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**Early medieval "gombiky" from Mikulčice:
archaeological context, function, occurrence, typology,
construction, and characterization of materials and
manufacturing processes**

Šárka Krupičková, Estelle Ottenwelter, Lumír Poláček, Luc Robbiola

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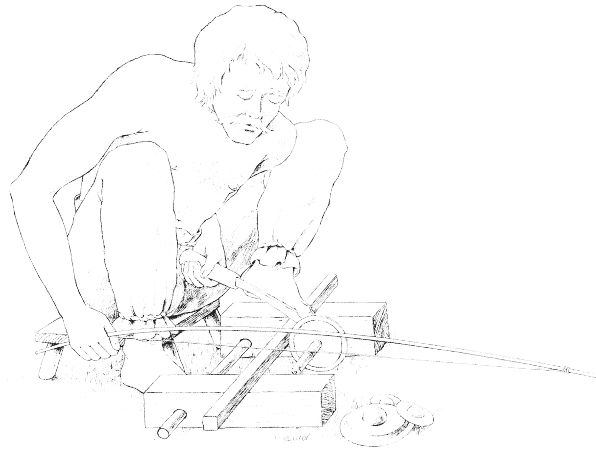
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Béla TÖRÖK
Alessandra GIUMLIA-MAIR

Layout:

Béla TÖRÖK
Boglárka TÓTH



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TABLE OF CONTENT

Preface	5		
Eulogy	7		
Committees and partners	9		
Scientific program	11		
Oral communications	11		
Posters	21		
Abstracts	25		
Oral communications	25		
Posters	100		
Social events	139		
Ancient copper metallurgy	143		
Kévin Costa, Emmanuel Dransart, Mehmet Shah, Michel Maillé: The metallurgical site of “Le Planet” (France): presentation and characterization of an original Neolithic metallurgy	145		
Céline Tomczyk, Kévin Costa, Bruno Desachy, Patrice Brun, Christophe Petit: Multivariate statistical study of lead isotopic data: proposal of a protocol for provenance determination	165		
Céline Tomczyk, Patrice Brun, Christophe Petit: Synthetic study of the emergence of primary copper sulphide metallurgy	183		
Dániel Molnár, Péter Barkóczy, János Gábor Tarbay, Béla Török: The Application of Computer Simulation on Reverse Engineering of Artefacts	193		
Roland Haubner, Susanne Strobl, Peter Trebsche: Analytical investigations on plate slags from the late Urnfield Period copper mining settlement at Prigglitz-Gasteil (Lower Austria)	205		
		Kévin Costa, Patrice Brun, Benoit Mille: Late Bronze Age new statistical and archaeometallurgical artefacts surveys from France and Switzerland (950 to 800 BCE)	219
		Stanislav Grigoriev: Development of metallurgical production in N-Eurasia and Europe and its socio-economic background	237
		Omid Oudbashi, Mathias Mehofer, Sepehr Bahadori, Ahmad Aliyari, Hasan Tala'i: The Emergence and Spread of Tin Bronze Alloying in Prehistoric Iran – The LBA Metallurgy in Sagzabad, Northern Iran	253
		Copper based alloys	271
		Alžběta Danielisová, Daniel Bursák, Ladislav Strnad, Jakub Trubač. Marek Fikrle: Life Cycles of Metals in the Iron Age (4th – 1st Century BC). Sourcing and Recycling of Copper Based Alloys	273
		Alessandra Giumlia-Mair, Athanasia Kanta: The <i>Kuwano</i> Sword from the Fetish Shrine at Knossos	289
		Alexander Maass, Angela Celauro, Stephen Merkel: «...nunc et in Bergomatium agro... » The zinc mining area in the Dossena-Gorno District near Bergamo as a possible source for Roman Brass	301
		Janka Istenič, Žiga Šmit: Non-ferrous metals in Roman (Late Republican and Early Imperial) military equipment from the River Ljubljanica, central Slovenia	329
		Milica Maric Stojanovic, Tatjana Tripkovic, Deana Ratkovic: Analyses of Ornaments on Roman Carriage and Horse Equipment from Eastern Serbia	341

