, stylistics, and iconography of silver vessels from both regions have been studied in detail. However, their technical characteristics have rarely been discussed, in particular, those of the southern ones. The current study presents a non-invasive scientific analysis on a partially-gilded silver box from *Jiangnanxidao* of Tang (southern China), uncovered from the pagoda crypt of the Famen Monastery, Shaanxi province. The results reveal that the box was made of refined silver from cupellation, and composed of five pieces, brazed together with hard solder. Ag–Cu alloy was identified to braze the ring foot and the box bottom. Brazing, hammering, engraving, repoussé, chasing, punching, and partial fire-gilding were employed to shape and decorate the box. More strikingly, the comparative analysis of technical details between this southern box and the previously reported northern silver vessels demonstrates that the former is more precise. Moreover, the similarities in motif expressions of southern-origin silver vessels after the mid-eighth century CE and northern-origin silver vessels before the mid-eighth century CE reflect the inheritance of decorative style. These differences and inheritance indicate that southern artisans after the mid-eighth century CE inherited the decorative technology of the northern-origin silver vessels before the mid-eighth century CE and developed them to greater perfection. The current study presents novel insights into the silver technology of southern China during the late Tang dynasty.

Keywords: Silver vessel, Repoussé, Chasing, Partial fire-gilding, Brazing, Famen Monastery

Introduction

Tang dynasty (618–907 CE) is considered as the "Golden Age" among different dynasties in China, since the period saw great achievements and peak level in precious artworks including silver-based creation [1–3]. The gold and silver vessels of this period are the epitome of multiple cultural and technical influences, such as of Central Asia, West Asia, and the Mediterranean [4–8]. Interestingly, the gold and silver vessels possess similar forms and decorations, which require diverse technical skills, such as casting, hammering, repoussé, chasing, engraving, fire-gilding, filigree, granulation, openwork, rivet, soldering, and inlay [6]. Based on the typology, stylistics, and iconography studies, silver vessels of the Tang period are divided into various stages [3, 6]. Among them, the mid-eighth century CE was an important point-in-time, when the An Lushan rebellion (755–763 CE) occurred [6, 9, 10]. This revolt declined the country's economy, resulting in the shifting of the economic center of the country from the north to the south. Consequently, silver vessels before and after the mid-eighth century CE show distinct characteristics. Before the mid-eighth century CE, silver vessels, including their form and decorative style, were strongly affected by the exotic culture and they

*Correspondence: yangjunchang@nwpu.edu.cn
[2] Institute of Culture and Heritage, Northwestern Polytechnical University, 127 Youyi Road, Xi'an 710072, China
Full list of author information is available at the end of the article

were popular among the nobles [6]. After that period, silver vessels were localized and more widely used among common people [6]. Moreover, these differences in form and decorative style are also prominent in silver vessels uncovered from different regions, i.e., the north and south of China. Ran [11, 12] believed that northern silver vessels experienced a period of foreign influence and finally they were localized; however, their further development was interrupted by the An Lushan rebellion. Nonetheless, the manufacturing industry of southern silver began to rise and prosper after the mid-eighth century CE, when the silver vessels were more decorative than their northern counterparts.

However, technical features of silver vessels from northern and southern regions have rarely been comprehensively discussed. Only a few reports focused on some of the northern-style silver vessels, recovered from Shaanxi, Henan, and Gansu [13–15]. Ma et al. [13] have carried out the metallographic analysis of silver pieces from a gilded silver cup, uncovered from a Tubo tomb (mid-eighth century CE) in the Dachangling cemetery of Gansu province. Though they confirmed the utilization of fire-gilding decoration, the decorative techniques have not been discussed in detail. Tan et al. [14] carried out the non-destructive analysis of three silver vessels, discovered from the Wei family cemetery (early eighth century CE) in Xi′an city, Shaanxi province. They have focused on the investigation of decorative methods. Furthermore, the tool marks of seven punches were recognized. Yao et al. [15] analyzed a gilded silver box, uncovered from the Xiaolizhuang site (mid-eighth century CE) in Henan province, by non-destructive methods to perform a detailed investigation on box decorations. They have identified decorative techniques and clarified the manufacturing procedures. These studies provide a preliminary understanding of manufacturing techniques of silver vessels from northern regions during and before the mid-eighth century CE. Nevertheless, the comprehensive understanding of metalwork during the Tang dynasty requires further systematic explorations, in particular, about the technical details of silver vessels after the mid-eighth century CE in southern China.

The current study presents a technical analysis of a southern silver box (ninth century CE) uncovered from the Tang pagoda crypt of Famen Monastery in Shaanxi province, China. Based on the non-destructive analysis, such as structural, compositional, and decoration technical analyses, the results revealed manufacturing techniques and decorative details of repoussé, chasing, punching, and partial fire-gilding. This study can enhance our understanding of silverwork techniques during the Tang dynasty.

Material and methods

Material

Famen Monastery, located in Famen town of Fufeng county, Baoji city, west of Xi′an, Shaanxi province, China (Fig. 1a), has attracted extensive research interest due to the discovery of four miraculous Buddhist finger bone relics and a large number of delicate tributes for the true body relic [16, 17]. These diverse tributes were uncovered from the underground palace of the Tang pagoda in the 1980s (Fig. 1b), where 336 items in total were unearthed, including 118 gold and silver artifacts, 35 textiles, 20 glassware, 16 porcelains, 70 bronzes and irons, 26 wooden lacquered objects, 11 stoneware, and 40 gems [16]. According to the stone *Yiwuzhang* (inventory stele), these treasures were placed in the pagoda crypt in 874 CE and most of them were donated by Emperor Yizong (833–873 CE) and Xizong (862–888 CE) of Tang, while some were offered by senior monks and eunuchs [18]. Moreover, the inscriptions on the gold and silver vessels suggest a variety of provenances, e.g., the products from the imperial workshop were labeled as "*Wensiyuan*", established in 854 CE in Chang′an (modern Xi′an), and the tributary gifts from regional officials were marked with the officials' names and their jurisdiction areas [18, 19].

