

Technical Features of A Ninth-Century Silver Vessel of Southern China Uncovered From Famen Monastery, Shaanxi Province

Panpan Tan

State Key Laboratory of Solidification Processing, Center for Nano Energy Materials, School of Materials Science and Engineering, Northwestern Polytechnical University <https://orcid.org/0000-0002-4956-6350>

Junchang Yang (✉ yangjunchang@nwpu.edu.cn)

State Key Laboratory of Solidification Processing, Center for Nano Energy Materials, School of Materials Science and Engineering, Northwestern Polytechnical University

Xinlai Ren

Famen Temple Museum

Research article

Keywords: Decorative techniques, Southern silver vessel, Repoussé, Partial fire-gilding, Tracing, Brazing, Famen Monastery, Tang dynasty

Posted Date: February 10th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-176618/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

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-8th century CE. The typology, stylistics and iconography of silver vessels from both regions have been studied in detail. Moreover, the analysis of northern-origin silver vessels has garnered significant attention in recent years. However, the technological characteristics of southern silver vessels are unknown. The current work presents a non-invasive scientific analysis on a partially-gilded silver box from *Jiangnanxidao* of Tang (China), which was uncovered from the pagoda crypt of the Famen Monastery in Fufeng County, Shaanxi province. The analytical results reveal that the box was made of high-quality silver, smelted by cupellation, and composed of five pieces, which were bonded together with some sort of a soldering alloy. The ring foot was brazed to the bottom of box with Ag–Cu alloy. Hammering, brazing, engraving, repoussé, tracing and partial fire-gilding were employed to shape and decorate the box. One should note that these techniques are commonly observed in Tang silver vessels. Besides, the production and decorative procedures were identified through the tool marks. More strikingly, the comparison of tracing details between the southern box, presented here, and the previously reported northern silver vessels demonstrates that the former is more precise in terms of decorative details. Moreover, the similarities in motif expressions of southern-origin silver vessels after the mid-8th century and northern-origin silver vessels before the mid-8th century reflect the inheritance of decorative style, whilst the differences in technical skills indicate the evolution of decorative techniques, which attained high perfection by the southern silversmiths after the downfall of northern China. The current study presents novel insights into the silver technology of southern China during the late Tang dynasty.

Introduction

Tang dynasty (618–907 CE) is considered as the “Golden Age” among different dynasties in China, during which gold- and silver-based artwork reached their peaks [1, 2]. The gold and silver vessels of this period indicate multiple cultural and technical influences, such as Central Asia, West Asia, and the Mediterranean [1, 3, 4]. Interestingly, the gold and silver vessels possess similar forms and decorations [5], which require diverse technical skills, such as casting, hammering, repoussé, tracing, engraving, fire-gilding, filigree, granulation, openwork, rivet, soldering and inlay [1]. After the mid-8th century CE, the political and economic situation became worse due to the An Lushan rebellion (755–763 CE), shifting the economic center from the northern to southern region, which also moved the manufacturing hub of gold and silver [1]. The silver vessels of the Tang dynasty have been classified based on typological, stylistic, and iconography features [1, 6, 7]. For instance, Qi [1] divided the development of silver-based artwork during the Tang dynasty into three periods, i.e., before the mid-8th century CE, till the end of 8th century CE, and the 9th century CE. He has argued that the forms and decorative styles of the first period silver vessels are strongly affected by the exotic culture and foreign influence, whereas the forms and decorative styles are more localized during the second period. The silver artifacts were also widely used among common people in southern China during the 9th century CE. Ran [6, 7] has agreed with Qi and

further discussed that the rise and prosperity of the southern silver manufacturing industry occurred after the mid-8th century CE, where silver vessels were more decorated than the northern counterparts. Also, the mirrored patterns were employed to decorate both sides of the vessel wall.

However, technical features of silver vessels from northern and southern regions have been rarely discussed. Only a few reports focused on some of the northern-style silver vessels, which are recovered from Shaanxi, Henan and Gansu [8–10]. Ma et al. [10] have carried out the metallographic analysis of silver pieces from a gilded silver cup, uncovered from a Tubo tomb (mid-8th century CE) in the Dachangling cemetery of Gansu province. Though they have confirmed the utilization of fire-gilding decoration, the decorative techniques have not been discussed in detail. Tan et al. [8] have carried out the non-destructive analysis of three silver vessels, which were discovered from the Wei family cemetery (early 8th century CE) in Xi'an city, Shaanxi province. They have focused on the investigation of decorative methods. Furthermore, the tool marks of seven chisels were recognized. Yao et al. [9] have analyzed a gilded silver box, which was uncovered from the Xiaolizhuang site (mid-8th century CE) in Henan province, with non-destructive methods to perform a detailed investigation of box decorations. They have identified decorative techniques and clarified the manufacturing procedures. These studies provide a preliminary understanding of manufacturing techniques of gilded silver vessels from northern regions during and before the mid-8th century CE. Nevertheless, the comprehensive understanding of metalwork during the Tang dynasty requires further work, especially about the technical details of silver vessels after the mid-8th century CE in southern China.

The current study presents a technical analysis of a southern silver box (9th 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 analysis, the results reveal manufacturing techniques and decorative details of repoussé, tracing and partial fire-gilding. This work shall enhance our understanding of silverwork techniques during the Tang dynasty.

Material And Methods

Famen Monastery, located in Famen Town of Fufeng County, Baoji city, western 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 [11]. 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 glasswares, 16 porcelains, 70 bronzes and irons, 26 wooden lacquered objects, 11 stoneware and 40 gems [11]. 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, whereas some were offered by senior monks and eunuchs [12]. In addition, the inscriptions on the gold and silver vessels provide more information about the respective provenances, e.g., the products from the imperial workshop were labeled as “*Wensiyuan*”, established in 854 CE in Chang'an (modern Xi'an), and tributary gifts from regional officials marked the officials' names and their jurisdiction areas [12–14].

A delicate silver box, found in the southeast corner of the rear chamber, was analyzed in this paper (Fig. 1c). The square-shaped box possesses straight walls, shallow belly, plain bottom and open ring foot, as shown in Fig. 2a and b. A buckle locks the box lid and body. The decorations are distributed on the outer surface of the lid, outer walls of the box, and rim of the ring foot. The designs of the outer surface of the box lid are relief motifs on a plain ring-matted background, which is divided into two regions by a circle of rhombus-shaped pearl roundel. The main motif distributes inside the rhombus, where two lions run among the passion flowers and creeping weeds.

On the other hand, four pairs of relief passion flowers were distributed at the four corners of the lid outside the rhombus, respectively (Fig. 2a and c). The motifs on box walls are plain lotus scrolls with a ring-matted background (Fig. 2b). Besides, a circle of raised lotus petal was designed at the rim of the lid surface and a circle of plain lotus leaves was employed to decorate the rim of the ring foot (Fig. 2b). It is worth noting that all the motifs were gilded except for the ring-matted background. More importantly, the Chinese-inked *Neiku*, i.e., the imperial personal storeroom [12], was written on the outer surface of the lid (Fig. 2c) and inscriptions about the size, weight and origin of the box were traced at the bottom, i.e., a gilded box lengthed 6 *Cun* and weighted 20 *Liang* was presented by the official Li, who was the minister of *Jiangnanxidao*, to the Emperor of the Tang Empire for celebrating the Yanqing festival (Fig. 2d). One should note that the *Jiangnanxidao* represents the regions around modern Nanchang city of Jiangxi province and the Yanqing festival celebrates the birthday of Emperor Yizong, established in 859 CE [16]. The length, width, height and mass of the box are 17.3 cm, 16.8 cm, 11.2 cm and 799 g, respectively [11].