Irina Zaytseva, Eduard Greshnikov, Ekaterina Kovalenko, Mikhail Murashev, Konstantin Podurets: Copper-based alloy reliquary crosses with niello decoration from North-Eastern Rus': the first studies of the niello composition and the technique of application	355	Ludmila Barčáková: The manufacture of replicas of early medieval "gombiky" from Mikulčice, Great Moravia, 9th century AD.	497
Svetlana Valiulina: Copper Incense Burner and Bronze Mirrors of the Toretsky Urban Settlement (Bolmer Town) in Tatarstan	369	Iron	509
Precious metals	391	Javier Franco Pérez, David Larreina-García, Iosu Etxezarraga, Xabier Alberdi: An insight into iron-making in the Basque Country (Northern Spain): Technical traditions from the First Millennium BC to the later Middle Ages	511
Alessandra Giumlia-Mair, Roberta Conversi, Maria Pia Riccardi: Middle Bronze Age Gold Sheet from Albareto (Parma), Italy	393	Carina Bennerhag, Lena Grandin, Ole Stilborg, Eva Hjärthner-Holdar, Kristina Söderholm: Early Iron Technology in the Circumpolar North	535
Alessandra R. Giumlia-Mair, Susan C. Ferrence, James D. Muhly, Philip P. Betancourt: New Evidence for Sophisticated Goldworking Techniques from Middle Minoan Crete	405	Costanza Cucini, Stefania De Francesco, Maria Pia Riccardi, Marco Tizzoni: Late Roman smithing workshops from Cascina Castelletto, Pioltello (Milan, Northern Italy)	551
Barbara Armbruster, Marilou Nordez, Maryse Blet-Lemarquand, Sebastian Fürst, Nicole Lockhoff, Pierre-Yves Milcent, Sylvia Nieto-Pelletier, Martin Schönfelder, Roland Schwab: Celtic gold torcs - An interdisciplinary and diachronic perspective	417	Márk Haramza, Béla Török: Metallographic examination of Hungarian Sabres from the 10th Century – first archaeometallurgical approach in the Carpathian Basin by a case study	565
Angela Celauro, David Loepp, Daniela Ferro, Tilde De Caro: Experimental and analytical study of gold parting processes used in ancient times	433	Ádám Thiele, Jiří Hošek, Nikolina AntoniĆ, Márk Haramza: Metallographic examination of nine medieval knives from Šepkovčica, Kobilic and Okuje (Republic of Croatia)	589
Réka Ágnes Piros, Viktória Mozgai, Bernadett Bajnóczi: New investigations made on the 5th-century AD horse harnesses from Untersiebenbrunn (Austria)	457	Vladimir I. Zavyalov, Nataliya N. Terekhova: The Problem of Studying Sources of Raw Materials for Medieval Craft Centers: Results from the Site of Istye 2 (Russia)	607
Šárka Krupičková, Estelle Ottenwelter, Lumír Poláček, Luc Robbiola: Early medieval "gombiky" from Mikulčice: archaeological context, function, occurrence, typology, construction, and characterization of materials and manufacturing processes	477		

Preface

The International Conference „Archaeometallurgy in Europe”, held at Miskolc in Hungary from the 19th to the 21st of June 2019 is by now a well-known and fully established international scientific meeting, at which scholars with different backgrounds can present their research on ancient metal finds, metal analysis, ancient mining, the reconstruction of various kinds of production processes, ancient technologies and every topic that belongs to metals and their transformation from ore to objects.

Our meeting at Miskolc was the fifth of a series that begun in Milan in 2003, followed in 2007 by the conference in Aquileia, both in Italy. The third was held at Bochum, in Germany, in 2011 and the fourth at Madrid, Spain, in 2015. The special aim of our 2019 conference was that of emphasizing and strengthening the interdisciplinary character and the various activities in the field of archaeometallurgy and widening the focus towards Eastern Europe.