A delicate silver box, found in the southeast corner of the rear chamber (Fig. 1c), was analyzed in this study. This box is in a floral shape and possesses straight walls, a plain bottom, and a splayed high ring foot (Fig. 2a, b). The lid cover is decorated in high relief on the front with two lions leaping and chasing each other in the center. The lions are surrounded with scrolling passionflowers also in high relief. These motifs are reserved on a ring-matted background and enclosed by a rhombus frame of raised pearl roundel. Outside the rhombus frame, the four corners of the lid cover are filled with four pairs of raised passionflowers, also on a ring-matted background; the rim of the lid cover is decorated with raised lotus petals (Fig. 2a, c). The box walls are decorated with scrolling lotus on a ring-matted background, and the rim of the ring foot is decorated with lotus leaves (Fig. 2b). Except for the matted ground, the relief motifs on the lid cover, main motifs on the box walls, and lotus leaves on the ring foot all were gilded (Fig. 2a).

More importantly, source information was found on the box. The Chinese-inked *Neiku* on the front of the lid cover (Fig. 2c) indicates that the box was collected in the royal storeroom [18]. The inscription was found on the outer surface of the bottom, i.e., a gilded box with length of 6 *Cun* and weight of 20 *Liang* was presented by the official Li of *Jiangnanxidao*, to the Emperor of the Tang Empire for celebrating the Yanqing festival (Fig. 2d). *Jiangnanxidao* represents the

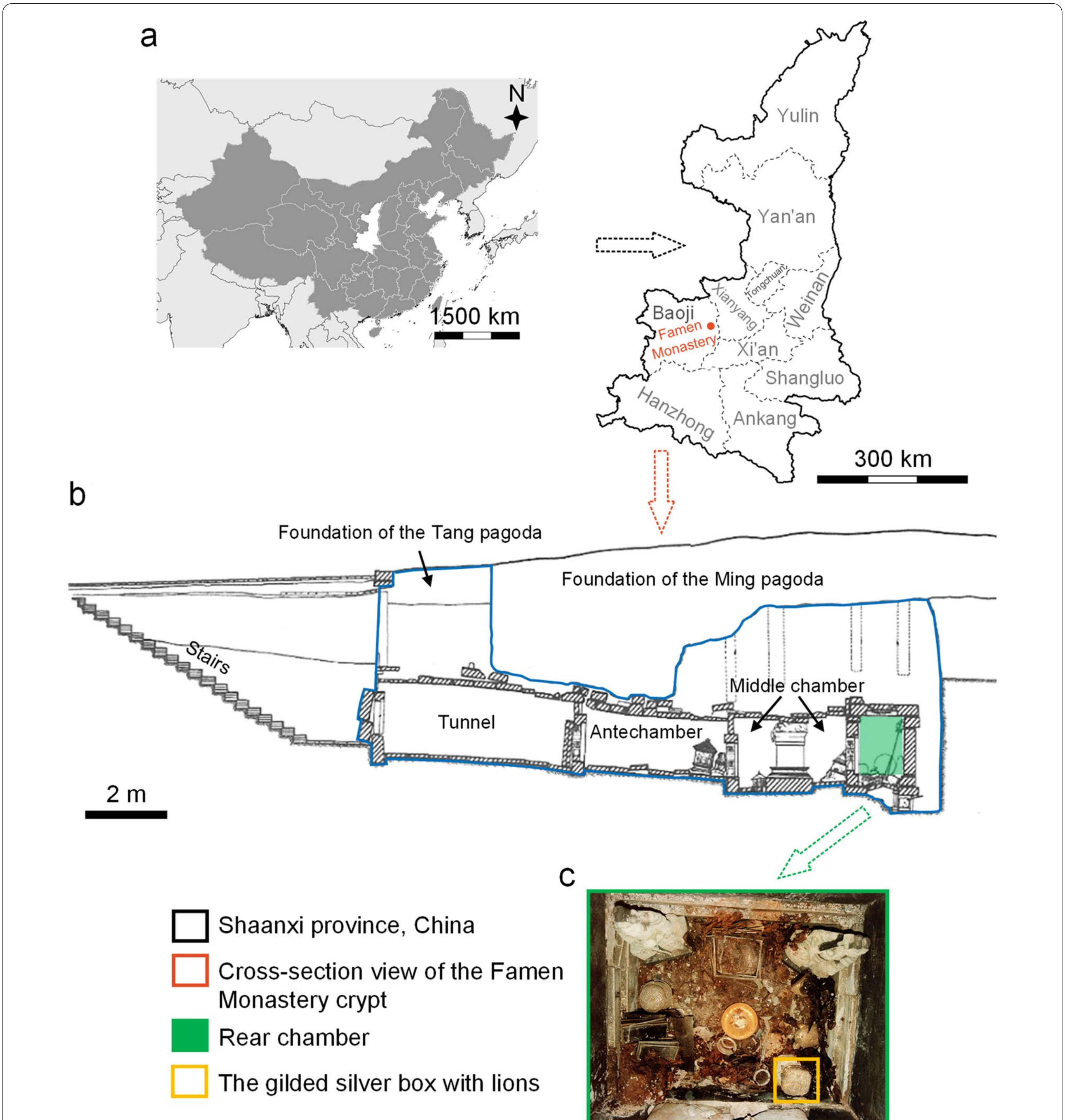

Fig. 1 **a** Geographical map of Famen Monastery; **b** cross-sectional view of stupa foundation and underground palace [16]; and **c** the location of the partially gilded silver box [20]

regions around the modern Nanchang city of Jiangxi province. Yanqing festival was established in 859 CE for celebrating the birthday of Emperor Yizong [21]. In summary, this box was first made in southern China, then it was presented to Emperor Yizong and stored in *Neiku*, and finally, it was taken to Famen Monastery in 874 CE. Therefore, this silver box was probably produced during the second half of the ninth century CE. The length, width, height, and mass of the box are 17.3 cm, 16.8 cm, 11.2 cm, and 799 g, respectively [16].