Methods

Microscopic analysis

The structure, morphology and tool marks of the gilded silver box were investigated by a 3D digital microscope (KEYENCE VHX-600, Japan) with large scene depth. A multi-focus system with high-resolution (1600 × 1200 pixels) photographed the observations.

Compositional analysis

Different components of the gilded silver box were analyzed by a portable X-ray fluorescence (p-XRF, Thermo Niton XL3t800, USA). The silver body was tested with the precious alloy mode (effective testing diameter: 8 mm), the gilt layer was tested with the electronic alloy mode (effective testing diameter: 3 mm), and the joining areas were tested with the standard alloy mode (effective testing diameter: 3 mm).

Results

Structure and composition

The microscopic investigations of the gilded silver box reveal that the box was composed of five parts, including the cover of box lid, the wall of box lid, the wall of box body, the bottom of box body and the ring foot. The p-XRF results demonstrate that these components were made of refined silver from the

same batch (Table 1). Moreover, a small amount of lead (Pb) was tested in the box lid (Table 1), which indicates that the cupellation was probably used for silver smelting [17].

As shown in Fig. 3a and b, the cover of box lid was soldered to the wall, whereas the wall was made of a silver strip by soldering both ends together. Therefore, the solders with green-colored corrosion were observed at the joining areas. Similarly, the wall and bottom of box body and ring foot were all soldered together (Fig. 3c–e). In addition, two pieces of metal were observed at the joining area between the box bottom and ring foot (Fig. 3f), which probably belong to the solder. Regrettably, the composition of these metallic pieces was not measured because of their placement in a narrow gap. Fortunately, the solder composition was analyzed at another joining area between the box bottom and ring foot, showing that the solder consisted of copper (Cu), silver (Ag) and zinc (Zn) (Ag: 67.7 wt. %, Cu: 28.0 wt. %, and Zn: 2.5 wt. %). According to the Ag-Cu-Zn ternary diagram, the given alloy has a melting point of ≈ 755 °C [18], which is much lower than the melting point of Ag (961.8 °C). This is an extremely important result, which shall be discussed below.

Furthermore, the box lid and body were mechanically locked together. The box lid wall has an even inner surface (Fig. 3g), whereas the outer rim of box body is relatively uneven, which was probably made by engraving and hammering (Fig. 3h).

Decorative techniques

Dominant motifs

It is obvious that two types of dominant designs are present on the box, i.e., relief motifs on the outer surface of the lid and plane motifs on the walls of the box and rim of the ring foot. Figure 4a–f shows the typical micrographs of the motifs. Concerning the relief motifs, technical details were clearly observed from the back of the lid. The chisels-made small hammering marks are observed on the main motifs (Fig. 4a and b), pearl roundels and rhombic frame (Fig. 4c), which indicate that the repoussé technique was used to make these relief motifs on the backside of the lid. Moreover, the closer observation of the front of lid reveals the presence of lines along the rims of relief motifs, which are composed of individual overlapping isosceles triangular marks (Fig. 4d and e), suggesting that the tracing technique was employed to enhance the reliefs. These lines were produced by hammering the chisel with a straight and sharp end along the silver at an angle and quickly moving blow-by-blow, which started from the base of triangle and finished at the sharp end of the mark. On the relief motifs, details were created by chisels with different ends, e.g., the chisel with a straight, thin and sharp end was utilized to detail the leaf (Fig. 4a), the chisel with a straight, thick and sharp end was employed to execute the details of lion face, and chisel with a circular end was used to make the lion eyes (Fig. 4f).

Similar to the relief motifs, the plane motifs on the box walls (Fig. 3h), rim of ring foot, and inscriptions on the outer surface of box bottom were also created by tracing (Fig. 4g and h). Interestingly, thin chiseling marks are found beside the strokes, e.g., the thin lines at the triangular base and beside the stroke (Fig. 4g and h), suggesting that the characters were positioned before tracing.

Ring-matted background

In addition to the major motifs, countless rings were traced in the background. On the outer surface of box lid, these small rings are spirally arranged from the center of the box to the rim (Fig. 4d and e). On the box walls, the rings are arranged parallel to the rims of the box lid and body (Fig. 3h). To obtain a deeper understanding of the ring-matted background, the diameters of 186 rings on the lid were measured and the results revealed that these rings are similar in size, i.e., 0.87 ± 0.05 mm (Fig. 5). The accuracy and uniformity indicate that the numerous rings were traced by one chisel with an inner spherical end, possessing a similar angle and intensity.

Gilding

Apart from the traced motifs, partial gilding was employed on the dominant motifs to distinguish them from the ring-matted background. The elemental analysis shows that mercury (Hg) and gold (Au) are present in the gilt areas (Table 1), indicating that the fire-gilding was used to achieve the golden appearance.

Besides, the precedence of tracing and gilding was clarified using a microscope. On the gilded motifs, the traced marks possess smooth rims and clean surfaces (Fig. 4a and d), indicating that these details were traced after the application of gilding. On the other hand, few rings next to major motifs are covered by the gilding (Fig. 4a, d, and f), suggesting that the rings were traced before the gilding process.

Therefore, the major manufacturing procedure of the partially gilded silver box can be summarized as below. First, the silver pieces of the cover and wall of the box lid, bottom and wall of the box body and ring foot were prepared. Second, the relief motifs on the box lid were produced by the repoussé technique and the plane motifs on the box walls were prepared by tracing. Third, the ring-matted background was traced. Fourthly, dominant motifs and the rims of five silver pieces were fire-gilded. Finally, the details of relief motifs were traced and the as-prepared pieces were soldered together.

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

Analysis zone		Analysis mode	Composition (wt. %)									
			Ag	Au	Cu	Hg	Fe	Pb	Ir	Zn	Ba	Ta
Box lid	Micro-area	Precious alloy	97.1	1.1	0.8			0.6				
Box body	Micro-area	Precious alloy	99.3		0.2		0.3		0.1			
	Micro-area	Precious alloy	99.4		0.2		0.1		0.2			
	Micro-area	Precious alloy	98.7		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	67.7	0.2	28.0			0.1		2.5		
Gilt layer (box lid)	Micro-area	Electronic alloy	56.4	36.3		6.1					0.3	0.4
	Micro-area	Electronic alloy	60.7	31.4		6.1					0.3	0.5
	Micro-area	Electronic alloy	58.4	32.8		6.8					0.3	0.3
	Micro-area	Electronic alloy	61.7	31.1		5.7					0.3	0.3
Gilt layer (box body)	Micro-area	Electronic alloy	60.6	31.4		6.1	0.3				0.3	0.5
	Micro-area	Electronic alloy	59.6	32.2		6.8					0.4	0.3

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 [1]. Also, large amounts of silver were shipped from different parts of the country to the central government and the imperial family [1]. The analysis of a silver smelting relic found in Hejiacun treasure shows that the percentage of Ag was much low, which indicates that the silversmiths were able to smelt high-quality silver during the Tang dynasty [17]. Figure 6 shows that most of the silver items possess a high percentage of Ag (> 80 wt. %) [8–10, 19–28]. Herein, the composition of the studied silver box and other silver fragments from the pagoda crypt [20–22] are overlapped with most of the data from the places outside the Famen Monastery (Fig. 6). Besides, in addition to the currently studied silver box, the presence of Pb has been reported in the silver objects uncovered from the Shaanxi province, including the tomb of Prince Li Xian, the joint tomb of Yanzhi and his wife, the tomb of Princess Li Chui, the Tang tomb of Yuanzitou site, and tombs in southern suburbs of Xi'an, from Sichuan province, i.e., Zhengkejiaxiang site, and from Xinjiang Uygur Autonomous Region, i.e., gilded silver ornaments collected in Yili Museum [22, 26]. Hence, it can be inferred that the cupellation was commonly used in silver smelting during the Tang dynasty.