The papers we present in this volume use scientifically collected data that allow the re-examination of aspects of archaeology and offer a view of antiquity based on materials science, supplemented by archaeological, literary and stylistic evidence, i.e. the methods by which human activities have been reconstructed in the past.

The presentation of research, availability of information, discussion and confrontation is an important side of this conference. Publishing new data and research in this frame - although in some cases only in short form - is important. The volumes of the conference „Archaeometallurgy in Europe” have been planned as a window on the world of archaeometallurgy, as general information for students, scholars and in general for anyone interested in these topics and, finally, as a tangible historical memory of the kind of studies carried out at this time. We all know that

research can be dated, just like the ancient objects we are studying. For these reasons and more, even though we received a good number of submissions, it is a pity that some interesting papers presented at Miskolc were not delivered for publication in this volume. Apparently, as it transpired at the conference, some of the authors decided to publish in a journal with impact factor. Nevertheless, a shorter or different version could have been submitted for publication in this volume as well, in particular as we know that the collection of papers, the peer-reviewing, corrections and the printing process normally take a couple of years. These volumes play an important role for our scholarly community, because they also represent an occasion for valuable corrections and discussion on weak points during the peer-reviewing stage, which is always carried out by two specialists in the field of the topic, while most journals with impact factor simply use their own reviewers, who do not know a thing about ancient metallurgy. The result is that the papers published in some journals are often less than mediocre.

We hope that the next volumes of this series will collect a larger number of papers presented at the conference, and we will be able to demonstrate once again that the frame within which archaeology can be studied is - and will be in the future - greatly enhanced by archaeometallurgical research.

We are very grateful to all reviewers and especially to the English native speakers who took the time to check the language of the papers in this volume.

To all of you a heartfelt thank you!

The editors

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Vasiliki KASSIANIDOU (Cyprus)

At the meeting of the Standing Committee that took place during the conference, Béla TÖRÖK (Hungary), Jiří HOŠEK (Czech Republic) and Miljana RADIVOJEVIĆ (UK) were nominated for membership of the Standing Committee and accepted, and an Advisory Committee without voting right was established.

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Contact:

Dr. Béla TÖRÖK
associate professor, head of institute
Institute of Metallurgy, University of Miskolc
3515 Miskolc-Egyetemváros, Hungary
bela.torok@uni-miskolc.hu
bela.torok69@gmail.com

Early medieval “*gombiky*” from Mikulčice: archaeological context, function, occurrence, typology, construction, and characterization of materials and manufacturing processes

Šárka Krupičková

Institute of Archaeology of the Czech Academy of Sciences, Brno, Čechyňská, Czech Republic

Estelle Ottenwelter

Institute of Archaeology of the Czech Academy of Sciences, Prague, Czech Republic

TRACES Laboratory (CNRS UMR 5608), Université de Toulouse, France

Lumír Poláček

Institute of Archaeology of the Czech Academy of Sciences, Brno, Čechyňská, Czech Republic

Luc Robbiola

TRACES Laboratory (CNRS UMR 5608), Université de Toulouse, France

Abstract:

This paper deals with the archaeological context, function, typology and technological study of a type of spherical hollow pendants termed *gombiky* (sg. *gombik*), which were worn by members of the Moravian elite in the 9th century AD. The *gombiky* were recovered in elite graves from Mikulčice – one of the major central places of Great Moravia. The archaeological context, occurrence in graves and function of these enigmatic objects are discussed. Their typology and construction based on their decorative technique are presented. In order to determine the metal composition, construction, and manufacturing processes of these types of ornaments, several specimens were investigated by stereomicroscopy (Olympus SZ60), X-ray radiography and scanning electron microscopy (SEM), supplemented by electron microanalysis (EDS). Replicas of each main type of *gombik* were manufactured by a professional goldsmith to understand the different stages of manufacture and soldering techniques. The results have evidenced the use of high purity gold alloys, silver alloys, gilded copper, different types of soldering techniques (diffusion bonding, hard solder), fire-gilding, specific tool marks and masterful chasing, filigree and granulation. The research provided a better understanding of the construction, manufacturing and soldering techniques and the stages of fabrication of this type of jewellery.