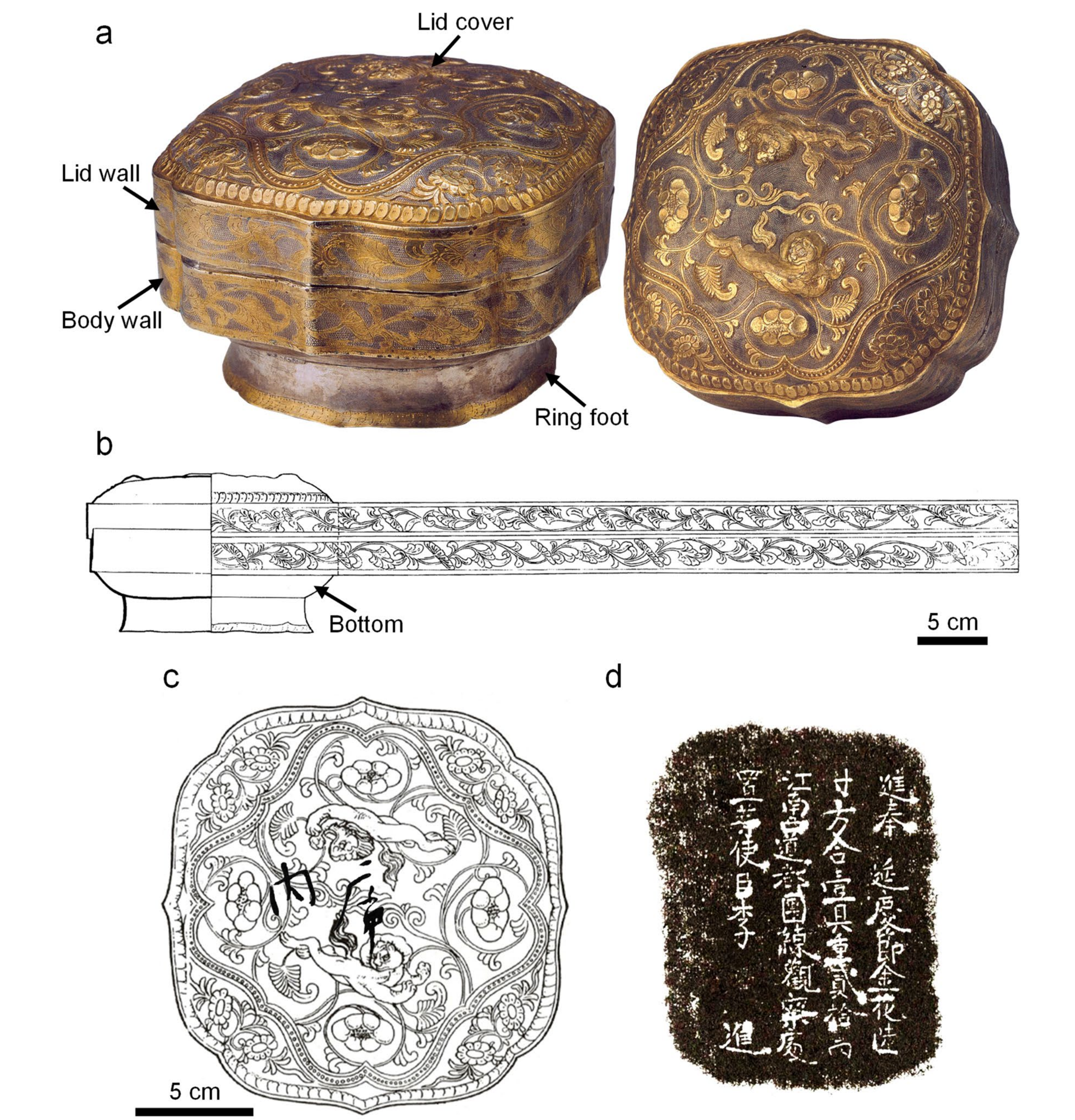

Fig. 2 **a** Digital photographs of the silver box (left) and motif on the lid cover (right) [20]; **b** line drawing of the side view and motif on the box walls [16]; **c** line drawing of the motif and Chinese-inked *Neiku* on the lid cover [16]; and **d** the inscription on the outer surface of the bottom [16]

Methods

The studied silver box is stored in the Famen Temple Museum. It was not allowed to take the box out of the museum for conventional laboratory analysis. Only portable analytical instruments with permission, such as the microscope and X-ray fluorescence (XRF) spectrometer, were permitted into the museum to conduct the non-destructive analysis.

Microscopic analysis

The structure, morphology, and tool marks of the box were investigated using a three-dimensional digital microscope (KEYENCE VHX-600, Japan) and recorded with high-resolution (1600 × 1200 pixels) images. An objective lens of VH-Z20R was used in this study, which has a magnification of 20–200 X and a depth of field ranging from 34 to 0.44 mm. The microscope consists of a 100 W halogen lamp cold light source. Therefore, the color of the image obtained using the microscope gets influenced by the yellow light. In order to obtain the original color of the gilded silver box, the white balance of the micrographs was corrected by using the Adobe Photoshop 13.0 software.

Compositional analysis

Different components of the box were analyzed using a handheld portable XRF spectrometer (p-XRF, Thermo Niton XL3t800, USA) equipped with a 2 W, 50 kV silver anode X-ray tube and high-performance silicon drift detector. The mode for alloy is divided into three modes due to certain elements. Precious Metals mode (effective testing diameter: 8 mm) is for the analysis of precious metal, including elements Ag, Au, Cu, Zn, Fe, Pb, Ir, Ti, Cr, Mn, Co, Ni, Ga, Nb, Mo, Ru, Rh, Pd, Cd, In, Sn, and Pt, where the platinum family element is included. Standard Alloy mode (effective testing diameter: 3 mm) is for the analysis of the unknown metal, including elements Ag, Au, Cu, Zn, Fe, Pb, Al, Ti, V, Cr, Mn, Co, Ni, As, Se, Zr, Nb, Mo, Ru, Pd, Cd, Sn, Sb, Hf, Ta, W, Re, and Bi, where more metallic elements are included. Electronics Alloy mode (effective testing diameter: 3 mm) is for the analysis of the metal coating, including elements Ag, Au, Cu, Zn, Fe, Pb, Hg, Al, Ti, V, Cr, Mn, Co, Ni, Se, Br, Zr, Nb, Mo, Pd, Cd, In, Sn, Sb, Ba, Hf, Ta, W, Pt, and Bi, where Hg could be measured. These different modes have little effect on the content of main elements.