Apart from the base composition, Ag, Cu and Zn were identified in the joining area between the box body and ring foot. However, there has been no ancient written record and scientific data on the utilization of silver-based solder 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) [29, 30]. The historical record and analytical data of silver objects after the Tang dynasty indicate the employment of silver-based solders. At the joining area of a silver artifact of the Liao dynasty (916–1125 CE), Ag–Cu alloy was detected as a solder [14].

In addition to Ag–Cu alloy, the literature of Qing dynasty (1636–1912 CE) recorded that Ag–Cu–Zn alloy was employed as a solder for copper objects [32, 33]. In modern metallurgy, Ag–Cu–Zn alloy is used to bond silver objects [34]. In the case of currently studied silver box, the content of Zn in the joint was found to be 2.5 wt. %. One should note that the Ag–Cu–Zn alloy has a melting point of ≈ 755 °C. If the influence of Zn is ignored, the Ag–Cu alloy has a melting point of ≈ 785 °C [18]. The small temperature difference of 30 °C does not worth the artificially alloying of zinc with Ag–Cu alloy by the Tang silversmiths. Therefore, the Ag–Cu alloy should be employed by the ancient artisan to braze silver box and ring foot, and the occasional smelting of copper introduced the Zn impurities.

Decorative techniques

Remarkably, the repoussé, tracing 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 these techniques. In the Wei family cemetery, a silver cup indicates the utilization of tracing technique to create motifs, a small round silver box applied tracing and partial fire-gilding to create and highlight the motifs, and a three-legged silver pot employed repoussé to shape the pot and tracing and

partial fire-gilding to create and decorate the motifs [8]. Moreover, a silver box from the Xiaolizhuang site used repoussé to shape the box, and tracing and all-over fire-gilding to produce and decorate the motifs [9].

In addition, the ring-matted background was also present on the aforementioned silver vessels. Figure 7 shows the diameter distribution of the rings of the ring-matted backgrounds, which are decorated on the silver cup from the Wei family cemetery, the all-over gilded box of Xiaolizhuang site and the currently studied gilded silver box. The statistical analysis reveals that the ring diameter on three vessels exhibits 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 tracing process. More strikingly, the ring diameter was closely related to the size of the vessel. To be specific, the gilded silver box of Xiaolizhuang site has the smallest dimensions (3.3 cm in diameter and 1.55 cm in height). It was decorated with a ring-matted background with the smallest diameter of the ring (average diameter: 0.50 mm) [9], whereas the silver cup from the Wei family cemetery has medium dimensions (5.2 cm in diameter and 4.5 cm in height). It was decorated with a ring-matted background with a medium ring diameter (average diameter: 0.71 mm) [8]. Lastly, the partially gilded silver box has the maximum dimensions (17.3 cm in length, 16.8 cm in width and 11.2 cm in height), and it was decorated with a ring-matted background with the maximum ring diameter (average diameter: 0.87 mm) (Fig. 7). These results indicate that the silversmiths during the Tang dynasty were experienced in choosing the different sizes of chisel for tracing rings according to the dimensions of the artifacts.

Though the silver vessels from northern and southern regions were prepared with the same techniques and decorative elements, the comparison of their technical details suggests that the southern-origin silver box from the pagoda crypt of Famen Monastery employed more sophisticated technology. The ring-matted backgrounds on the silver box and pot from the Wei family cemetery and the silver box from the Xiaolizhuang site were quite rough and the rings were overlapped under the microscope. One should note that the rings overlapping was so severe, especially the rings on the small round box, that the single ring was difficult to be recognized [8, 9]. Besides, the silver cup of the Wei family cemetery and the currently studied silver box (Fig. 4d and e) do possess distinct ring-matted backgrounds, however, the latter contains a more regular ring arrangement [8]. In addition to the ring-matted background, the details of the traced motifs also reflect different technical skills. In the case of silver vessels from the Wei family cemetery, the triangular tracing marks on the silver cup are deep, however, the lines made up of isosceles triangles are unsmooth and these triangles are unevenly spaced. The tracing marks of main motifs on the three-legged pot are also different, while the tracing marks of other motifs are blurred. In addition, the triangular tracing marks on the small round box could be recognized in the main motifs, but the traced line on the rim is indistinct and unfinished [8]. With respect to the silver box of the Xiaolizhuang site, the traced marks are shallow and some are even out of shape [9]. In the case of partially-gilded silver box from the Famen Monastery, the tracing lines are smooth and triangular marks are clear and deep (Fig. 4a, d, and f).

According to the inscription and inked *Neiku* on the Famen gilded silver box, it could be speculated that the box was first produced in *Jiangnanxidao* and, then, it was presented by official Li to the Emperor for the Yanqing Festival and collected in *Neiku*. Finally, along with other treasures, the box was donated to the true body relic in Famen Monastery. Therefore, it is reasonable to assume that the silver box was made by the most experienced silversmith in the southern region. Overall, these observations confirm that the silver technology in the southern areas of the Tang dynasty was well developed.

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

Based on the above discussion, it can be concluded that same techniques were employed in the southern-origin silver box and the northern-origin silver vessels, however, the former demonstrated more exquisite decorations in terms of technical details. It is undeniable that the lions' decorated box must be made by the most skilled silversmith in the southern region as a gift for the Emperor, however, it is also true that the southern vessels of the late Tang dynasty must be exquisite enough and even more delicate than the northern silver vessels to be loved by the Emperor. The appearance and rise of the most sophisticated southern-origin silver vessels derive from the political and social backgrounds.

Before the mid-8th century CE, frequent interactions with the west strongly influenced the design and manufacturing of silver vessels in China, especially Persia, Sassanian and Sogdian [4]. During the early Tang dynasty, silver was partially imported and processed by foreign metalsmiths living in China [37]. The members of the Royal family and nobles were the major customers of these delicate silver artifacts. Therefore, the Chang'an region is considered as the manufacturing center of silver artifacts during the early Tang dynasty. Subsequently, the raw silver was shipped to the Chang'an region from different suppliers and the skilled craftsmen congregated here to utilize their talent [5]. The silversmiths of this period employed the foreign techniques and further developed them to the greater perfection, resulting in some innovative forms due to the combination of foreign and traditional methods [4], such as the treasures of Hejiacun hoard in Xi'an [38].