Early medieval “*gombiky*” from Mikulčice: archaeological context, function, occurrence, typology, construction, and characterization of materials and manufacturing processes

Šárka Krupičková
Estelle Ottenwelter
Lumír Poláček
Luc Robbiola

Introduction

This paper deals with the archaeological context, function, typology and technological study of a specific early medieval artefact – a spherical hollow button, named *gombik*. This artefact appears in the material culture of Great Moravia – the first Slavic early state located in present southeast Moravia (Czech Republic) and southwest Slovakia, along the Morava river basin (Fig.1a, Fig 1b). Great Moravia emerged at the turn of the 8th and 9th centuries and lasted one hundred years. It was destroyed at the beginning of the 10th century under the attack of the ancient Magyars. The Great Moravian territory was represented mainly by fortified centres – so-called strongholds – and their religious architecture. The seat of the Moravian ruler may have been Mikulčice Stronghold, where the largest concentration of religious architecture was recognised with the remains of ten churches (Fig.1c). The most important group of graves were found in the church cemeteries. The elite’s graves are particularly rich. Men are buried with weapons – swords, axes, spears, spurs and dress fittings, buckles and strap ends with incrustation of precious

metal, cross-pendants, and sometimes jewellery including *gombiky* while women are buried with a lot of jewellery – earrings, rings, pendants, beads or whole necklaces and the so-called enigmatic *gombiky*. *Gombiky* played a specific role in the Great Moravian material culture. They were used as prestigious clothing fasteners or pendants, as well as luxurious amulets usually found in pairs in the wealthiest graves and we can categorise them among the elite attributes. There are several types of *gombiky* which can be classified according to their composition (gold, silver or copper-based alloys), construction and techniques of decoration. A technical study aiming to characterise the materials and manufacturing processes used in the manufacture of the main representative type and materials was conducted using SEM/EDS analysis, and X-ray radiography. A replica of each type of *gombik* was fabricated (see the contribution of L. Barčáková in this volume). This study follows the detailed work on gilded *gombiky* from Mikulčice and Prague Castle (Ottenwelter et al. 2020), and presents a global vision of *gombiky* manufactured in different materials (gold, silver and copper alloys).

