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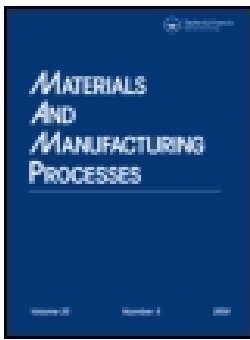
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Early Medieval *gombiky* from the “Lumbe Garden” cemetery, Prague Castle

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ABSTRACT

This paper presents a typological and technical study of *gombiky* (hollow spherical pendants) from the excavations of the Early Medieval cemetery “Lumbe’s Garden” in Prague Castle, in which the state elite linked to the early Czech princely environment was buried. The goal of the research is the characterization of the material and the manufacturing techniques. The *Gombiky* were characterized by optical stereomicroscope (Olympus SZ60), X-radiography, scanning electron microscopy (SEM), supplemented by electron microanalysis (EDS), and metallographic examination. Replicas were manufactured by a goldsmith.

The typological and material study evidenced five main types of *gombiky*, according to the shells’ shape, the decorative technique, and the material.

Most of the pieces were of unalloyed copper or copper alloys with a small amount of tin (ca. 2%) and were fire-gilt. The different components are soldered with an Ag–Cu hard solder. A pair of *gombiky* was made of almost pure silver with ca. 2% of copper. A gold alloy was also identified. The *gombiky* are decorated by chasing and repoussé, but also with granulation and filigree work, glass cabochons, and gilding.

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Bohemia; chasing; filigree; *gombik*; gilding; granulation; jewels; manufacture; material; medieval; metallography; replica; SEM/EDS; soldering

Introduction

This paper presents a typological and technical study of a set of seven *gombiky* (hollow spherical pendants) from the excavations of the Early Medieval cemetery of “Lumbe’s Garden” in Prague Castle. Here was buried the state elite belonging to the princely environment of the early Czech state. The aim of this research is the characterization of material and techniques used in their manufacture.

Gombiky (*gombik*(y):sing/pl) are hollow, spherical pendants mainly found in graves of wealthy individuals. They are supposed to be prestigious clothing fasteners, a status symbol for upper social classes or luxurious amulets [1]. In this cemetery, they are found mostly in children (mainly girls’) graves [2], placed around the neck of the deceased.

Materials and methods

The *gombiky* were first examined on an Olympus SZX7 stereomicroscope (10–40x magnification). X-ray radiography was undertaken to investigate the internal construction and analyses conducted by SEM/EDS (TESCAN VEGA 3 with an Oxford INCA 350 EDS system and PHILIPS XL30 equipped with an EDAX system) on the different components of the jewels, on unvarnished and cleaned surfaces. The dimensions were measured with the Olympus SZX7 stereomicroscope and Olympus Quick PHOTO camera 3.0 software.

Metallographic analysis was carried out on available samples to characterize metal composition, solder, metallic coating, and corrosion extent. Shell cross-sections were examined with an

Olympus BX60 reflected light metallographic microscope and an Olympus E-450 digital camera. Finally, replicas were manufactured by a professional goldsmith in order to understand the steps of manufacture, evaluate time of manufacture, level of difficulty, and weight of precious metal used.

Condition of the artifacts

Burial, past chemical restoration, treatments and decades of inappropriate handling and storage affected the state of preservation of the *gombiky* and their surface composition. They are mostly in an advanced mineralization state, covered by remains of corrosion products or newly formed tarnish layers. We had thus the possibility of using available fragments for metallographic examinations and analyses, and to have access to the otherwise inaccessible metallic core, so as to obtain more accurate results.

Results and discussion

Five main types of *gombiky* can be distinguished in the set of the “Lumbe Garden” cemetery, by considering material, shape of the shells, and decorative technique as featuring parameters. The first type is represented by a pair of “two-layered *gombik*” of gold, with corrugated strips and colored glass cabochon decoration. The second is a single pair of massive silver *gombiky* with chased and repoussé decoration. The third type comprises three specimens made of gilded copper with chased and repoussé decoration. The fourth type is represented by a pair

of octo-lobed shell *gombiky* of gilt copper with granulation and glass cabochons decoration. The fifth type comprises a pair of gilded copper *gombiky* with granulation work and glass cabochons decoration. One example of each type was analyzed.

All *gombiky* consist of two joined identical shells (usually hemispheres). The upper shell is pierced. In most cases, the suspension system is a loop fixed with a clamp with straight legs, flattened on the internal side, inserted in a hole, and fixed with a ring of plain circular-section wire, soldered at the top hemisphere. *Gombiky* differentiate from each other by material, shape and size of their shell, type of suspension loop fitting, decorative technique, and motifs depicted on the surface. They are usually found in pairs, and one, if not both, contains a small metallic pellet which makes them chime.

Gold “two-layered *gombik*” 16 – 14 (grave 16-object 14) with corrugated strips and colored glass cabochon decoration

Description

The central part of the *gombik* 16–14 (Fig. 1) consists of two joined plain hemispheres of 18 mm of diameter (Fig. 1 A₁–A₂) (Fig. 2e). The upper hemisphere is pierced in the center. The suspension loop fitting is a circular loop with two elongated legs (Fig. 1G) made of a strip of metal of 3.1 mm width, decorated with 3 block-twisted wires (Fig. 1J) of 0.4 mm diameter alternating with two loosely twisted double wire (Fig. 1H) of 0.6 mm diameter. (Fig. 2c). The suspension loop is inserted in the upper hemisphere and soldered to it with a rope of block-twisted wire forming six circles of increasing diameter (F) (Fig. 2d). This *gombik* is decorated with blue (Fig. 1C₁) and green (Fig. 1C₂) glass cabochons inserted in bezels (Fig. 1D) (Fig. 2a). The bezels are decorated with a ring of block-twisted wire (Fig. 1E) (Fig. 2g) of 0.4 mm diameter. Four blue glass cabochons (Fig. 1C₁) must have been set on each hemisphere, but one is missing and was replaced by a small, irregular, green cabochon, probably a clumsy attempt of repair (Fig. 2a). Four green glass cabochons (Fig. 1C₂) must have originally been on the joining area of the two hemispheres, but one is now missing, as also the bottom cabochon. According to the diameter of the bezel, it was probably a blue cabochon, because green cabochons have a larger diameter (6.1 mm) than the blue ones (5.1 mm).

Twelve corrugated strips (Fig. 1B) (Fig. 2f) (width 1.4 mm and thickness 0.1 mm) are vertically placed between the bezels with glass cabochons. They separate the blue cabochons and follow the joining line of the two hemispheres. Corrugated strips also vertically join the green cabochons to the suspension loop and the bottom bezel. Nine different types of components and a total of 58 parts were needed to produce this *gombik*. The bezels, loop, wires (Fig. 1J), and corrugated strip were manufactured from strips of metal. The hemispheres are embossed discs. The wires (Fig. 1H) were probably drawn and then twisted. All the components were soldered together.

Condition of the artifact and quality of work

This *gombik* is in a good state of preservation, but the corrugated strips were mechanically deformed by overburden (Fig. 2a, 2d, 2f). Two glass cabochons are missing and a bezel