However, the situation changed after the mid-8th century CE. The political and economic downfall in northern China due to the An Lushan rebellion resulted in the migration of businessmen and official artisans towards the south [1]. It is worth noting that the south contained abundant gold, silver and lead resources, which are the major raw materials for the production of gold and silver vessels. Gold production accounted for 92 %, whereas silver production accounted for 94 % during the Tang dynasty [1, 39]. The increase in commercial activities shifted the manufacturing center of gold and silver from the north to south [5]. The written record shows that five regions in the south, including *Jiangnanxidao*, frequently presented gold and silver artifacts to the imperial court [40]. In terms of decorations on silver artifacts, some southern-origin silver vessels after the mid-8th century CE have very similar decorative styles to the silver vessels recovered in the north before the mid-8th century CE, e.g., ring-matted background.

On the other hand, the northern-origin silver vessels after the mid-8th century CE contained simple decorations. For instance, the silver vessels produced by the *Wensiyuan* were without decoration or with

gilded motifs on a smooth background [15]. However, from a technological perspective, the same motif expressions were utilized by silversmiths in both north and south regions, where the main motifs were highlighted by a combination of repoussé and gilding techniques. In summary, the manufacturing of southern-origin silver vessels after the mid-8th century CE was far more delicate and diverse, inheriting the decorative techniques of the northern-origin silver vessels before the mid-8th century CE.

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-8th century CE. The box consisted of five refined silver pieces, which were smelted by a commonly used silver smelting technique during the Tang dynasty, i.e., cupellation. Furthermore, the results revealed that hammering, brazing, engraving, repoussé, tracing and partial fire-gilding were used to shape and decorate the box. One should note that 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. This type of solder was also used for brazing the silver objects during the Liao dynasty. Strikingly, the comparison of decorative details between the southern-origin silver box and previously reported northern-origin silver vessels demonstrated the employment of more delicate and sophisticated decorative techniques in the southern region. The similar decorative features among the south-made silver box after the mid-8th century CE and north-made silver vessels before the mid-8th century CE demonstrate the inheritance of decorative styles. Furthermore, different technical skills of both types of silver vessels exhibit the evolution of decorative techniques, which attained high perfection by the southern silversmiths after the downfall of northern China. The current study presents novel insights into the development of silver technology during the Tang dynasty and motivates further research on the comparison 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.

Declarations

Acknowledgments

The authors thank the Institute of Historical Metallurgy and Materials in University of Science and Technology Beijing and Joint International Research Centre on Scientific Preservation of Cultural Heritage of “Belt and Road” for their supports. We also thank the Shaanxi Institute of Archaeology for the support of analytical equipment. Special thanks go to Mr. Jie Jiang, Mr. Gaoju Zhang, and Mr. Hongzhe Luo from the Famen Temple Museum for their cooperation.

Authors' contributions

PT designed and performed the experiments, analyzed the experimental data, and wrote the manuscript. JY directed the work. XR provided the partially gilded silver box for analysis.

All authors read and approved the final manuscript.

Funding

Humanities and Social Science Foundation of Ministry of Education of China (20YJAZH071).

Availability of data and materials

All data generated or analyzed during this study are included in this article.

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, Baota Road, Famen County, Baoji 722201, China.

References

1. Qi D. Research on Tang gold and silver vessels. Beijing: China Social Sciences Press;1999 (**in Chinese**).
2. Shang G. History of arts and crafts of the Tang dynasty. Hangzhou: Zhejiang Literature & Art Publishing House;1998 (**in Chinese**).
3. Rawson J. The Ornament on Chinese Silver of the Tang Dynasty (Ad 618-906). In: British Museum Occasional Paper No. 40. Department of Oriental Antiquities; 1982.
4. Gyllensvärd B. T'ang gold and silver. Bull. Of the Museum of Far Eastern Antiquities (Stockholm). 1957;(29):1-230.
5. Kieser A. A "golden age" just for the living? silver vessels in Tang dynasty tombs. Tang Studies. 2015;33(1):62-90.
6. Ran W. Discoveries and features of northern silver vessels of Tang dynasty. Relics and Museology. 1997;(5):56-60 (**in Chinese**).
7. Ran W. Discoveries and features of southern silver vessels of Tang dynasty. Journal of Northwest University (Philosophy and Social Sciences Edition). 1994;24(4):94-98 (**in Chinese**).

8. Tan P, Yang J, Li X. Primary study on silver vessels from Wei family cemetery of the Tang dynasty in Xi'an Shaanxi province. *Research on Qian Mausoleum Culture*. 2014;8(0):38-49 **(in Chinese)**.
9. Yao Z, Gong Y. Study on a silver box unearthed from the Tang Dynasty (AD 618–907) tomb at Xiaolizhuang Site, Henan Province, China. *Heritage Science*. 2019;7(1).
10. Ma Q, Scott AD. Metallographic study of gilded silver cup from Dachangling tomb of Tang dynasty in Sunanyugu autonomous county, Gansu province. In: Chinese Materials Research Society, editor editors. *Proceedings of materials conference of China in 2002*. Beijing: Metallurgical Industry Press; 2003. p. 2104-2107 **(in Chinese)**.
11. Shaanxi Institute of Archaeology, Famen Museum, Baoji Cultural Heritage Administration, Fufeng Museum. *Excavation report of Famen Temple: Ⅹ*. Beijing: Cultural Relics Press;2007 **(in Chinese)**.
12. Ge C. Treasures from Famen Monastery and Neiku of Tang dynasty. In: Zhang Q, Han J, editors. *Proceedings of the 1st International Symposium on History and Culture of Famen Monastery*. Xi'an: Shaanxi People's Education Press; 1992. p. 75-80 **(in Chinese)**.
13. Lu Z. Some thoughts about gold and silver from crypt of Famen Monastery. *Archaeology*. 1990; (7):638-644 **(in Chinese)**.
14. Yang X. *Fine gold artifacts and their techniques of China*. Beijing: China Science Publishing & Media Ltd. (CSPM);2008 **(in Chinese)**.
15. Shaanxi Institute of Archaeology, Famen Museum, Baoji Cultural Heritage Administration, Fufeng Museum. *Excavation report of Famen Temple: Ⅹ*. Beijing: Cultural Relics Press;2007 **(in Chinese)**.
16. Wang Q. *Ce Fu Yuan Gui*. Beijing: Zhonghua Book Company;1960.
17. Yi B. The primary study of silver smelting in Tang dynasty. *Cultural Relics*. 1972;(6):40-45 **(in Chinese)**.
18. Okamoto H, Schlesinger ME, Mueller EM. *ASM Handbook, Vol. III: Alloy Phase Diagrams*. USA: ASM International;1992.
19. Ma J, Zhang K, Cheng B, Dong D. Microstructure analysis of silver relics from joint tomb of Chen Yuantong of Tang dynasty in Fujian. *Sciences of Conservation and Archaeology*. 2009;21(3):59-66 **(in Chinese)**.
20. Yang J, Jett P, Zhao X, Taube M. Silver wires of Tang dynasty: Technological analysis. *Archaeology and Cultural Relics*. 2007;(6):106-109 **(in Chinese)**.
21. Yang J, Zhao X. Study on gold and silver ornaments decorated on textiles from crypt of Famen Monastery. In: Wang H, Song D, Wang H, editors. *Proceedings of the 8th National Conference on Archaeology and National Deli (Chemistry)*. Guangzhou: Lingnan Art Publishing House; 2004. p. 72-80 **(in Chinese)**.
22. Yang J, Jett P, Brostoff L, Taube M. A technical study of silver samples from Xi'an, Shaanxi province, China, dating from the Warring States period to the Tang dynasty. In: *Proceedings of the 6th International Conference on the Beginnings of the Use of Metals and Alloys*. London: Archetype Publications Ltd.; 2009. p. 170-176.