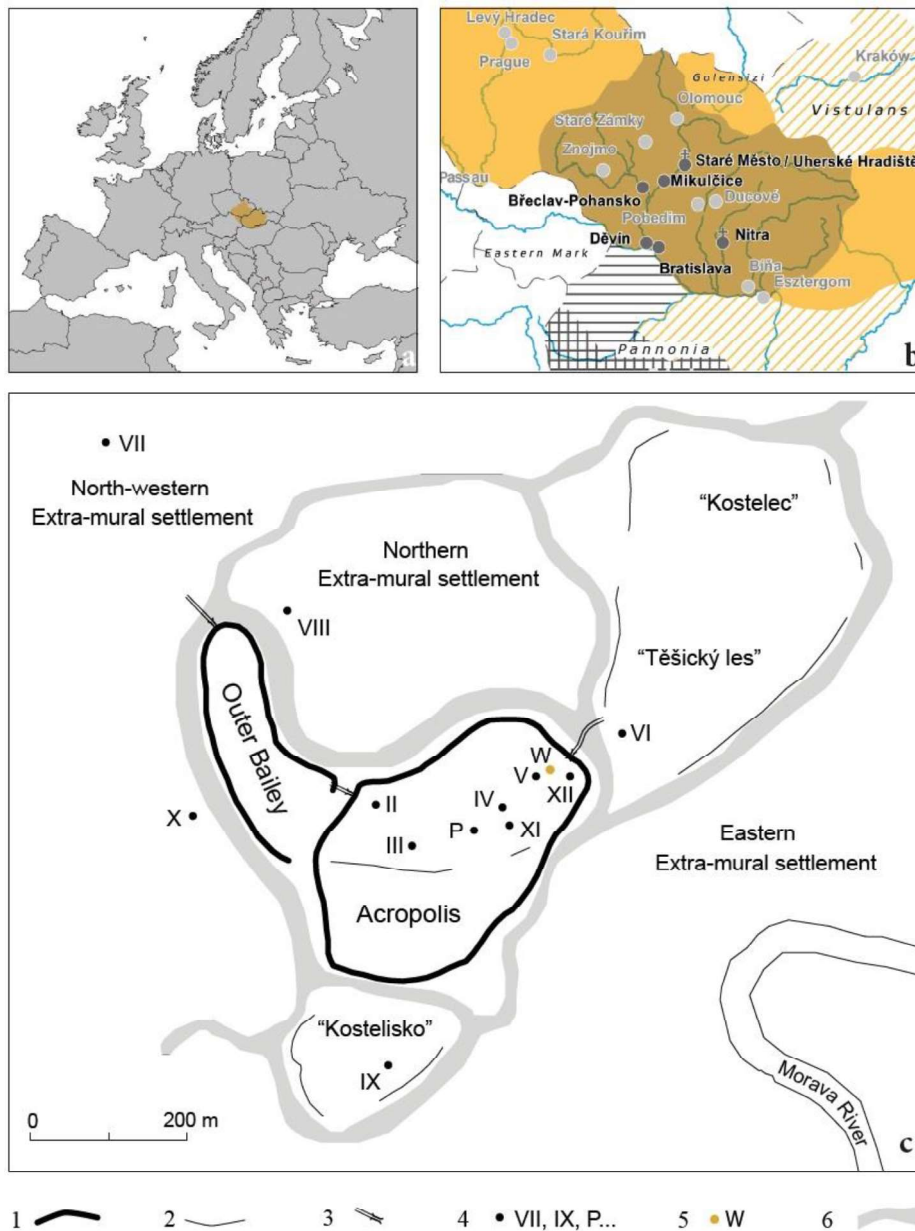


Fig. 1: Localization of Great Moravia (a, b) and the Mikulčice Stonghold (c) with visualization of the recovered buildings: 1– fortifications, 2– significant terrain boundaries, 3– gateways and bridges, 4– churches with their number (II-XII) and palace (P), 5– metal- casting workshop (W), 6– silted up river branches (after Kouřil ed., 2014, 12–13; Poláček 2018, 68–69; graphics by M. Vlach and L. Zahradníková).

Archaeological context, occurrence and function

Over 600 exemplars of *gombiky* have been recovered from Great Moravian graves so far (Pavlovičová 1996, 95), among which 376 pieces come from Mikulčice. The majority of the *gombiky* from Mikulčice are made from gilded copper (153 pcs.), followed by silver alloys (112 pcs.) and to a much smaller extent, gold alloys (19 pcs.) or a specific combination of materials (13 pcs. gilt silver, 1 pc. silver-plated copper alloy; 17 pcs. from copper; 7 pcs.

from iron, 1 pc. from lead; 4 pcs. remain unspecified and 49 pcs. are glass buttons) (Krupičková in preparation).

The number of graves with *gombiky* varies ordinarily between 6 and 11.5% at the central graveyards (Chorvátová 2009, 14–16), but in Mikulčice the percentage increases to 15%. On the other hand, the occurrence of metal *gombiky* in the hinterland and in the countryside is low and *gombiky* are represented in a very few graves. Therefore, it is evident that the presence

of *gombiky* is connected to the presence of the elite in the central places. The hinterland's graves with *gombiky* might document the burials of the local chiefs working for the central elites.