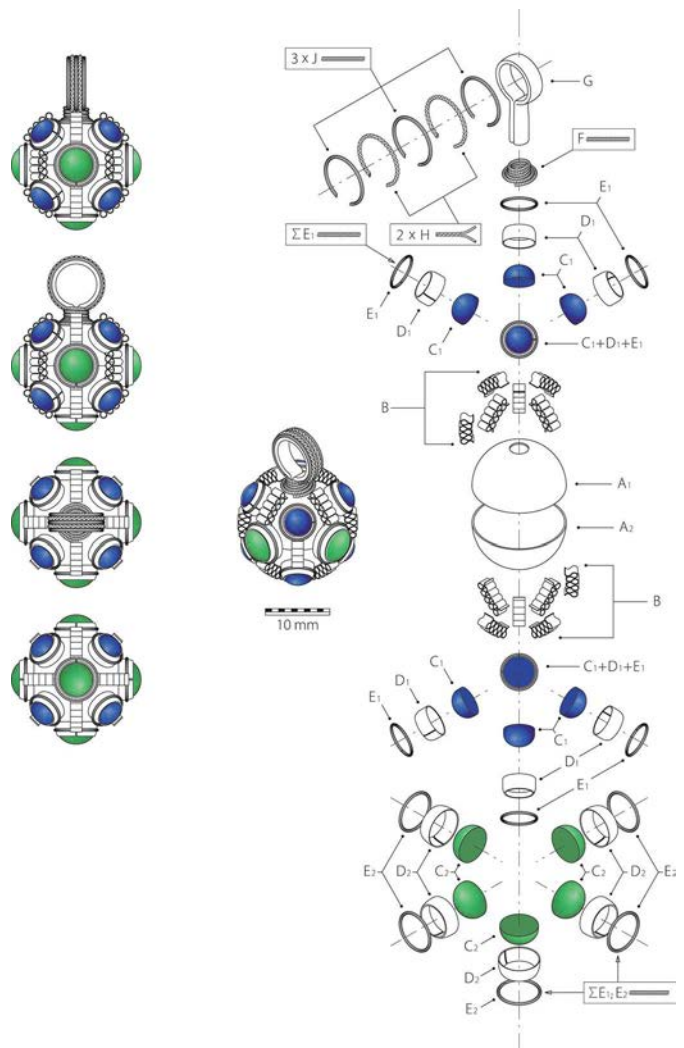


Figure 1. *Gombik* 16-14: exploded view of the different components: A₁ upper hemisphere; A₂ lower hemisphere; B corrugated strips; C glass cabochons; D bezels; E ring of block twisted wire; F coil of block twisted wire; G loop; H twisted wires; J block twisted wires (drawing G. Plítková).

was filled with a tiny fragment of green glass, probably in an unsuccessful attempt to replace the original cabochon. The overall quality of the artifact is very high.

Scanning electron microscopy and microanalyses

SEM microanalyses on the surface of the *gombik* showed that ternary alloys of gold–silver–copper were used for the different components of the *gombik* (Table 1). Analyses on solder areas, in particular between the wires decorating the loop and between the corrugated strips and bezels, evidenced a higher percentage of copper and more than 30% of silver.

Silver *gombik* 115-7 with repoussé and chased decoration

Description (Fig. 3)

The surface is divided into three diamond panels, in the middle of which is depicted a bird, holding a leaf in the beak (Fig. 3a). A foliate ornament fills the spaces between the panels, (Fig. 3c) and dots fill the space around them. A Maltese cross inside a

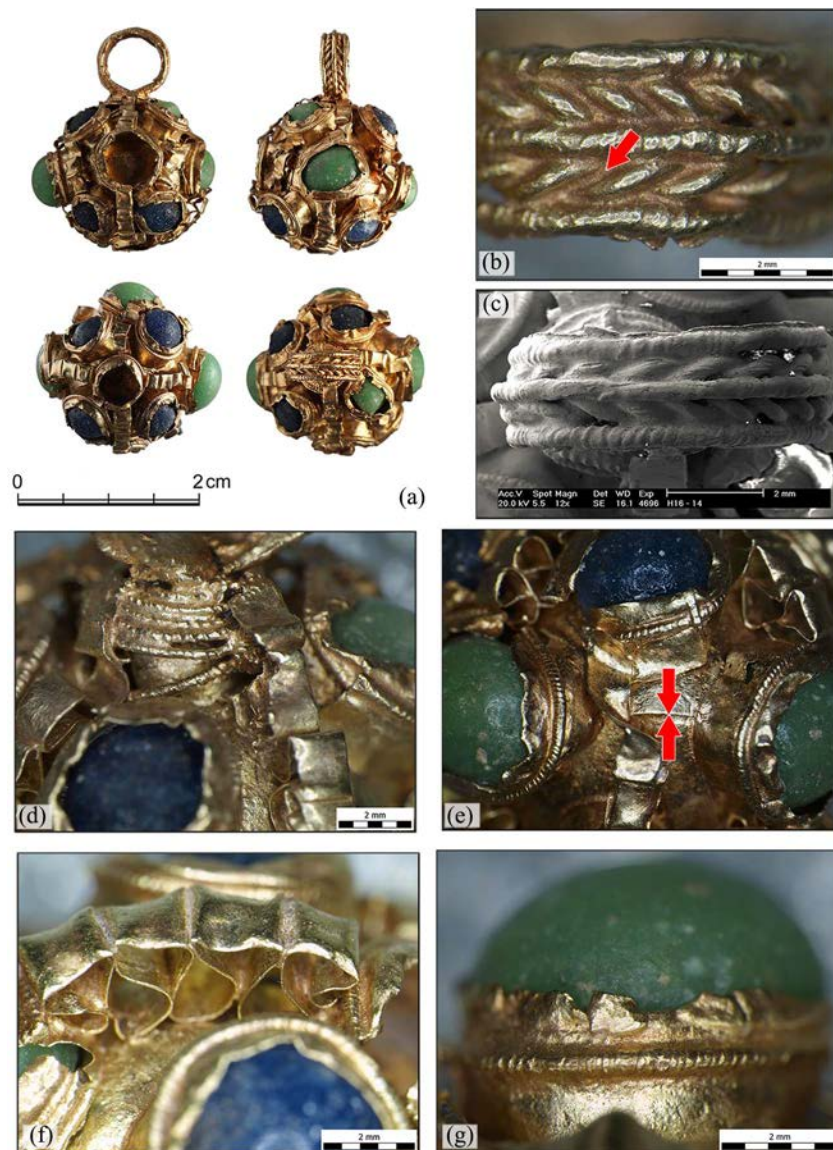


Figure 2. Gombik 16-14: a general view (photo J. Sobek); b decorated loop with reddish solder area between the wires (photo E. Ottenwelter); c SEM micrograph (SE image) of loop with different decorative wires (photo D. Janová); d detail of coil of block twisted wire (photo E. Ottenwelter); e detail of two hemispheres (photo E. Ottenwelter); f detail of the corrugated strip (photo E. Ottenwelter); g detail of green cabochon in its bezel (photo E. Ottenwelter).

circle is depicted on the bottom (Fig. 3b). The *gombik* consists of two hemispheres (diameter 46 mm, thickness 0.1 mm) made from blank discs of metal embossed in a block (Fig. 4a). The decoration was made principally by chasing but also in

repoussé work (Figs. 4c, 4d). The hemispheres were soldered together (Fig. 4f). A loop of wire (diameter 1.5 mm) is fixed with a clamp made of a metal strip (width 2.7 mm) inserted in a ring of smooth, round-sectioned wire, soldered to the upper hemisphere (Figs. 4g, 4h). This example consists of four different kinds of components and five parts in total.

Table 1. Analyses performed on *gombik* 16–14.

Gombik 16-14	Chemical composition [Wt. %]		
	Au	Ag	Cu
Hemisphere (A ₁)	55.7	31.1	13.2
Hemisphere (A ₂)	59.9	26.5	13.6
Corrugated strip (B ₁)	61.4	30.8	7.8
Corrugated strip (B ₂)	80.2	15.2	4.6
Bezel (D ₁)	57.6	30.5	11.9
Bezel (D ₂)	51.6	30.6	17.8
Wire (E)	53.4	31.4	15.2
Wire (H)	54.3	31.4	14.3
Wire (J)	51.1	32.7	16.2
Suspension loop fitting (G)	58.1	35.2	6.7
Solder area between (D) and (B)	52.2	33.8	14
Solder area between (J) and (H)	51	35	14

Condition and quality

Both *gombiky* of this pair are in very poor condition (Fig. 3a). Only 30% of the object is preserved, and it was broken in many extremely brittle fragments because of severe intergranular corrosion (Fig. 3f). The surface is tarnished (Fig. 3c) and the fragments are almost completely mineralized (Fig. 3e).