23. Li H, Wei C, Li D, Fan Q, Liu Y. XRF analysis on several ancient silver vessels. *Archaeology*. 1988; (1):85-88 **(in Chinese)**.
24. Chengdu Institute of Archaeology. Analytical report of silver vessels from the Zhengkejiaxiang site of Tang and Song dynasties in Chengdu city. *Archaeological discoveries in Chengdu*. 2013;(0):644-646 **(in Chinese)**.
25. Yang M. Conservation and analysis of silver hairpins from Tang tombs in Xi'an. In: School of Cultural Heritage of Northwest University, Applied Chemistry Committee and Archaeology and Cultural Heritage Preservation of the Chinese Chemical Society, Chinese Society of Archaeometry, editors. *Conservation of Cultural Heritage and Archaeometry*. Xi'an: Sanqin Publishing House; 2006. p. 268-272 **(in Chinese)**.
26. Wang X. Study on manufacturing techniques of a gilded silver belt collected in Yili museum. Xi'an: Northwest University; 2019 **(in Chinese)**.
27. Han R, Sun S, Li X. *Microstructures metallic materials of ancient China: Introduction*. Beijing: China Science Publishing & Media Ltd.(CSPM); 2015 **(in Chinese)**.
28. Cui J, Liu S, Wei D, Wu X. Zhongguo wuyin gongyi de shouci faxian he chubu yanjiu. *Bianjiang kaogu yanjiu*. 2008;7314-321 **(in Chinese)**.
29. Ban G. *Book of Han*. Beijing: Zhonghua Book Company (in Chinese); 1962 **(in Chinese)**.
30. Su J. *Tang materia medica*. Hefei: Anhui Science and Technology Press; 1981 **(in Chinese)**.
31. Zheng F. Zuo Zhaojingjing. In: Han Y, Xu C, editors. *Jinglinglingchiyizhu*. Vol. 4. Shanghai: Shanghai Guji Press; 2015. p. 276-296 **(in Chinese)**.
32. Wang S. Wanshoushan Guangchusi Ciqiku Tongzuo, Xizuo Zeli, Neigongyouzuo Xianxingzeli. In: *Qingdaijiangzuozelihuibian*. Vol. 1. Henan: Elephant Press; 2000. p. 1181-1218 **(in Chinese)**.
33. Zhao C, Zhao J, Zhang Q, Yu Q, Xue H. Review of precious metal alloys for jewelry and relevant brazing technology. *Welding & Joining*. 2017;(5):18-21 **(in Chinese)**.
34. Twitchett D. *Sui and Tang China, 589-906*. Cambridge: Cambridge University Press; 2008.
35. Shaanxi History Museum, School of Archaeology and Museology at Peking University, Aurora Center for Study of Ancient Civilizations of Peking University. *Selected treasures from Hejiacun Tang hoard*. Beijing: Cultural Relics Press; 2003 **(in Chinese)**.
36. Qi D. Gold and silver wares on the Belitung Shipwreck. In: Krahl R, Guy J, Wilson JK, Raby J, editors. *Shipwrecked: Tang treasures and monsoon winds*. Singapore: Arthur M. Sackler Gallery, Smithsonian Institution, National Heritage Board of Singapore, Singapore Tourism Board; 2010. p. 221-227.
37. Ouyang X, Song Q. *Geography*. In: *New book of Tang*. Beijing: Zhonghua Book Company; 1975. **(in Chinese)**.