Gombiky were found mainly in children's graves (girls' graves according to the other associated grave goods) or in adult female's graves, but they are also present in male graves (Chorvátová 2009, 14–16). The occurrence of *gombiky* in the graves of Mikulčice follows the general trend in Moravia—54% of *gombiky* were found in children's graves (age categories *infans I*, *infans II*), and 37% in the graves of adolescents and adults (age categories *juvenis*, *adultus*, *maturus*, *senilis*), among which there were 19% of female graves, 13% of male graves and 5% undetermined graves. It is surprising that *gombiky* do not belong to a specific gender. This is unusual in the context of other European early medieval societies such as the Viking or Frankish environment, in which grave goods are strictly gender separated (Krupičková in preparation).

Gombiky are found most often in pairs near the collarbones. However, we have also evidence of graves with more pairs of *gombiky* in this position or just one single *gombik* near the throat or on the chest. The function of these artefacts remains unclear. We have clear evidence that some of them were used as buttons (Fig. 2a). Textile parts of an eyelet from the original garment are preserved on a pair of *gombiky* from Mikulčice's graves No. 498 and 889. The eyelets were threaded through the *gombik*, stitched to the fabric, and were

intended as fasteners. They also served to attach the *gombik* to the fabric (Krupičková et al. 2019, 59–64). On the other hand, we also have evidence that small glass *gombiky* were used as pendants in necklaces). These are threaded on a string with other pendants and ornaments such as copper coils (Fig. 2b). *Gombiky* used as pendants are mainly made of glass, which are more typical for the hinterland of the centres and the countryside than for central graveyards like Mikulčice. Over 50 published pieces of evidence of *gombiky* used like pendants are known from the former Great Moravian territory (Krupičková et al. 2019, 65–69). A single case comes from Mikulčice, from grave No. 472, where a pair of copper alloy *gombiky* was found associated with a necklace (Klanica et al. 2019, 81–82). It cannot be excluded that *gombiky* found near collarbones with beads might indicate the presence of a specific decorative ornament hanging across the chest, like those found in northern and eastern Europe (e.g. Martin 1995, 43–44; Jørgensen et al. 1997, 59, Fig. 46; Ajbabin and Chajredinova 2009, 118, Taf. 146; Ierusalimskaja and Borkopp 1996, 46; Ierusalimskaja 2012, 61, 68, 74).

Gombiky could also have a further function since some of them contain a metallic pellet, which makes them jingle like bells. The frequent occurrence of the *gombiky* in children's graves together with the sound-effect might link them to an apotropaic function. This is the usual interpretation of the finds of jingle bells, the largest concentrations of which occurs in children's graves (Smetánka 2003, 11–16).



Fig. 2: Exact evidences of using *gombiky*: a – *gombiky* Inv. No. 1174a/57 and 1174b/57 from grave 498, employed as buttons and b – glass *gombik* and bead from grave No. 391/55 from Dolní Věstonice – Na pískách, employed as necklace-pendant (after Krupičková et al. 2019, 58, 64).

Typology

Gombiky are a composite of several typologically consistent components, and they can be divided into 3 construction types: two hemispheres, a single globe and collar and finally a combination of both forms (Fig. 3).