Scanning electron microscopy and microanalysis

Electron microanalysis performed on the surface and on the cross-section of a fragment (Fig. 3e) showed that the material

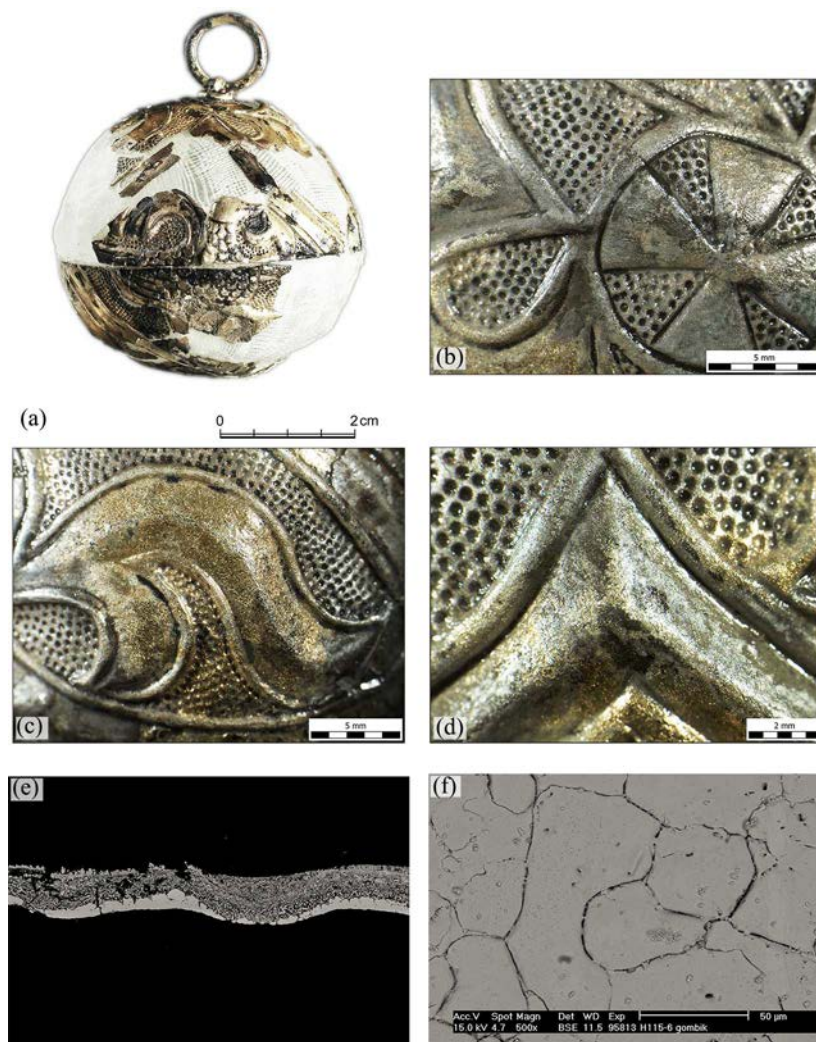


Figure 3. Gombik 115-7: a general view (photo J. Sobek); b Maltese cross (photo E. Ottenwelter); c tarnished foliate ornament (photo E. Ottenwelter); d detail of repoussé and chased decoration (photo E. Ottenwelter); e polished cross-section of fragment (115-6) showing advanced state of mineralization of the hemispheres (photo K. Kolářová); f micrograph (BSE image) of etched surface (photo D. Janová).

is almost pure silver with a small amount of copper (less than 2.6%) (Table 2). Analysis of the loop detected only silver.

The experimental manufacture of this type of *gombik* (Fig. 4) showed that, in comparison with other jewelry types [3], in particular earrings and beads from this period (2.5–5 g), an important amount of silver was needed (15 g). The manufacture of this *gombik*, with chased and repoussé decoration, is also time consuming (119 hours) [4].

Gilded copper alloy gombik 104-4 with repoussé and chased work decoration

This type belongs to the most numerous group of *gombik* from the “Lumbe Garden” necropolis. They all consist of two

symmetrical hemispheres (Fig. 5A₁–A₂) made of two blank disks of copper shaped with a doming tool on a doming block or lead block. The upper hemisphere (Fig. 5A₁) is pierced on top; a loop (Fig. 5D) fixed with a clamp (Fig. 5C) is placed through a ring (Fig. 5B) soldered to the upper hemisphere. The hemispheres bear a decoration by repoussé and chasing techniques. In the repoussé technique, the sheet metal is shaped by stretching, thinning the metal outward from the reverse. In the chasing technique the sheet metal is undercut and textured by working the sheet from the obverse or front side [5]. A chaser’s pitch inside the hemisphere held the metal in place, to allow work on the exterior of the object. Remains of burnt organic material were identified on the internal side of fragments of *gombiky* 115-8 and 115-9 (Fig. 7h). *Gombiky* of this type were fire gilded. Subgroups can be distinguished according to the motifs on the surface.

Table 2. Analyses performed on *gombik* 115-7.

Gombik 115-7	Chemical composition [Wt. %]	
	Ag	Cu
Hemisphere, cross-section	97.4	2.6
Loop	100	–
Ring	98.1	1.9
Clamp	97.7	2.3

Gombiky with geometrical and cross decorations

Description of gombik 104-4 (Figs. 5–6)

The *gombik* is composed of two hemispheres (diameter almost 30 mm, Fig. 5A₁–A₂), joined together. Inside is a

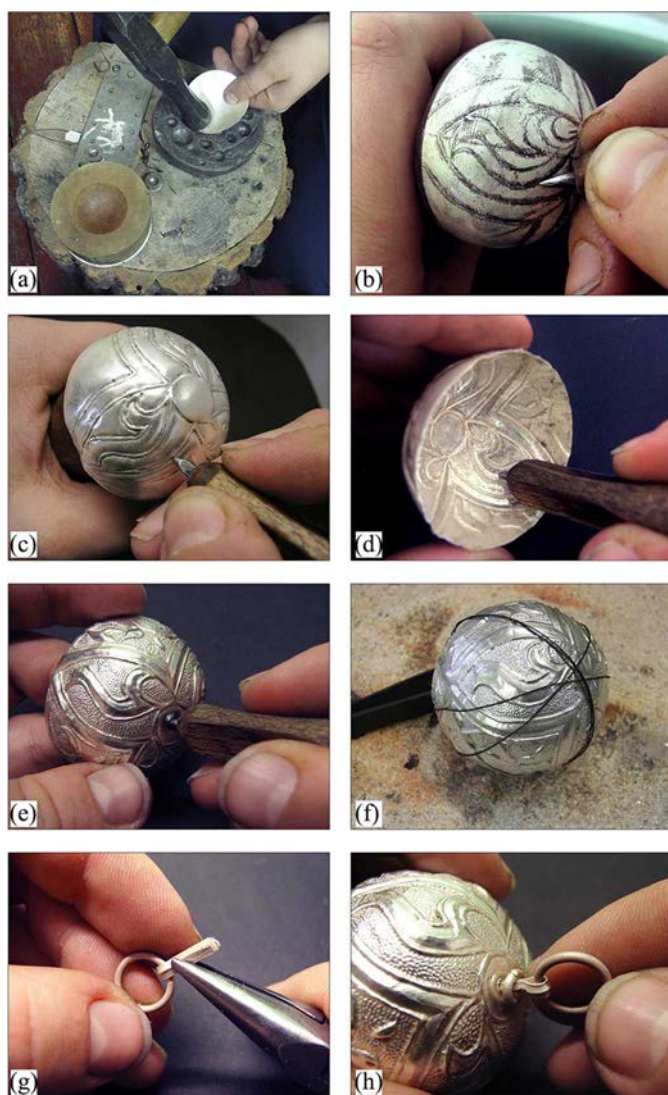


Figure 4. Different steps of manufacture of gombik 115-7 replica: a disk blanks are hammered into the depression in the lead block from edge to center; b the pattern is sketched with a pencil; c the chasing is carried out with a steel liner and follows the pattern; d the decoration is outlined by repoussé work from the reverse; e piercing the upper hemisphere; f soldering the halves of gombik; g triangular profiled strip forming a clamp is inserted in the loop for suspension; h clamp placed in the perforation and soldered (photo. L. Barčaková).

small pellet (diameter 2.2 mm, Figs. 5E; 6d). The suspension system consists of a loop (Fig. 5D) fixed with a clamp (width 2.7 mm; Fig. 5C) inserted in the upper hemisphere through a small ring (Fig. 5B). This piece is decorated on the entire surface (Fig. 6a) with five crosses in a circle (Fig. 6b): on top, bottom, and three along the joining area. Around the crosses there are four smaller circles, defining three areas with a circle in the middle and six semi-circles. The craftsman used drawing compasses to outline the decoration. The depression left by the compass is visible in the center of circles and crosses (Fig. 6c). Five types of components were needed for this gombik.

Condition and quality

Gombik 104-4 is almost complete (Fig. 6a). The bulk metal is almost entirely mineralized. The gilding layer is worn in

many places, where internal corrosion products were dissolved by previous chemical treatment (Fig. 6e). Gombiky of this type are of excellent quality. The chased decoration is perfect.