In the current study, Precious Metals mode was used to analyze the base of the box, Standard Alloy mode was employed to analyze the joining area, and Electronics Alloy mode was utilized to explore the gilt layer. Moreover, the measuring head touched the tested surface during the analysis. Notably, 3–5 measurements were conducted on every component of the box and the valid data were incorporated into the final reported result. The measurement time for each spot analysis was 30 s and the elemental results detected were normalized.

Results

Structure and composition

The microscopic investigations of the gilded silver box reveal that the box was composed of five parts, including the lid cover, lid wall, body wall, bottom of the box, and the ring foot (Fig. 2a, b). The p-XRF spectroscopy results demonstrate that these components were made of refined silver (Table 1).

Presence of solder was observed at the joint between the lid cover and lid wall, joint between the body wall and box bottom, joint between the box bottom and ring foot, joint of lid wall, joint of the body wall, and joint of ring foot (Fig. 3a, b; Additional file 1: Fig. S1). These solder are in silver color (Fig. 3a) and some are with green corrosion (Additional file 1: Fig. S1), indicating that metal alloy solder with copper was used to bond these components. Moreover, two pieces of metal in silver color were found at the joining area between the box bottom and ring foot (Fig. 3b), indicating that alloy solder in the form of platelets was used by the Tang's artisan to braze different

Table 1 p-XRF spectroscopy results of the partially-gilded silver box

Analysis zone		Analysis mode	Composition (wt. %)							
			Ag	Au	Cu	Hg	Fe	Pb	Ir	Zn
Back of box lid (no gilding)	Micro-area	Precious alloy	97.5	1.1	0.8			0.6		
Bottom of box body (no gilding)	Micro-area	Precious alloy	99.4		0.2		0.3		0.1	
	Micro-area	Precious alloy	99.5		0.2		0.1		0.2	
	Micro-area	Precious alloy	98.8		0.4		0.6		0.2	
Ring foot	Micro-area	Precious alloy	97.0	1.3	0.8		0.4		0.5	
	Micro-area	Precious alloy	97.0	1.3	0.8		0.4		0.5	
Joining area (box body + ring foot)	Micro-area	Standard alloy	68.7	0.2	28.4			0.1		2.5
Gilt layer (box lid)	Micro-area	Electronic alloy	57.1	36.7		6.2				
	Micro-area	Electronic alloy	61.8	32.0		6.2				
	Micro-area	Electronic alloy	59.6	33.5		6.9				
	Micro-area	Electronic alloy	62.6	31.6		5.8				
Gilt layer (box body)	Micro-area	Electronic alloy	61.6	31.9		6.2	0.3			
	Micro-area	Electronic alloy	60.4	32.7		6.9				

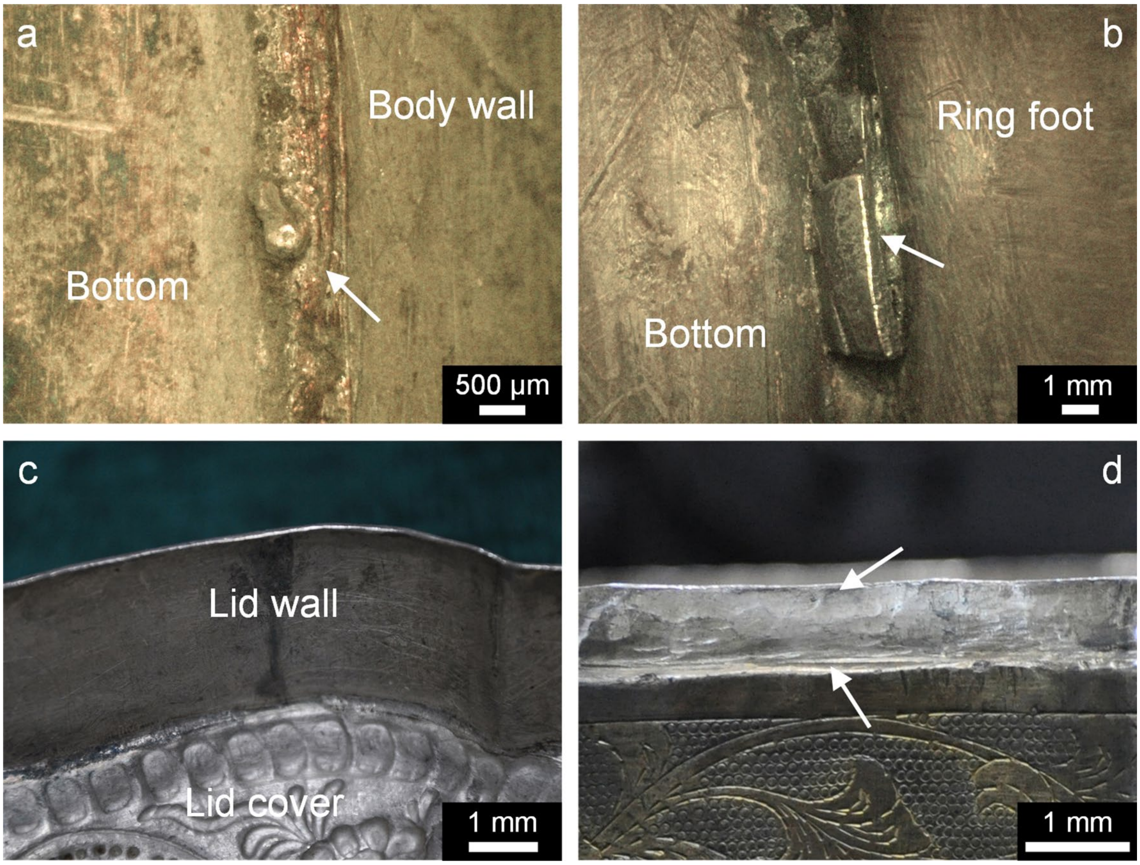

Fig. 3 Typical micrographs of the silver box: **a** the joint between the box bottom and body wall; **b** soldering metals at the joint between the box bottom and ring foot; **c** even inner surface of the lid wall; and **d** engraved edge of the outer surface of the body wall

parts of the box. Herein, we made an attempt to measure the chemical composition of the solders; however, they (including the solder platelets) were in such narrow positions that it was very difficult to detect their composition. Fortunately, a set of valid data was obtained for the joint between the bottom and the ring foot. The result shows that the solder mainly consisted of silver (Ag), copper (Cu), and zinc (Zn) (Table 1), indicating that silver-based alloy (hard solder) was used to solder the different part of the box.