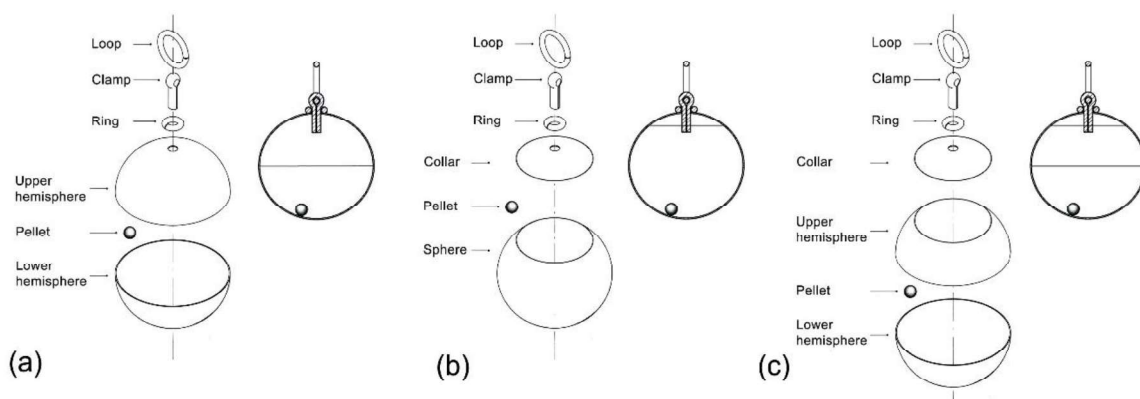


Fig. 3: Three types of construction (drawing G. Plítková in Ottenwelter et al., 2014, p. 171, modified by L. Zahradníková).

This basic construction is decorated on the surface with different techniques. The detailed typology of *gombiky* is based on the type of decoration (Tab. 1). The most common type are chased *gombiky* with vegetal, simplified geometrical or animal motifs. So far, there are 164 pcs (44%) of chased *gombiky* in Mikulčice. Most of them are decorated with a palmetto motif. The second most common group is represented by the granulated type (68 pcs., 18%), where the granulation work covers the entire surface or creates a geometrical design. The two prevailing types are complemented with other decoration techniques including rich filigree work, applications of bosses, beaded wires, twisted wires, corrugated strips or settings of glass cabochons. This less common group is represented in Mikulčice with 34 pcs. (9%) (Krupičková in preparation). A low percentage of *gombiky* are not decorated (15 pcs., 4%). It is currently impossible to define the decoration type for 29 pcs which were damaged by an accidental fire (8%). The remaining specimens are glass and iron *gombiky* made with another technology).

Materials and manufacturing processes

A total of 38 representative metallic *gombiky* from Mikulčice (4 specimens in gold, 21 in silver and 13 in gilded copper alloys) was

The suspension system is usually made of three elements: a loop, a staple and a ring, but sometimes there are made of only two components: a split loop and a ring (Ottenwelter et al. 2020).

investigated at the Institute of Archaeology of the Czech Republic, Prague to identify the metal composition of the different components, identify the mounting of the *gombiky*, the processes involved in their manufacture and tool marks and repairs (Ottenwelter 2018, 2019, 2020a; Ottenwelter et al. 2020; Ottenwelter 2020b, Ottenwelter in press). The analyses were performed on the sub-surfaces (Sub-surfaces were created by micro-scratches performed on the surface with a scalpel under a microscope) and cross-sections - when available - to limit the impact of corrosion and surface enrichment which can distort results (Blakelock 2016, 918). The investigation methods followed the methodology set up for the study of the early medieval jewellery from the Lumbe Garden at Prague Castle (Ottenwelter et al. 2014). It included observation under a stereomicroscope, X-ray radiography, analysis of each component and the solder area with SEM/EDS, metallography, when fragments were available, manufacture of replicas by a professional goldsmith (see article of L. Barčáková in the same volume), measurement of each component, and weighing of the gold and silver alloy *gombiky*. The SEM observation and EDS elemental analysis were performed on a PHILIPS XL30 Scanning Electron Microscope equipped with an energy-dispersive X-ray

spectrometry (EDAX system), operated by J. Janová in the Department of Structure and Phase Analyses (Faculty of Mechanical Engineering VUT in Brno, Czech Republic).

In this paper, six representative *gombiky*, two for each material will be presented in detail as case studies. The analyses were performed on each component and solder area to characterize the materials and the soldering techniques. The decoration techniques, including granulation, filigree work and gilding were also investigated. The different steps of the manufacture are presented in detail in the contribution of L. Barčáková in this volume.