Scanning electron microscopy and microanalysis

Electron microanalyses were performed on the surface and on a cross-section of a fragment of gombik 104-1. They showed that unalloyed copper was used for the hemispheres (Table 3). White particles of lead were present in the corroded matrix. The two hemispheres were soldered (Fig. 6b) together with a hard solder containing silver (66.8%) and copper (33.2%), also smeared on the surrounding areas. Observation under stereomicroscope revealed silvery areas near the connecting region, where the gilding is worn (Fig. 6e). Surface analyses on these areas determined a higher percentage of silver. Analyses on silvery surfaces on the edge of the worn gilt layer evidenced a layer of silver. However, a cross-section of 104-1 (Fig. 6g) showed that the gombiky were not originally silver-plated, but only gilded. The localized silver coating under the worn gilded layer must be interpreted as smeared solder.

Components of the suspension system on gombik 104-1: the ring is made of copper with a small amount of tin and antimony and the clamp of a copper alloy with a small amount of tin and arsenic. The polished, unetched cross-section (Fig. 6g) of a fragment of 104-1 showed that it was fire gilded. The gilding layer contains ca. 2% Ag. The gilding was observed in recesses where it was best preserved. It has a porous structure (Fig. 6f), as it has been partly burnished, due to difficult access to its decoration. Its preserved thickness ranges from 8 to 10.4 μm .

Gombik 115-8 with rosettes, interlaced and arm motifs decoration

Description

The spherical gombik (diameter approx. 30 mm; thickness 0.2 mm) consists of two joined hemispheres. The upper one is pierced to allow the suspension system to be inserted. A loop (diameter 10.3 mm) is fixed with a clamp (width 1.9 mm), inserted through the top hemisphere and fixed by a ring (diameter 5.9 mm). No pellet is present inside the gombik. The entire surface is decorated (Fig. 7a) by chasing and repoussé work. Three panels are defined by interlaced motifs. An eightfold rosette, surrounded by a wreath with chevron motifs, is depicted in the middle of each panel (Fig. 7b). A triangle, with an inscribed flower with three petals, is depicted on the bottom. An arm (Fig. 7f) is visible along the three sides of the triangle. The gombik was made from four kinds of components and five parts.

Condition and quality

Both gombiky of this pair are in very poor condition and incomplete. Gombik 115-8 has ca. 50% of the body preserved and was broken in many extremely brittle, completely mineralized fragments. The surface was covered by silver chlorides and copper corrosion products (Figs. 7b, 7d, 7f). No attempt to clean the surface was done, because the fragments were

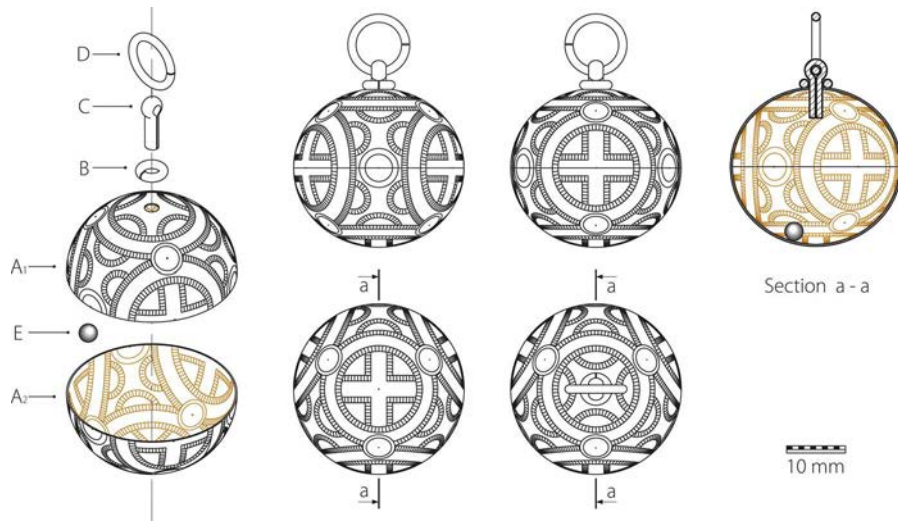


Figure 5. Gombik 104-4: exploded view of the different components: A₁ upper hemisphere; A₂ lower hemisphere; B ring; C clamp; D loop; E pellet (drawing G. Plítková).

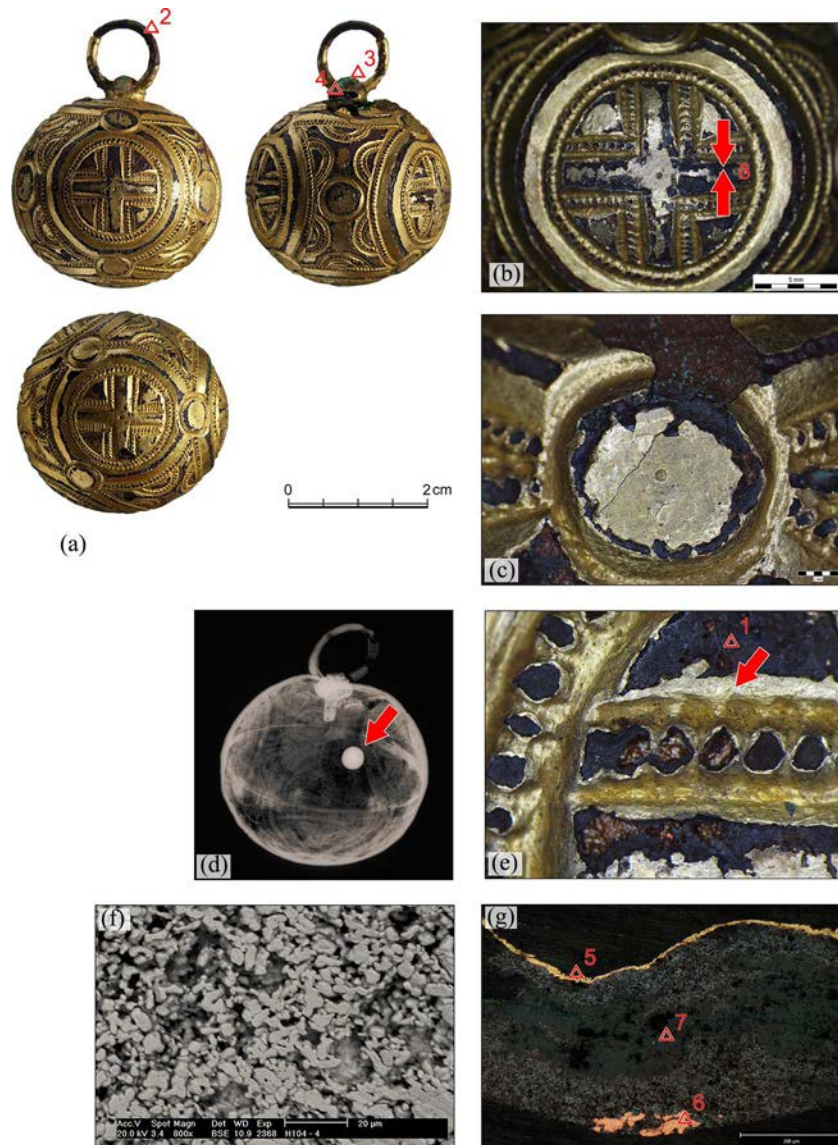


Figure 6. Gombik 104-4: a general view (photo J. Sobek); b solder area and cross ornament (photo E. Ottenwelter); c drawing compasses depression (photo E. Ottenwelter); d X-radiograph (D. Perlík); e silvery area under worn gilding layer (photo E. Ottenwelter); f SEM micrograph (BSE image) of gilding layer (photo D. Janová); g polished cross-section of fragment of 104-1, showing analysed points (photo E. Ottenwelter).