Furthermore, the box lid and body were mechanically locked together. The lid wall shows an even inner surface (Fig. 3c), whereas the outer rim of the box body is relatively uneven, which was made by engraving to remove silver and then hammering to even the engraved areas, for locking with the box lid (Fig. 3d).

Decorative techniques

Dominant motifs

Clearly, the following two types of dominant designs are present on the box: one is relief motifs on the lid cover; and the other is plane motifs on the box walls and the rim of the ring foot (Fig. 2a, b).

Figure 4 shows typical micrographs of the lid cover. The punch-made small marks are observed on the back of the reliefs (Fig. 4a–c), indicating that the repoussé technique was used to make these relief motifs on the back [22–25]. Besides, the closer observation of the front of the reliefs reveals that they were further enhanced with chased outlines which are composed of overlapping isosceles triangles (Fig. 4d, e). These lines were produced by rapidly hammering a liner punch (with a line end) which quickly moved along the silver at an angle, without the loss of silver [23, 25–27]. This process started from the blunt of the line and finished at its sharp end. On the surface of relief motifs, details were created using various types of punches, e.g., a liner punch with a sharp end was utilized to detail the leaf (Fig. 4a, d), a liner punch with a blunt end was employed to execute the details of lion face (Fig. 4f), and a ring punch (with a ring end) was used to make the lion's eyes (Fig. 4f).

Similar to the relief motifs, the plane motifs and inscription were also created by the chasing technique

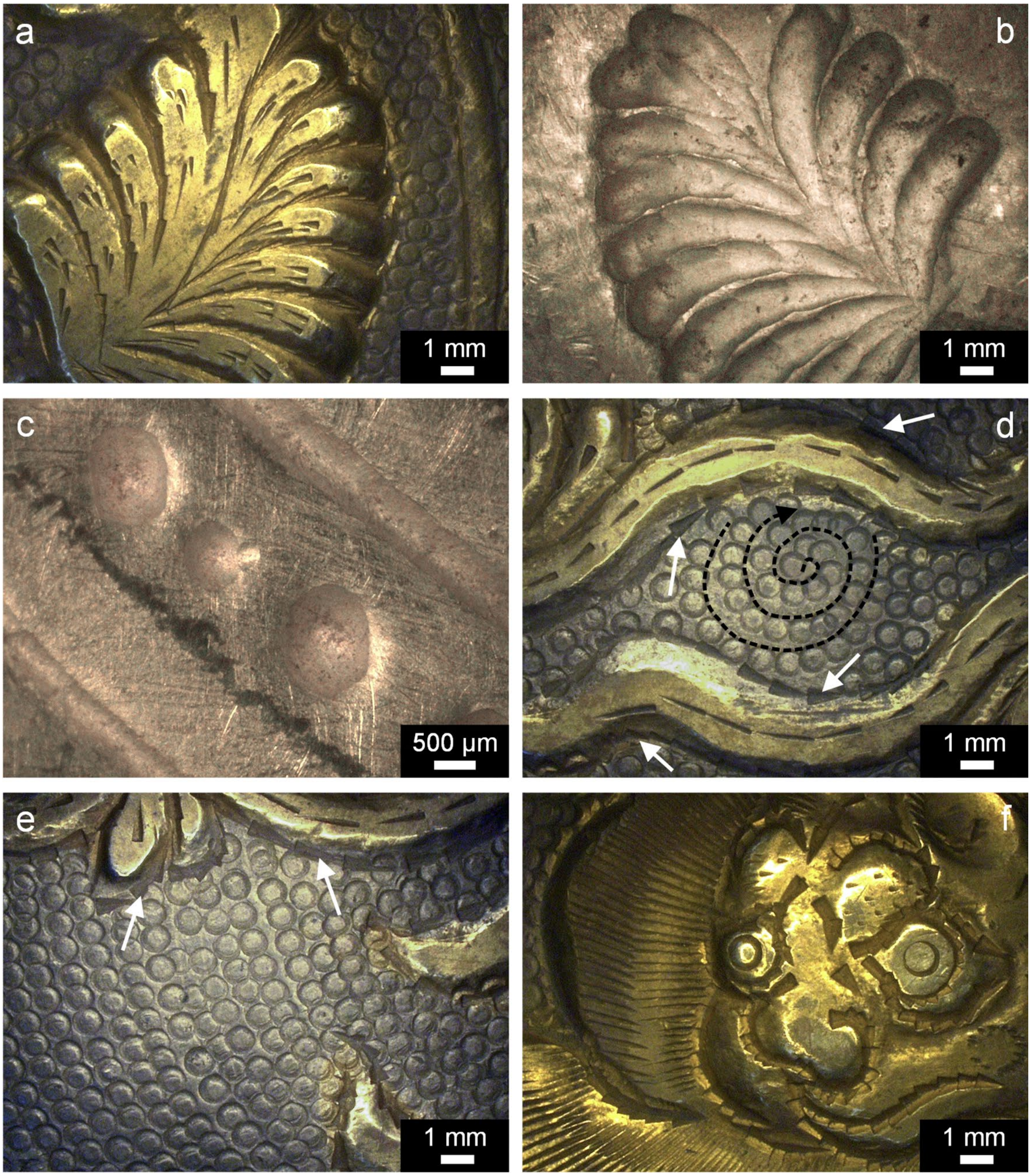

Fig. 4 Typical micrographs of motifs on the lid cover: **a** front of the passionflower leaf; **b** back of the passionflower leaf; **c** back of the pearl roundel; **d** matted background in the central part of box lid; **e** matted background next to the center of box lid; and **f** front of the lion's head

(Fig. 5a, b). Interestingly, traced marks are found beside the strokes of the inscription (Fig. 5c, d), indicating that the characters were positioned before chasing.