Figures

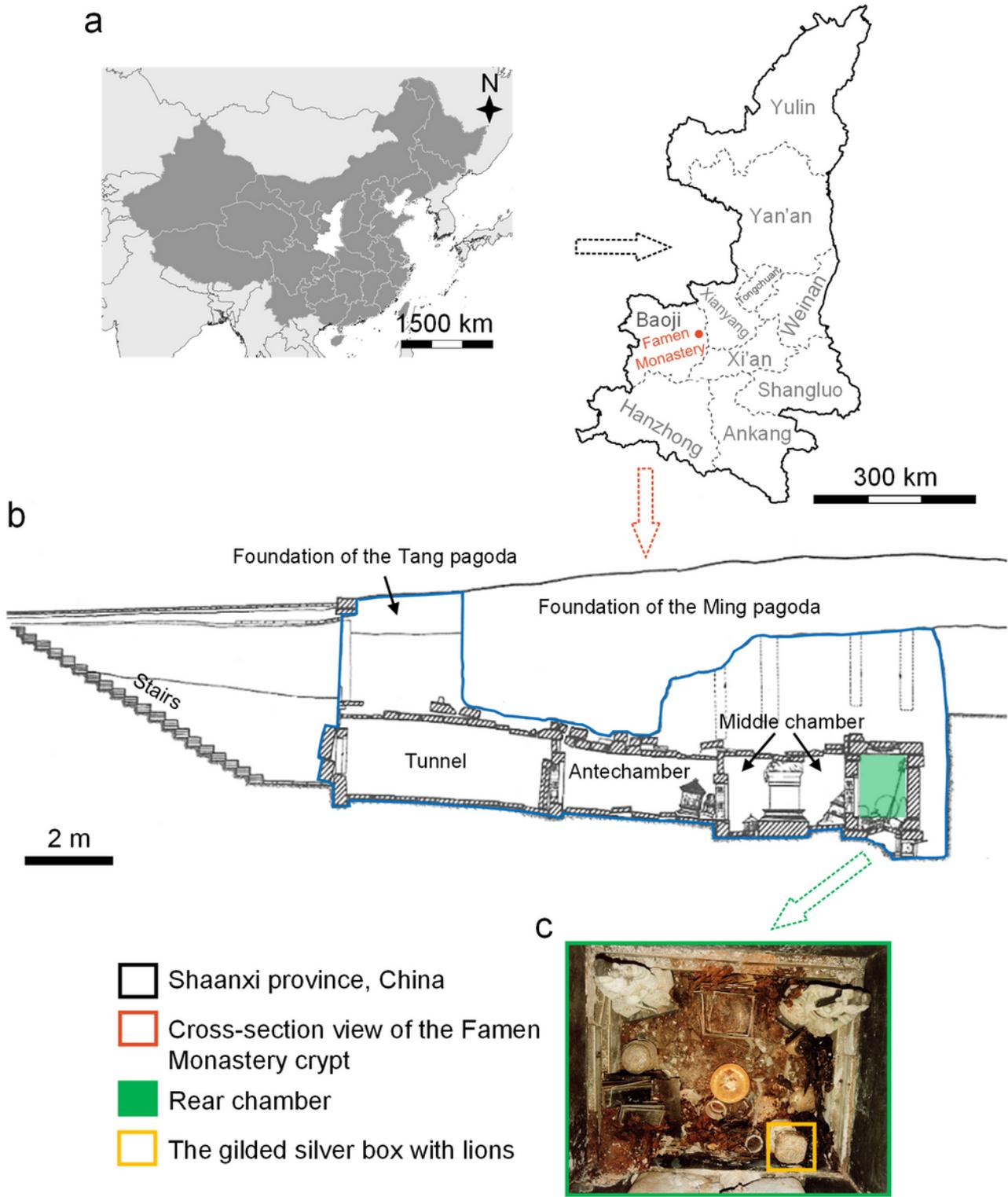


Figure 1

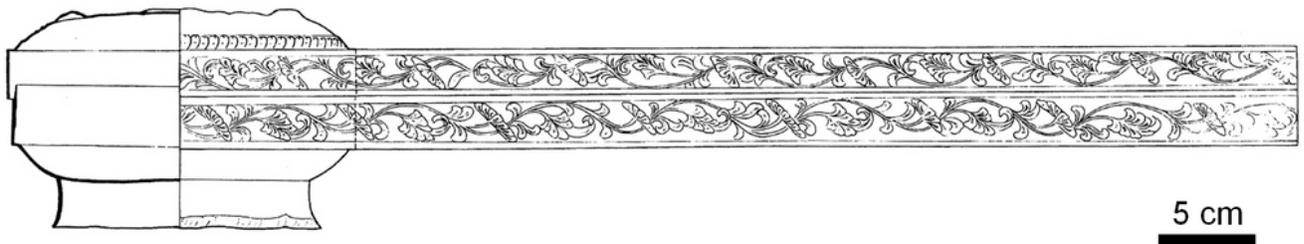
(a) Geographical map of Famen Monastery; (b) cross-sectional view of stupa foundation and underground palace [11]; and (c) the location of the partially gilded silver box [15]. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or

area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

a



b



c



d



Figure 2

(a) Digital photographs of the partially-gilded silver box (left) and motif on the box lid (right) [15]; (b) line drawing of the side view and motif on the box wall [11]; (c) line drawing of the motif and Chinese-inked Neiku on the outer surface of box lid [11]; and (d) the traced inscription on the bottom [11].

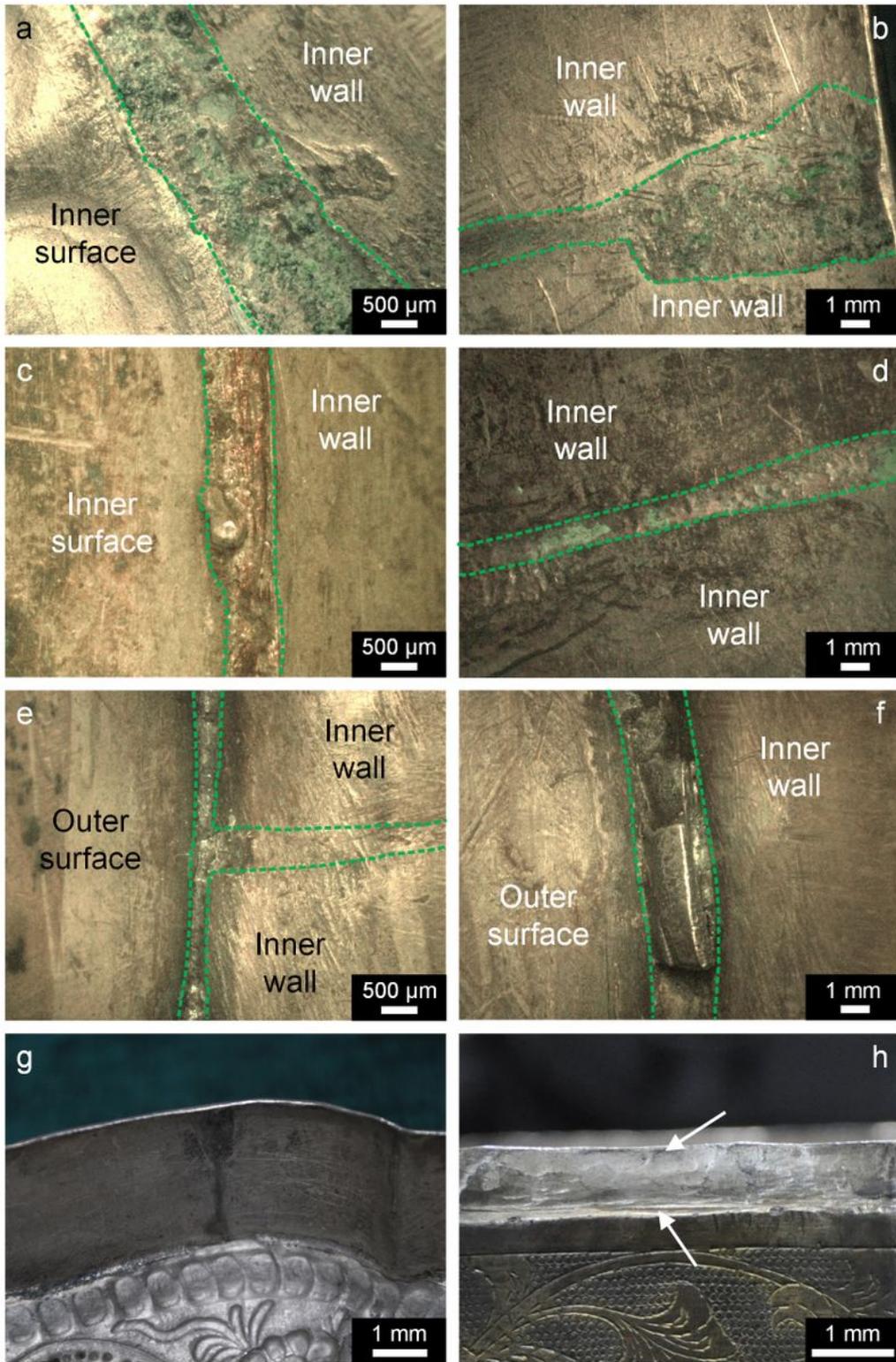


Figure 3

Micrographs of joining areas of the partially-gilded silver box: (a) joint between cover and wall of the box lid; (b) joint of the wall of box lid; (c) joint between bottom and wall of the box body; (d) joint of the wall of box body; (e) joint between the box body and ring foot; (f) soldering metals at the joining area between the box body and ring foot; (g) smooth rim of the box lid; and (h) engraved and hammered edge of the box body.