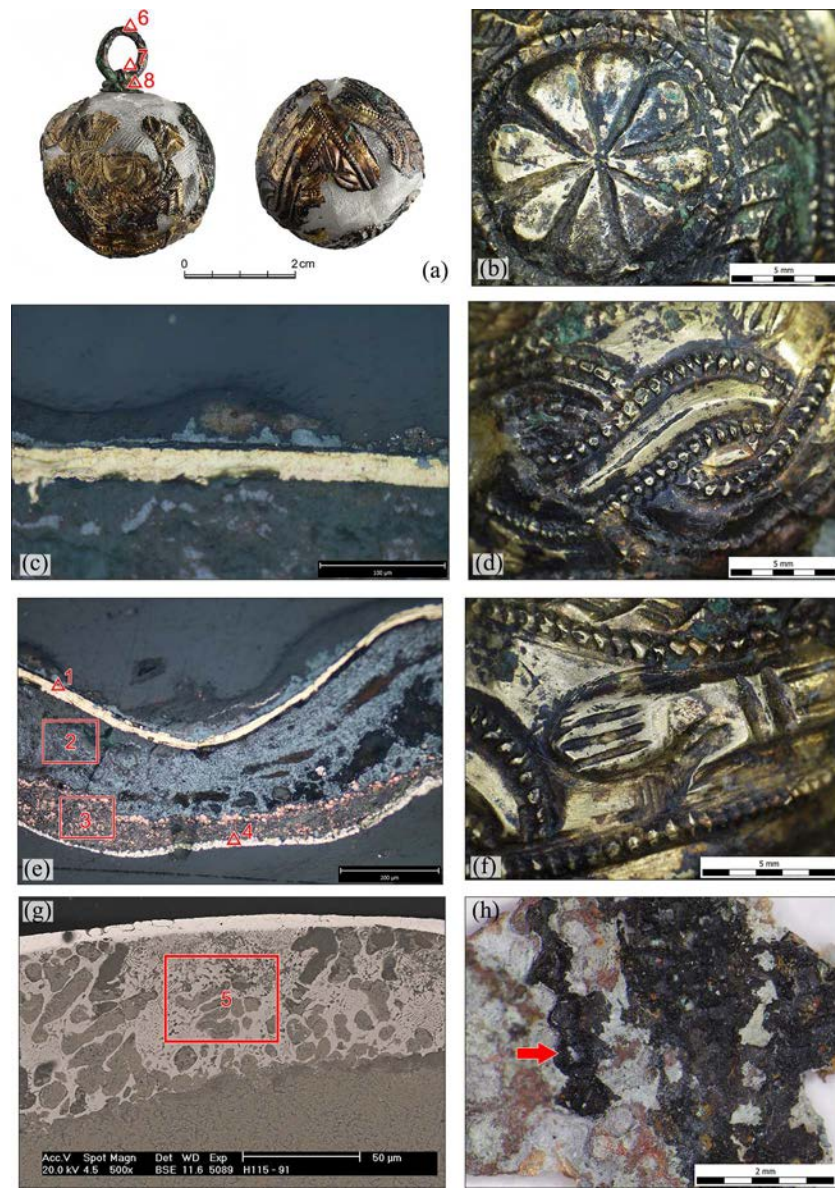


Figure 7. Gombik 115-8: a general view (photo J. Sobek); b eightfold rosette ornament (photo E. Ottenwelter); c detail of gilding, polished cross-section (photo E. Ottenwelter); d interlaced motifs (photo E. Ottenwelter); e polished cross-section of fragment from 115-8 with analysed points and areas (photo E. Ottenwelter); f detail of the arm motif (photo E. Ottenwelter); g fragment cross-section of 115-9 showing solder under gilding, SEM micrograph (BSE image—photo D. Janová); h remains of pitch on the internal wall of the gombik (photo E. Ottenwelter).

too fragile; therefore, analyses of the hemispheres were conducted on a polished, unetched cross-section of fragments from 115-8 and 115-9 (Figs. 7c, 7e, 7g). The quality of the chasing and repoussé work is exceptional.

Scanning electron microscopy and microanalysis

SEM microanalysis on the surface of the suspension system detected the presence of a small amount of tin in the loop and the ring (Table 4). Tin was also detected in the corroded

Table 3. Analyses performed on *gombik* 104-4.

Gombik 104-4	Chemical composition [Wt. %]										
	Au	Ag	Hg	Cu	O	Cl	Sn	Pb	As	Sb	Si
Hemisphere A, corroded metal, point 1	–	–	–	83.8	13.9	2.3	–	–	–	–	–
Loop D, corroded surface, point 2	–	–	–	84.8	11.4	–	3.8	–	–	–	–
Clamp C, corroded surface, 104-1, point 3	–	–	–	73.4	–	–	22.2	4.2	0.2	–	–
Ring B, corroded surface, point 4	–	–	–	81.4	12.9	0.4	4	–	–	1.1	0.2
Gilding layer, cross-section, point 5	84	2.3	12	1.7	–	–	–	–	–	–	–
Metallic core, cross-section, point 6	–	–	–	98.9	1.1	–	–	–	–	–	–
Inclusions, corr. core, cross-section, point 7	–	–	–	4.8	–	–	–	95.2	–	–	–
Solder area between hemispheres, point 8	–	66.8	–	33.2	–	–	–	–	–	–	–

Table 4. Analyses performed on *gombik* 115-8.

<i>Gombik</i> 115-8	Chemical composition [Wt. %]						
	Au	Ag	Hg	Cu	O	Sn	Cl
Gilding layer, cross s., point 1	80.5	3.3	12.7	3.5	–	–	–
Hemisphere, corr. matrix, cross s., area 2	–	–	–	62.1	21.4	6.7	9.8
Hemisphere, corr. islands, matrix, cross s., area3	–	–	–	74.2	15	10	0.7
Silver plating internal side, cross s., point 4	–	87	–	13	–	–	–
Solder between hemispheres, cross s. 115-9 area5	–	57.5	–	42.5	–	–	–
Hemisphere, particles in corr.matrix, cross s. 115-9	–	–	–	97	–	3	–
Loop, corr. surface, point 6	–	–	–	85.4	11.6	3	–
Clamp, corr. surface, point 7	–	–	–	96	4	–	–
Ring, corr. surface, point 8	–	–	–	88	8.4	3.6	–

and partly mineralized matrix of a hemisphere fragment (Fig. 7e) at levels of up to 10% (areas 2, 3). The high content of tin is probably the result of corrosion and enrichment phenomena on the surface. Analyses of metallic particles in the corroded matrix of 115-9 detected 3% Sn, a level closer to the tin content of the suspension system. This composition was probably closer to that of the material of the hemisphere. Solder area analyzed on a fragment of *gombik* 115-9 (Fig. 7g) evidenced the use of a binary Ag–Cu hard solder used on the two hemispheres. The solder was smeared on the internal side (point 4) (Fig. 7e). The *gombik* was fire-gilded (Figs. 7c, 7e).

The gilding contains a small amount of silver (point 1; av. thickness 7.5 μm).

Gombik 84-1 with foliate, bird and cross ornament

Description

The surface is divided into three diamond panels with a bird holding a leaf depicted in the center (Fig. 8a and 8c). A foliate ornament fills the spaces between the panels. A cross in a circle decorated with chevrons (Fig. 8e) decorates the bottom. A circle with chevron decoration is also around

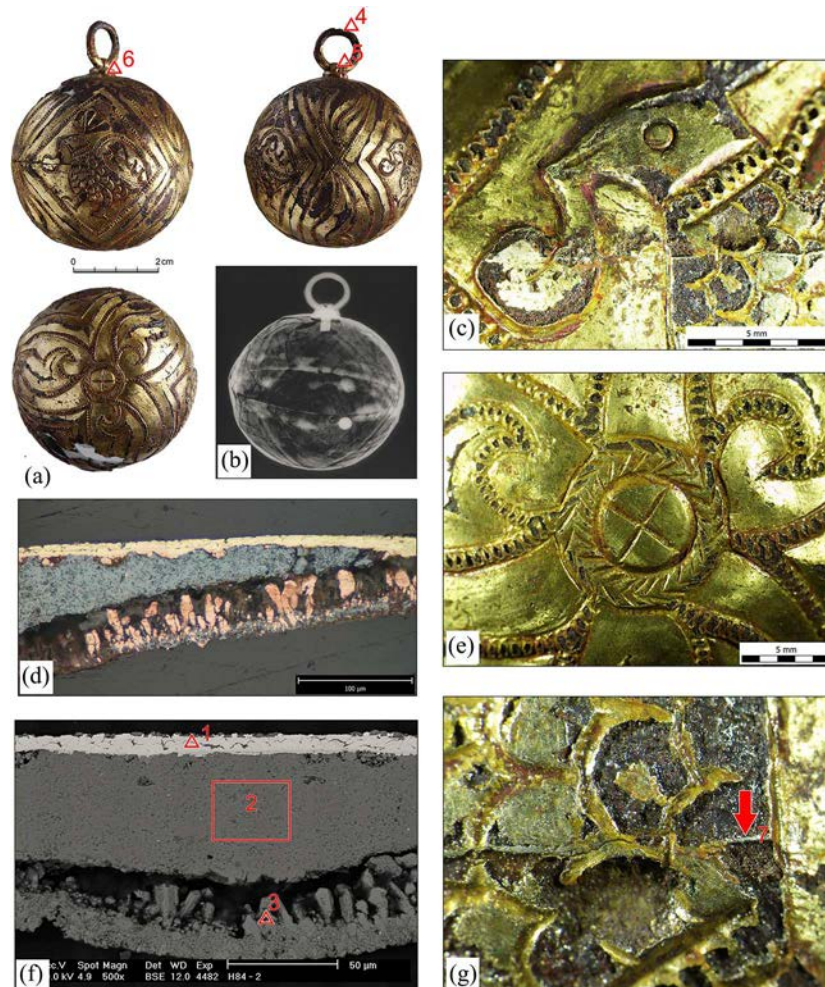


Figure 8. *Gombik* 84-1: a general view (photo J. Sobek); b X-radiograph (I.Nacherová); c detail of bird holding a leaf (photo E. Ottenwelter); d polished, unetched cross-section (photo E. Ottenwelter); e detail of cross motif inside a chevron wreath (photo E. Ottenwelter); f polished, unetched cross-section with analysed points and areas, SEM micrograph (BSE—photo D. Janová); g solder between hemispheres (photo E. Ottenwelter).