Ring-matted background

In addition to the major motifs, countless rings are present in the background. They were produced by the punching technique, i.e., rapidly hammering a ring punch which quickly moved along the silver plate to imprint the ring [27]. On the lid cover, these small rings are spirally arranged from the center to the rim (Fig. 4d, e). On the box walls, the rings are arranged parallel to the rims of the lid wall and body wall (Fig. 5a, b). For the more comprehensive understanding of the ring-matted background, the diameters of 186 rings on the lid were measured, and the results revealed that these rings are very

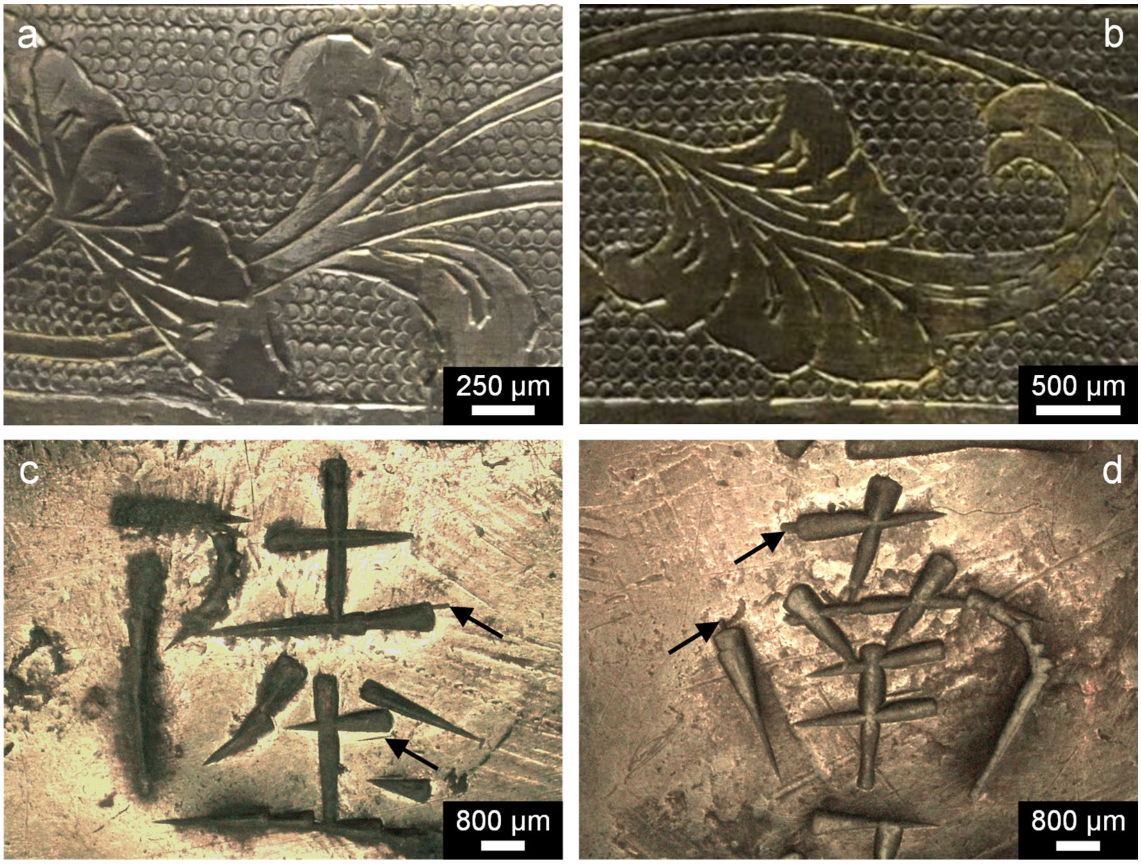

Fig. 5 **a** Motif on the lid wall; **b** motif on the body wall; **c** the chased character *Liu* on the box bottom; and **d** the chased character *Nan* on the box bottom

similar in size, i.e., 0.87 ± 0.05 mm (Additional file 1: Fig. S2).

Gilding

Apart from the production of motifs, partial gilding was employed on the dominant motifs to distinguish them from the background. The result of elemental analysis shows that mercury (Hg) and gold (Au) are present in the gilt areas (Table 1), indicating that the fire-gilding technique was used to achieve the golden appearance [28–30].

Besides, the precedence of chasing, punching, and gilding was clarified using the microscope. On the gilded motifs, the chased lines possess smooth rims and clean surfaces (Fig. 4a, d), indicating that these details were created after the application of gilding. On the other hand, few rings next to motifs are covered by the gilding (Fig. 4a, d, and e), suggesting that the rings were punched before the gilding process.

Therefore, the major manufacturing procedure of the partially gilded silver box is summarized below. First, five silver components of the box were prepared. Second, the relief motifs were produced by the repoussé technique and the plane motifs were created by the chasing technique. Third, the matted background was punched with a ring punch. Fourth, fire-gilding was applied. Fifth, the outlines and details of motifs were chased. Finally, the as-prepared parts were soldered together with a silver-based hard solder.

Discussion

Compositional analysis

Rich mineral resources and lenient policies facilitated the mining and smelting of silver during the Tang dynasty. The record shows that the government allowed private silver mining and more than 58 silver mines were operating under the tax revenue system [6]. Moreover, large amounts of silver were shipped from different parts of the country to the central government and the imperial family [6]. The analysis of a silver slag found in the Hejiacun treasure reveals that the percentage of Ag was extremely low, which indicates that the silversmiths were able to smelt high-quality silver during the Tang dynasty [31]. The statistics show that most of the silver items of the Tang period possess a high percentage of Ag (> 80 wt. %) (Additional file 1: Table S1). Herein, the composition of the studied silver box and silver fragments from the pagoda crypt fall within most of the data measured in other silver vessels from the places outside the Famen Monastery (Additional file 1: Fig. S3 and Table S1).