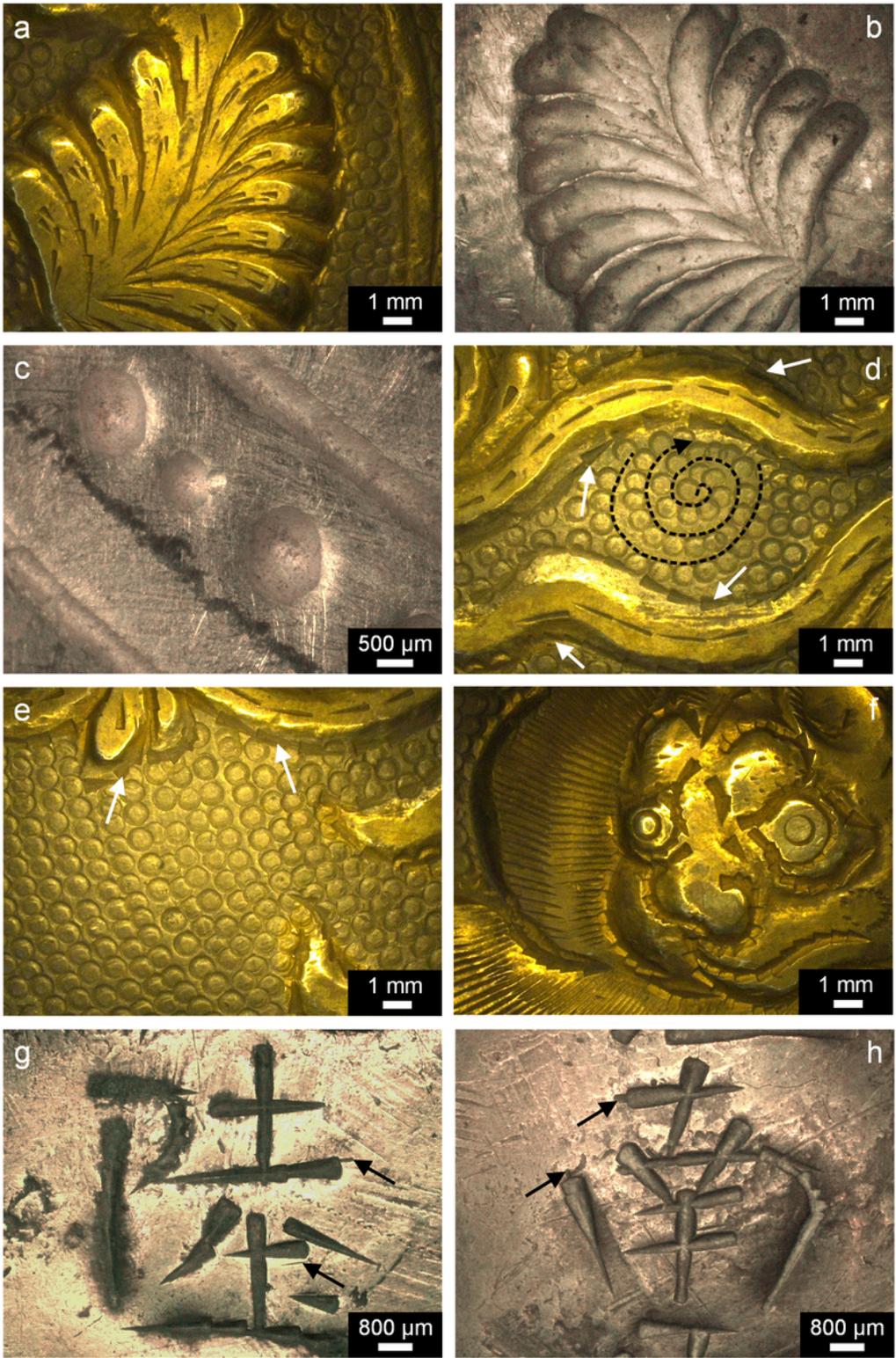


Figure 4

Micrographs of motifs and inscriptions on the partially-gilded silver box: (a) front side of the creeping weed; (b) backside of the creeping weed; (c) backside of the pearl roundel; (d) ring-matted background in the central part of box lid; (e) ring-matted background next to the center of box lid; (f) the lion head; (g) the traced character Liu on the box bottom; and (h) the traced character Nan on the box bottom.

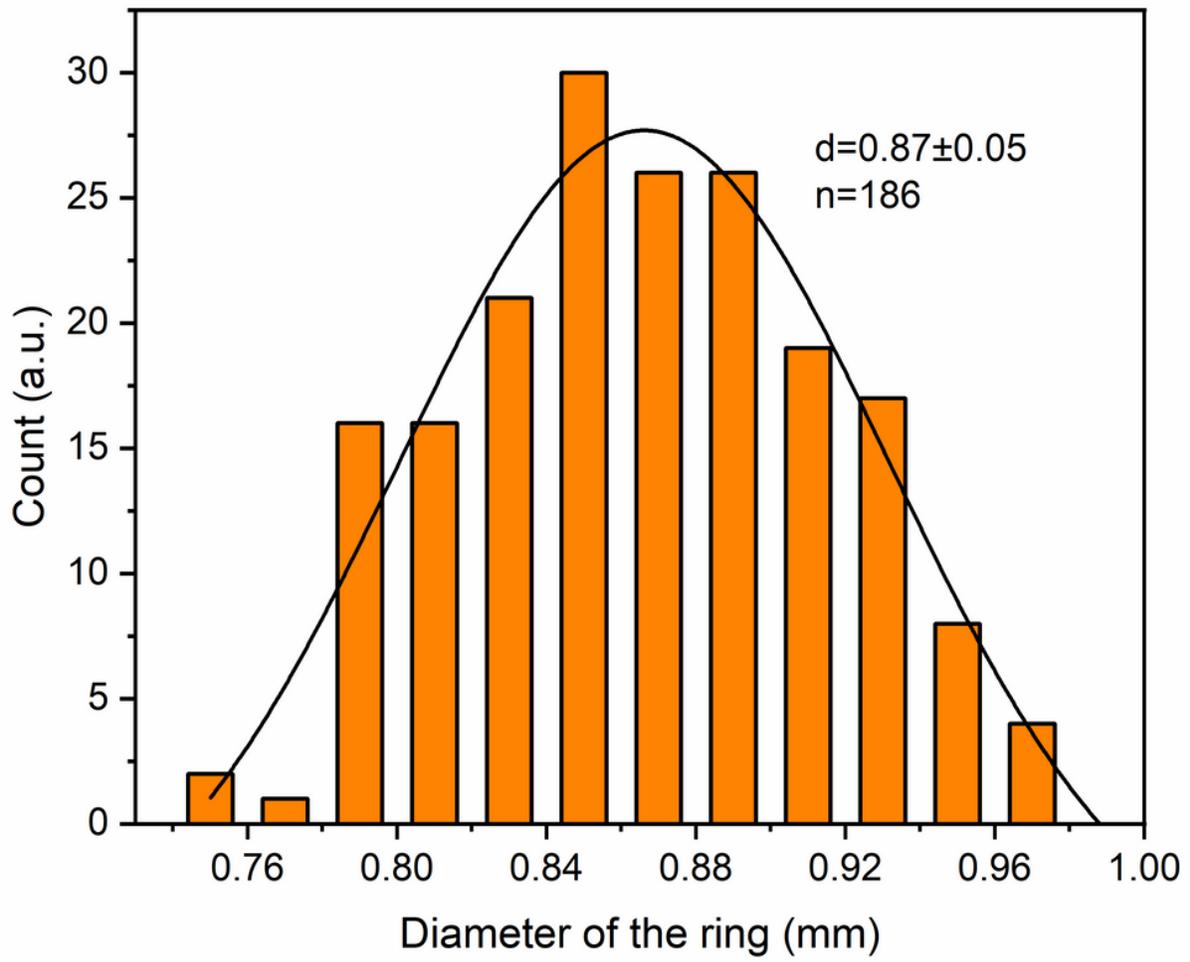


Figure 5

The diameter distribution of the rings of ring-matted background on the lid.