Table 5. Analyses performed on *gombik* 84-1.

Gombik 84-1	Chemical composition [Wt. %]					
	Au	Ag	Cu	Pb	Hg	O
Gilding, cross s., point 1 (84-2)	80	–	3.4	–	16.6	–
Hemisph., cross s. corr. matrix, point 2 (84-2)	–	–	86.9	–	–	13.1
Hemisphere, cross s., core partly corr., point 3 (84-2)	–	–	97.2	–	–	2.8
Loop, corr. surface, point 4	–	–	86.1	2.9	–	11
Clamp, corr. surface, point 5	–	–	86.5	2	–	11.5
Ring, corr. surface, point 6	–	–	86.4	3.1	–	10.5
Solder on hemisph. point 7	–	70.9	29.1	–	–	–

the suspension loop. The size and motif on the surface are very similar to that from grave 115. It consists of two hemispheres (diameter 44 mm; thickness 0.2 mm) and the suspension system is similar to that of the previous example. A pellet is present inside (Fig. 8b). The *gombik* consists of five different components and six parts.

Condition and quality of the work

The condition of both *gombiky* is rather poor. *Gombik* 84-2 is in a better state of preservation, almost complete, but it was broken in many fragments. *Gombik* 84-1 is only 65% preserved. The upper hemisphere is incomplete. Both are almost completely mineralized; however, islands of preserved copper were present on observed cross-sections (Fig. 8d and 8f). The gilding layer is preserved mainly in recesses and is covered by copper corrosion products. The quality of this kind of *gombik* is very good.

Scanning electron microscopy and microanalysis

SEM microanalysis was performed on a polished, unetched cross-section from one hemisphere (Fig. 8d and 8f) and on the surface of the various components of the suspension system. The solder on the surface between the two hemispheres (Fig. 8g) was analyzed. Analyses performed on the islands of metallic core (Fig. 8f, point 3) showed that unalloyed copper was used for the hemispheres. Lead was detected in all parts of the suspension loop, indicating thus that a different material was used for these parts. It is impossible to state the exact content of lead originally present in the alloy, because the corroded surface was analyzed. Analyses on a

preserved area of the loop of 84-2 with visible metallic core detected 2% Pb.

The *gombik* was fire-gilt (point 1; Table 5). The gilded layer (thickness 8.3 and 11 μm) appears quite porous, due to probable incomplete burnishing (Fig. 8d). In this case, no silver was detected in the gilding. The solder (Fig. 8f) is very close to the eutectic mixture of silver and copper (Ag 71.9%, 28.1% Cu) with a melting point of 779°C, being much lower than that of copper (1084°C) [5], allowed safe soldering of the two copper hemispheres.

Gilded Copper alloy Gombik 74b-2 with Octolobed Shells and Glass Cabochons

Description (Fig. 9)

This *gombik* has a pumpkin shape (diameter 14.5 mm; height 8.8 mm) and consists of two octolobed shells (thickness 0.2 mm), soldered together (Fig. 9A₁–A₂). The top shell is perforated (Fig. 9A₂) and a suspension loop (Fig. 9D) with straight ends, made of wire (diameter 1.5 mm) is inserted in the opening at the top. A ring (Fig. 9C₂) made of two decorative round-sectioned twisted wires (diameter 0.5 mm) keeps the suspension loop in the hemisphere. The base is decorated by a similar ring (Fig. 9C₁), made of two round-sectioned twisted wires, surrounding a bezel (Fig. 9B) with a blue glass cabochon (Fig. 9E; diameter 3.3 mm). This *gombik* is made of six different components and seven parts. No pellet is inside (Fig. 9B).

Condition and quality

The *gombik* is complete but in a rather poor condition (Fig. 10a). Past chemical treatment using complexing agent (Chelaton[®]) dissolved corrosion products, leading to the loss of the gilding, in particular on the top of the lobes. (Fig. 10c and 10e). The *gombik*'s copper shell is in advanced state of mineralization and the two shells do not match well (Fig. 10a).

Scanning electron microscopy and microanalysis

SEM microanalysis on the surface of the different parts showed that unalloyed copper was used for the hemispheres

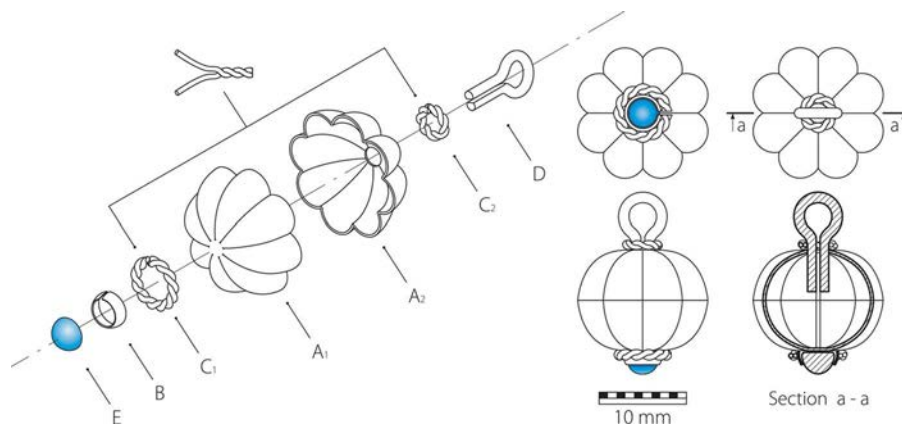


Figure 9. Gombik 74B-2: exploded view showing the different components: A₁ lower octolobed shell; A₂ upper octolobed shell; B bezel; C₁ lower twisted wire ring; C₂ upper twisted wire ring; D loop; E glass cabochon (drawing G. Plítková).