In addition to the dominant element Ag, a trace amount of Pb was also detected in the box lid (0.6 wt. %) and in the silver-based solder (0.1 wt. %), respectively (Table 1). Historically, argentiferous lead ore was the most important silver ore [32–35], which was an important source in Tang China [31]. Cupellation was used to refine silver, utilizing the feature that lead has high affinity to silver and is also relatively easy to be separated from silver [31, 36]. During the process, the argentiferous lead was oxidized and most lead was turned into lead oxide (litharge) along with other impurities (e.g., zinc oxide, lead sulfide, zinc sulfide), leaving behind the silver [32, 37–39]. Lead used in this process could either be from the argentiferous lead ore or be added in as part of the furnace charge [40]. Finally, trace amounts of lead were sometimes inevitably left in the silver. More than 80 wt. % of Pb detected in the silver slag of the Hejiacun treasure indicated the employment of the cupellation technique [31]. Moreover, we have summarized all the analytical results of the Tang silver objects which were published in other papers. The result shows that 28.2% of the Tang silver objects contain Pb varying from 0.01 wt. % to 1.16 wt. % (Additional file 1: Table S1). These minute quantities of lead were probably derived from the refining process of silver by the cupellation technique.

Apart from the base composition of the box, Ag, Cu and Zn were identified in the joint between the box bottom and ring foot. However, there has been no ancient written record and scientific data on the solder used for the silver objects during and before the Tang dynasty. Only two fluxes for promoting soldering silver were mentioned, i.e., *Hutonglei* (a glue gum from Populus diversifolia) and *Lusha* (NH_4Cl) [41, 42]. The historical record and analytical data of silver objects after the Tang dynasty provide clues for the soldering of silver items. At the joining area of a silver artifact of the Liao dynasty (916–1125 CE), Ag–Cu alloy was detected as a solder [43]. Ag–Cu–Zn alloy was recorded as a solder for copper objects in the literature of Qing dynasty (1636–1912 CE) [44, 45]. Moreover, Ag–Cu–Zn alloy is used to bond silver objects in modern metallurgy [46].

The content of Zn in the joint of the currently studied silver box was found to be 2.5 wt. %. According to the Ag–Cu–Zn ternary diagram, the given alloy has a melting point of ~ 755 ℃ [47]. If the influence of Zn is ignored, the Ag–Cu alloy has a melting point of ~ 785 ℃ [47]. The small temperature difference of 30 ℃ was not worth the artificial alloying of zinc with Ag–Cu alloy by the Tang silversmiths. Moreover, it is known that the Chinese traditional zinc-smelting technology originated during the Ming dynasty (1368–1644 CE) [48]. Therefore, the element Zn here should not be from the metallic zinc, but was from the impurities associated with silver and copper. Herein, most zinc should correspond to the impurity associated with the copper ore, due that the silver refining process could oxidize/sulfurize the most zinc impurity. Therefore, it is expected that the Ag–Cu alloy should have been employed by the ancient artisan to braze silver box and ring foot.

Decorative techniques

Remarkably, the repoussé, chasing, punching, and fire-gilding were employed to create and decorate the motifs of the box. These techniques were commonly used on the Tang's silver vessels. The published technical analyses of silver vessels from the Wei family cemetery and Xiaolizhuang site in northern China also demonstrate the use of these techniques. In the Wei family cemetery, analysis of a silver cup indicates the utilization of chasing and punching, analysis of a small round silver box indicates the use of chasing, punching, and partial fire-gilding, and analysis of a three-legged silver pot indicates the employment of repoussé, chasing, punching, and partial fire-gilding [14]. Moreover, a silver box from the Xiaolizhuang site used repoussé, chasing, punching, and all-over fire-gilding [15].

Specifically, the ring-matted background was present on the all the aforementioned silver vessels. Figure 6

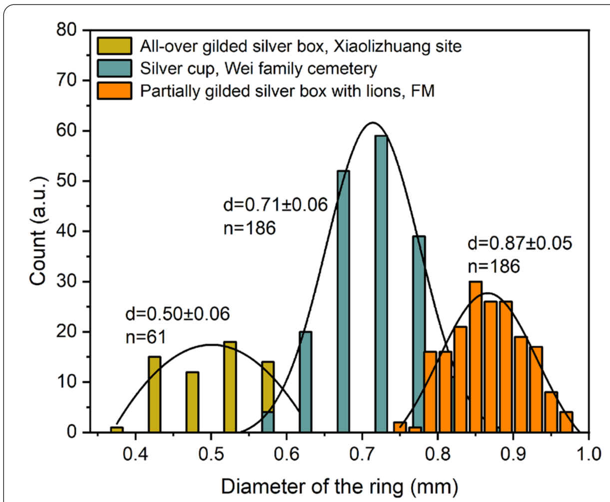

Fig. 6 The ring diameter distributions of the ring-matted backgrounds on the all-over gilded silver box from the Xiaolizhuang site, the silver cup from the Wei family cemetery, and the partially-gilded silver box from the Famen Monastery

shows the diameter distribution of the rings. The statistical analysis reveals that the ring diameter on three vessels exhibits only a small standard deviation, which indicates that the skilled silversmith of the Tang dynasty was able to accurately control the ring size during the rapid punching process. More strikingly, the ring diameter was closely related to the size of the vessel. To be specific, the gilded silver box of the Xiaolizhuang site exhibits the smallest dimensions and is decorated with a ring-matted background with the smallest ring diameter [15], whereas the silver cup from the Wei family cemetery has medium dimensions and is decorated with a matted background with a medium ring diameter [14] (Fig. 6 and Additional file 1: Figs. S6 and S7). The partially gilded silver box of this study has the maximum dimensions and is decorated with a ring-matted background with the maximum ring diameter (Figs. 4d, e, 6). These results indicate that the silversmiths during the Tang dynasty were experienced in selecting the different sizes of punch end according to the dimensions of the artifacts.