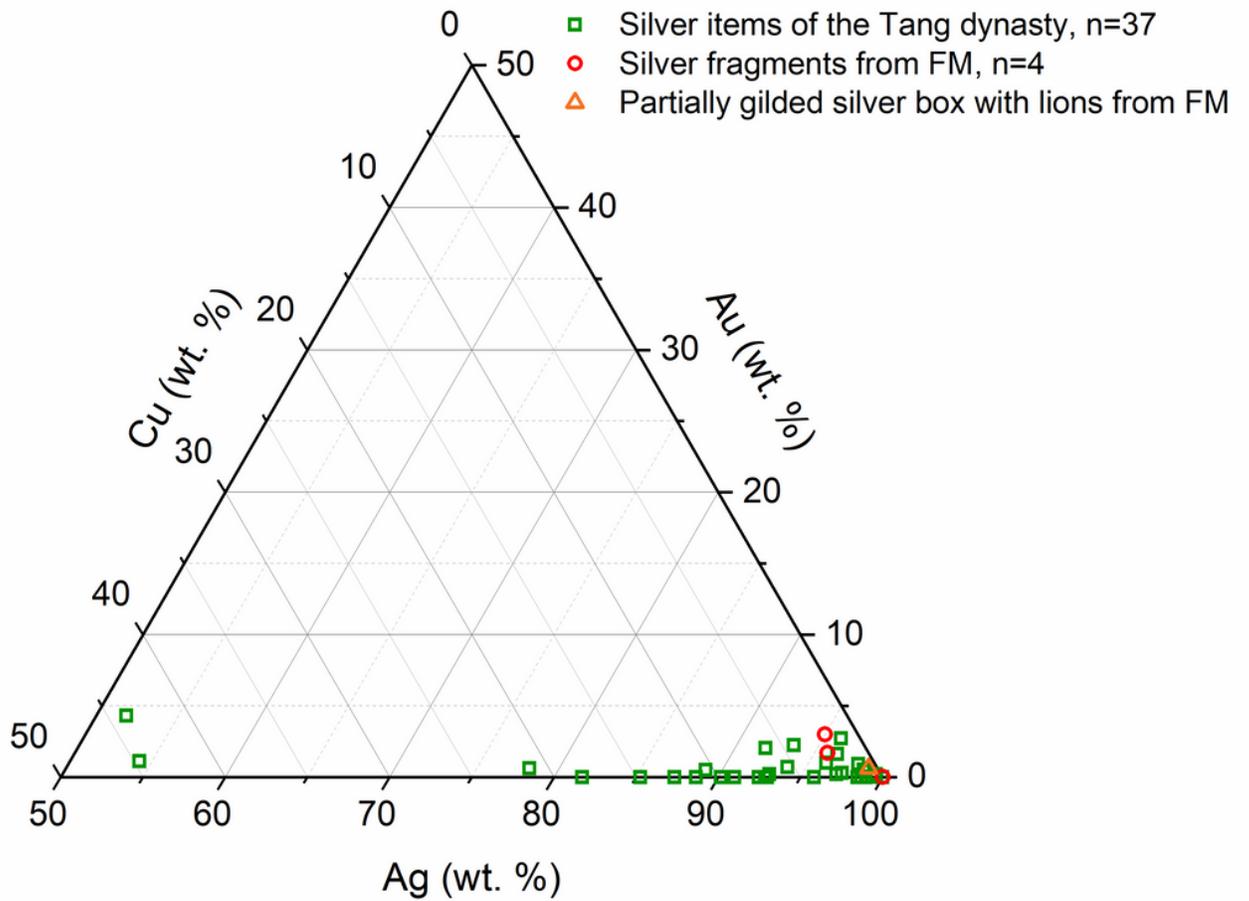


Figure 6

Elemental distribution of Ag, Au and Cu in silver artifacts from the Tang dynasty.

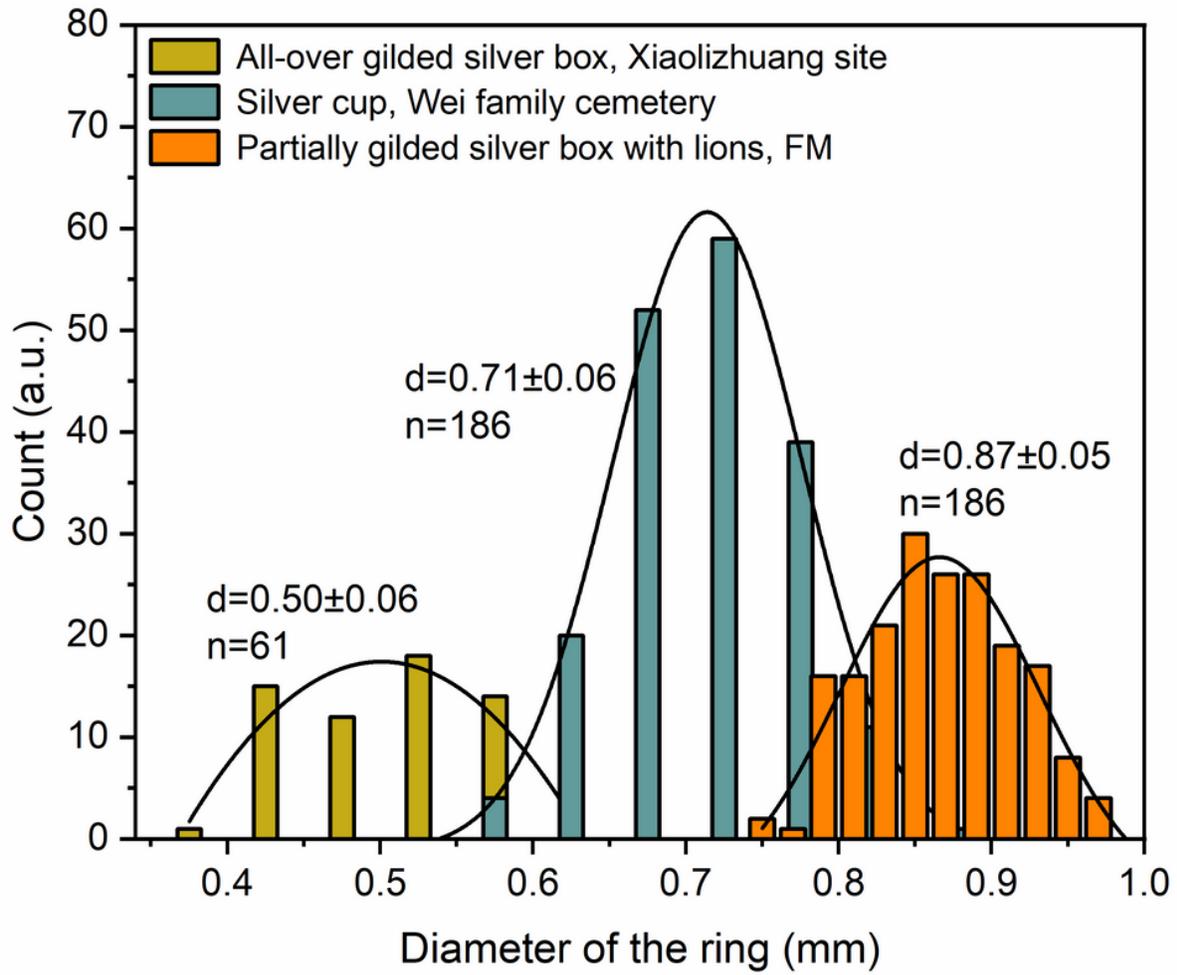


Figure 7

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.