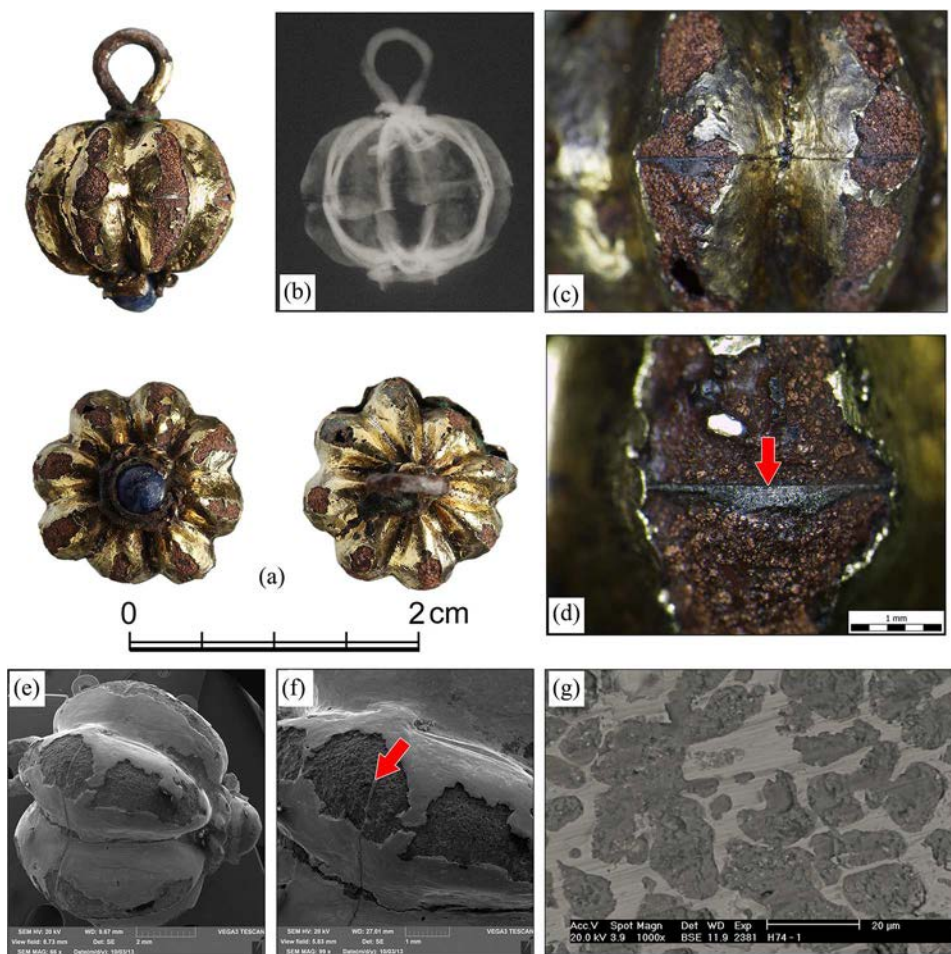


Figure 10. Gombik 74B-2: a general view (photo J. Sobek); b X-radiograph (I.Nacherová); c tarnished gilding (photo E. Ottenwelter); d solder between the two shells (photo E. Ottenwelter); e SEM micrograph (SE image) (photo Š. Msallamová); f SEM micrograph (SE image) of solder (photo Š. Msallamová); g SEM micrograph (BSE image) of solder area between two hemispheres, gombik 74B-1 (photo D. Janová).

(Table 6). A higher content of tin was found by surface analyses on bezel and twisted ring, but as they are corroded, the higher Sn content is presumably due to enrichment of tin corrosion products of the surface and do not correspond to a higher concentration of tin in the alloy. The bulk metal of the different parts was certainly unalloyed copper. The alloy used for the bezel is different, as some arsenic was detected. The *gombik* was fire-gilded, as mercury was detected. Silver is also present on the gilding layer and it is higher on surface areas where tarnishing was observed under stereomicroscope (Fig. 10c). Silver may have been part of the amalgam used to gild the *gombik*, or the object may have been initially silvered and then gilded. No fragment was available for a

metallographic analysis to check this hypothesis. The solder used to join the two shells (Figs. 10d, 10f, 10g) is a hard solder alloy of silver and copper (82.8% Ag, 17.2% Cu) (Fig. 10g).

Gilded copper alloy gombiky with granulation and glass cabochons (gombik 53-14)

Description (Fig. 11)

This *gombik* consists of two hemispheres (Fig. 11A; diameter 15 mm) shaped on a doming block and soldered together. The upper hemisphere is pierced to allow a loop with long legs (Fig. 11G) made from a bent metal strip to be inserted. A ring with circular section is soldered around it (Fig. 11F). A piece of wire fills the gap between the loop and the hole (Figs. 12e, 11H). The *gombik* is decorated with granulation (Fig. 11I) and blue glass cabochons (Fig. 11D; diameter 4.5 mm) fixed inside bezels (Figs. 11E; 12a, 12d). Beaded wires (Fig. 11C) are at top and bottom of hemispheres (Fig. 12e) and around each bezel (Fig. 12d). Four blue glass cabochons (Figs. 11D; 12d) are mounted in a bezel, placed on the connection in equidistant positions. A cabochon is on the bottom of the *gombik*. Round-sectioned wires (Fig. 11B; diameter 0.3 mm; Fig. 12c) placed vertically define four equal panels on each hemisphere. Simple wires (Fig. 11B)

Table 6. Analyses performed on gombik 74B-2.

Gombik 74B-2	Chemical composition [Wt. %]						
	Au	Ag	Cu	Hg	As	Sn	P
Shell, bulk metal (A ₂)	–	1.2	98.2	–	–	0.6	–
Twisted ring (C ₂)	–	5.8	91.4	–	–	2.3	0.5
Bezel (B)	–	0.6	95.1	–	0.9	3.4	–
Solder area between shells	–	82.8	17.2	–	–	–	–
Gilding layer (A ₁)	83.6	7.1	2	7.3	–	–	–
Gilding layer (C ₁)	82.8	6.1	1.7	9.4	–	–	–

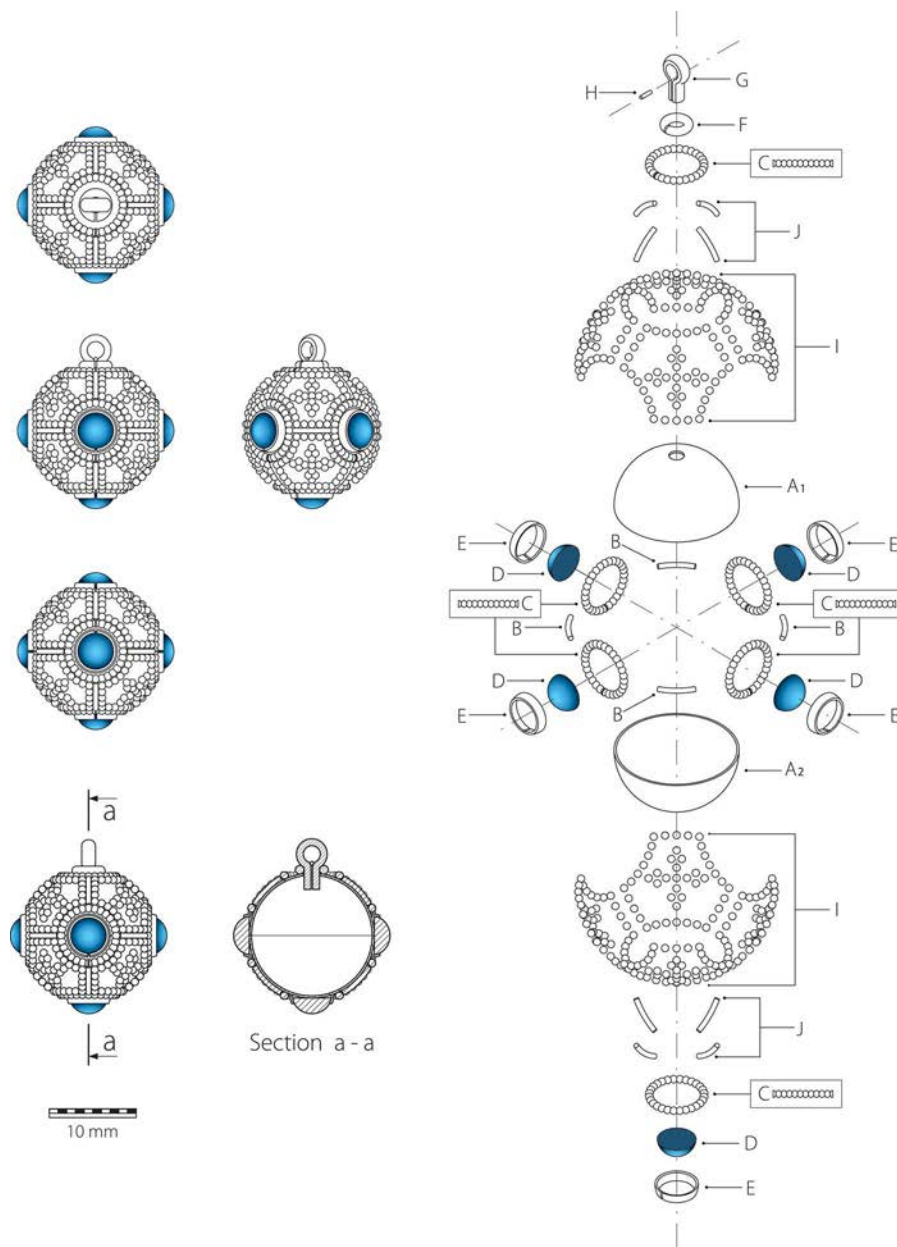


Figure 11. Gombik 53-14: exploded view showing the different components: A₁ upper hemisphere; A₂ lower hemisphere; B wires; C beaded wires; D glass cabochons; E bezels; F ring; G loop; H wire fragment; I granules; J wires (drawing G. Plítková).

are also placed on the joining area and connect horizontally the glass cabochons. Each hemisphere has four equal hexagonal panels, decorated with a granulation cross (Fig. 12b). A line of granules (diameter 0.7 mm) runs along the hexagonal panels. This type of *gombik* is made with eight different components (hemisphere, loop, ring, bezel, cabochon, granule, round smooth wire, beaded wire).