Though the silver vessels from northern and southern regions were prepared by the same techniques and using the same decorative elements, the comparative analysis of their technical details suggests that the southern-origin silver box from the pagoda crypt of Famen Monastery employed more sophisticated technology. The matted backgrounds of the silver box and pot (Wei family cemetery) and the silver box (Xiaolizhuang site) are quite rough with overlapping rings (Additional file 1: Figs. S4b, S5b and S7b). Moreover, the rings on the small round box (Wei family cemetery) overlapped so severely that is difficult to recognize the single ring (Additional file 1: Figs. S4b and c) [14, 15]. Besides, the silver cup of Wei family cemetery (Additional file 1: Fig. S6b) and the currently studied silver box (Fig. 4d, e) possess distinct ring-matted backgrounds, however, the latter contains a more regular ring arrangement [14]. In addition to the matted background, the details of the chased motifs also reflect different technical skills. In the case of silver vessels from the Wei family cemetery, the chased lines on the silver cup are deep, discontinuous, and unsmooth (Additional file 1: Fig. S6c and d); the chasing marks on the three-legged pot are blurred (Additional file 1: Figs. S5c and d); some chased lines on the rim of the small round box are indistinct and unfinished (Additional file 1: Fig. S4d) [14]. With respect to the silver box of the Xiaolizhuang site, the chasing marks are shallower and some are even out of shape (Additional file 1: Figs. S7c and d) [15]. Concerning the currently studied silver box, the chased lines are smooth, and triangular chasing marks are clear (Fig. 4a, d, and f).

In terms of decorative techniques, in summary, artisans of the Tang dynasty were skilled at processing of silver vessels, while the artisans in the southern region after the mid-eighth century were more experienced.

Perspective on the manufacturing of southern-origin silver box of the Famen Monastery

Noteworthy, this gilded silver box with lions was donated by Emperor Yizong as a tribute to the true body relic. On one hand, this box must be one of the most precious gifts of Yizong. On the other hand, it must represent the most sophisticated silver technology of that period, which partly indicates the prosperity of the southern luxury industry in the late Tang dynasty. The major reason for the prosperity of southern silver technology derives from the shift of the country's economic center after the mid-eighth century CE.

Obviously, the shift of economic center resulted in the migration of official artisans from the capital in the north toward the economically thriving south [6]. Moreover, they also brought high metalworking skills to the southern regions. The rich mineral deposits in the south and more flexible mining policies provided abundant raw materials for the ample production of gold and silver vessels. The statistics showed that southern mining accounted for 92% of the country's gold production, and accounted for 94% of silver production [49]. Furthermore, the relatively unrestricted trading time and area promoted the further development of the economy in the south further [6]. Under this circumstance, the migrating artisans were able to show their talents to meet the market demands, and not just to cater to for the nobilities' tastes, which blossomed southern luxury industry and commerce, such as the gold and silver of Belitung Shipwreck [49]. The written record shows that five regions in the south, including *Jiangnanxidao*, frequently presented gold and silver artifacts to the imperial court [50]. This reflects that southern silver vessels after the mid-eighth century CE were probably even more loved by the imperial family, compared to the coetaneous northern silver vessels. Moreover, the currently studied silver box was produced in the late-ninth century CE, thus it is expected that the silverwork techniques of southern China must have been well developed for almost 100 years.

Besides, noteworthy, *Wensiyuan* was established in the mid-ninth century and as the imperial workshop. Silver artifacts produced there catered to the imperial family's tastes and represented the aesthetics of society during that period. Among the silver artifacts uncovered from the pagoda crypt of Famen monastery, eight were the products of *Wensiyuan* [16]. All these northern-origin silver artifacts have a different decorative feature from the gilded silver box studied herein. Specifically, they have no decoration or process gilded motifs standing out on a smooth background [20]. Interestingly, most of the southern-origin silver artifacts recovered from the pagoda crypt of Famen monastery are endowed with complex decorations, including abundant motifs decoration and the use of ring-matted background. This type of decoration could be widely found on gold and silver vessels of southern-origin after the mid-eighth century CE, such as the Dingmaoqiao treasure [6] and Belitung Shipwreck treasure [49]. More strikingly, this type of complex decoration also appears on the gold and silver artifacts of the early Tang period, such as the Hejiacun treasure [51]. Thus, it could be inferred that these delicate southern-origin silver vessels likely took over the decorative style of northern silver vessels before the mid-eighth century CE.

Consequently, these changes of decorations and differences in technical details indicate that southern artisans after the mid-eighth century CE inherited the decorative technology of the northern-origin silver vessels before the mid-eighth century CE and developed them to greater perfection.

Conclusions

The detailed technical analysis of southern-origin partially-gilded silver box from the Famen Monastery enhanced our understanding of the silverwork during the Tang dynasty after the mid-eighth century CE. The box consisted of five refined silver pieces, which were smelted by a commonly used silver refining technique during the Tang dynasty, i.e., cupellation. Furthermore, the results revealed that brazing, hammering, engraving, repoussé, chasing, punching, and partial fire-gilding were used to shape and decorate the box. Noteworthy, most of the aforementioned techniques were widely used during the Tang dynasty. Moreover, the Ag–Cu alloy was utilized to bond the box bottom and ring foot. Strikingly, the similar decorative features among the south-made silver box after the mid-eighth century CE and north-made silver vessels before the mid-eighth century CE demonstrate the inheritance of decorative styles. Moreover, different technical skills of both types of silver vessels exhibit the evolution of decorative techniques, which resulted in attaining high perfection by the southern silversmiths after the downfall of northern China. The current study motivates further research on the comparative analysis of northern and southern silver vessels during the Tang dynasty.

Abbreviations

p-XRF: Portable X-ray fluorescence; Ag: Silver; Cu: Copper; Pb: Lead; Zn: Zinc; Hg: Mercury; Au: Gold; FM: Famen Monastery.

Supplementary Information

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Additional file 1. Additional Figures S1–S7 and Table S1.

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Authors' contributions

PT designed and performed the experiments, analyzed the experimental data, and wrote the manuscript. JY directed the study. XR provided the partially gilded silver box for analysis. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this article and its additional file.

Declaration

Competing interests

The authors declare that they have no competing interests.

Author details

[1] State Key Laboratory of Solidification Processing, Center for Nano Energy Materials, School of Materials Science and Engineering, Northwestern Polytechnical University, 127 Youyi Road, Xi'an 710072, China. [2] Institute of Culture and Heritage, Northwestern Polytechnical University, 127 Youyi Road, Xi'an 710072, China. [3] Famen Temple Museum, Famen County, Baota Road, Baoji 722201, China.

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