Condition and quality

The *gombik* is not complete, most of the loop and a glass cabochon are missing. The gilding layer is damaged on most granules (Figs. 12b, 12c), but is well preserved on the hemispheres. The gilding is covered by a thin layer of copper oxides, possibly silver sulfides, and has a reddish and sometimes dark color. The glass cabochons are well preserved (Fig. 12d). The granules are almost all completely mineralized.

They were partly dissolved by previous chemical cleaning. A few still contain a metallic core (Fig. 12c). The quality of the work is high.

Scanning electron microscopy and microanalysis

SEM analysis on the surface of the different components indicates that a copper alloy containing a small amount of tin was used to manufacture the *gombik*. The tin content is probably coming from the copper ore used either from an used scrap material and was not deliberately added, as the analysis of similar *gombik* 53-15 revealed use of almost pure copper (Sn 0.6%) on the surface of a granule (metallic bulk matrix).

The analysis also showed that the *gombik* was fire-gilded with an amalgam containing silver (Table 7).

The analysis of the broken loop revealed a highly mineralized material in which tin was present at a high percentage.



Figure 12. Gombik 53-14: a general view (photo J. Sobek); b granulation cross ornament (photo E. Ottenwelter); c small islands of metal are still present in the corroded granules (photo E. Ottenwelter); d blue glass cabochon in bezel surrounded by beaded wire (photo E. Ottenwelter); e suspension system (photo E. Ottenwelter).

Table 7. Analyses performed on *gombik 53-14*.

<i>Gombik 53-14</i>	Chemical composition [Wt. %]										
	Au	Hg	Ag	Cu	Sn	O	Si	P	S	Cl	Ca
Gilt layer hemisph. A	85.2	6.2	5.5	3.1	–	–	–	–	–	–	–
Bulk metal, granule I	–	–	–	97.3	2.7	–	–	–	–	–	–
Bulk metal, loop, corr. surface (G)	–	–	–	74.3	7	12.4	1	1	1	1.3	2

This may be explained by surface enrichment with tin corrosion products.

Conclusions

All *gombiky* from the Lumbe's garden cemetery are multi-component artifacts made by drawing, cutting, embossing, twisting, and soldering discs, wires, strips, bosses, granules, hemispheres. The decoration was carried out by chasing and inserting glass cabochons.

Gilded copper-based alloys were used to manufacture most *gombiky* (80%). Unalloyed copper was used for *gombiky* 84-1 and 104-4. Almost pure copper with a small tin content (2–3%) was used for *gombiky*, 115-8, 74B-2, and 53-14. Small amounts of arsenic and antimony in a copper-tin alloy were detected in the clamp and the ring of *gombik* 104-4, while only

small amounts of As were detected in the copper-tin alloy of the bezel of *gombik* 74B-2. Variations can also occur within the same object, as was observed on the components of the suspension system of *gombiky* 84-1, 115-8, 74B-2, and 104-4. Silver with a small amount of copper (2.5%) was used to manufacture the pair of *gombiky* from grave 115. Ternary Au–Ag–Cu alloys were used for the pair of two-layered *gombiky* from grave 16.

Decoration techniques include chasing and repoussé, granulation and filigree work, the use of glass cabochons, applied bosses and gilding. The chasing and repoussé technique concerns almost exclusively *gombiky* made of gilded copper alloys (84-1, 115-8, 104-4) or silver (115-7). Granulation work is found on one pair of *gombik* (H 53-14), while filigree work was used to decorate two kinds of *gombiky* (16-14, 53-14). Glass cabochons mounted in bezels decorate three kinds of *gombiky* (16-14, 74B-2, 53-14).

Gilding was extensively employed on copper alloys. All copper alloys *gombiky* are fire-gilded. Silver is almost always present in the gilding layer.

The number of different parts used in the manufacture of *gombiky* fluctuates according to the number of base components forming the plain jewels and the complexity of the decoration within each type. Three to five different components (loop, ring, clamp, hemisphere, and pellet) are employed in the manufacture of the plain *gombik*. If we also count the components of the jewels decoration, their number increases considerably, according to the complexity of the decoration. *Gombik* 74B-2 features six different components, *gombik* 53-14 has eight, and *gombik* 16-14 has a total of nine different components. If we consider the total number of components soldered to form the *gombiky*, 16-14 features a total of 51 components, whereas *gombik* 104-4 has five components. The time-consuming chasing and repoussé decoration techniques must be also taken into consideration in judging the complexity of the jewel.

The solder used to join copper-alloy components is a hard silver-copper solder often close to the eutectic composition (Ag 78%, Cu 22%). This solder was identified on *gombiky* 84-1, 115-8, and 104-4. It has not been possible to determine the soldering technique for silver alloys.

The variation in the component size and material shows that components, in particular granules and filigree, but also hemispheres, bosses, loop and clamps, were semi-finished products prepared in advance, employed when needed and sometimes made of copper from different ores.

Differences in quality, in raw material, number of components and technology can be distinguished in the various categories of jewels, and they demonstrate that the raw material came from different locations, that various technologies were employed and that a number of goldsmiths worked on this assemblage of jewels. Variations in the bulk metal used to manufacture the different components of the *gombiky* (unalloyed copper, copper alloys with a small amount of tin (2–3%), the presence of lead, arsenic, and antimony) clearly demonstrate that copper of diverse provenance were used to manufacture these objects.

Silver was detected in most cases in the gilding layer, in a percentage fluctuating from 2.3 to 6.5%, but was not present in the gilding of *gombik* 84-1. Further differences are recognizable in the thickness of the preserved gilding measured at the cross-section of available fragments. The average thickness of the recorded gilding layer is 7–8 μm , but it is two- to three-times thicker in the case of *gombik* 104-3 (19.2 to 28.8 μm) [3]. The number of parts from which the *gombiky* are composed also shows differences. The usual number of the components of the suspension loop is three (loop, clamp and ring), however, in the case of *gombiky* 74B-2 and 53-14 we only have two components (loop and ring). *Gombik* 16-14 has a total of seven components forming the suspension system. Some *gombiky* have a pellet inside (84-1, 104-4).

The size of the *gombiky* is also significant. The two largest pairs (115-6, 115-7, and 84-1, 84-2) have very standardized components. The chased and repoussé decoration is very similar too. Despite the fact that they are made of different

materials, they seem to have been made by the same goldsmith. *Gombiky* from grave 104 and 115 were manufactured by a very skilled goldsmith. *Gombik* 84-1 is probably a local product, since the gilding layer does not contain silver, unlike other gilded copper alloys from the Lumbe Garden necropolis that show similarities to Great Moravian jewels [6].

For the moment, it is difficult to compare the results of this study with jewels from other major sites of the same period, since limited studies have been published so far on the nature of the material and construction of early medieval Bohemian and Moravian jewels. Furthermore, most of the analyses were obtained by X-ray fluorescence spectrometry (XRF) on probably tarnished and corroded surfaces. The obtained results are possibly distorted. Moreover, this method cannot properly detect coatings and the solder area is usually analyzed together with the bulk metal, thus increasing the copper content. In order to compare the raw material, alloys and technology used in Bohemia and Great Moravia, it would be necessary to carry out systematic studies on similar jewels from centers of the Great Moravian Empire (Mikulčice, Staré Město u Uherského Hradiště, Rajhrad-Rebešovice, Pohansko, Nitra) as well as other important contemporaneous centers, especially from significant Bohemian sites such as Budeč and Stará Kouřim. Ideally, analyses should be done by SEM/EDS, as this method allows precise analyses of the component and solder areas. This is important in order to establish a database of comparable data. A very detailed examination of the jewels under a microscope prior to analyses and the identification of components, metallic coating, X-radiography are necessary in order to understand the construction and decoration techniques employed. The use of metallography on available fragments is also very helpful to collect more precise results than with surface analyses. The nature of past treatments performed on the artifacts also has an important impact on the results and must be evaluated. It is important to analyze freshly cleaned and uncorroded surfaces to obtain accurate results. Once these data are available, additional features will complete the typology of early medieval jewels and it will be possible to identify the origin and deduce influences of the Great Moravian Empire and possible changes in Bohemia. Local workshops and possibly local goldsmiths and trade routes might be more accurately identified.

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