Gold

Four gold alloy *gombiky* were investigated. Among them are exquisite specimens demonstrating high goldsmithing skills. Two specimens will be presented here: a so-called “two layered” *gombik* made with a rich decoration of filigree and granulation and a small chased piece (more about golden artefacts from Mikulčice in Kouřil-Poláček 2013).

“Two-layered” *gombik* 594-1122b/57 (177š)

This *gombik* was discovered in Mikulčice-Valy, in grave 505, near the third church (basilica). It belonged to a wealthy adult female (20-30 years old). The grave goods included three pairs of *gombiky*, seven earrings in gold and silver alloys, gilded copper belt fittings in form of a codex, and a knife (Klanica et al. 2019, 94-95, 269).

The *gombik* is complete and in good condition. The *gombik* has a total height of 26 mm and a diameter of 17 mm. It weighs 10.1 g. It consists of two hemispheres and has a two element (split loop - ring) suspension system (Fig. 4b), made of a semi-circular sectioned split loop inserted in a boss and straightened by two rings of different diameter made of tight twisted strips (Fig. 4c). It is intricately decorated with filigree and granulation work (Fig. 4a). Decorative components include 6 bosses, 24 undulating strips decorated by 2 double rows of granules, 24 omega-shaped strips, 13 rings of tight twisted strips with two different diameters and approximately 1600 granules with a diameter of 0.5 mm.

A total of seven different types of components were manufactured to produce this *gombik* (hemisphere, split loop, tight twisted strips, boss, undulating strips, omega-shaped components, granules) and approximately 1670 components had to be soldered together.

The *gombik* is decorated with 6 bosses, four placed on the joins of the hemispheres, one on the centre of the upper hemisphere and the last one on the centre of the lower one (Fig. 4a). The omega shaped ornaments are soldered as mirrored pairs (Fig. 4g). Four pairs are placed longitudinally along the joining area of the two hemispheres; four are placed on the upper hemispheres and four on the lower hemispheres, horizontally at the middle of each quarter. The undulating strips are ornamented with a double row of granules, soldered on the edges (approx. 60-70 granules per strip). The strips are soldered to the bosses between two rings of tight twisted strips creating a two-layer effect (Fig. 4c, d, f). The suspension system is inserted in the upper pierced hemisphere (Fig. 4c) and soldered with patches of hard solder, some of which are still visible on the object (Fig. 4e, i).

SEM/EDS elemental microanalysis performed on the different components and solder areas as shown on Fig. 4 are demonstrating that the different components were made of ternary alloys of Au-Ag-Cu with an average percentage of 90 wt.% Au, 5.2 wt.% Ag and 4.8 wt.% Cu (Tab. 2, object 1). The gold alloy used is of high purity and matches the composition of Byzantine jewellery (Oddy- and La Niece 1986). Patches of solder that failed to melt are visible on the hemisphere under an undulating strip (Fig. 4c, e, i). The analysis performed on the solder patches (point 12) showed that a hard Au-Ag-Cu solder with a slightly higher percentage of Ag (6.9 wt.%) and a higher copper content (13.8 wt.%) than the bulk metal was used to assemble the different components as well as the granulation work (Fig. 4f). The temperature differential varies from 65°C to 100°C below the melting temperature of the soldered alloy. The goldsmith had therefore quite a convenient temperature differential to solder safely the different components. This *gombik* required a very high level of technological skill. The goldsmiths had an excellent knowledge of the material and soldering technique. This is the most time-consuming type of *gombik* found at Mikulčice (see the presentation of L. Barčáková in this volume).



Fig. 4: *Gombik*, 594-1122b/57 Mikulčice: a-general view; b-detail of upper part of the *gombik*; c-detail of the twisted strip around the split loop; d-detail of filigree and granulation work; e-unmelted patches of solder; f-detail of granulation work on undulating strips; g-detail of omega shaped ornaments soldered on the hemispheres; h-detail of the decorative components, SEM micrograph, SE image (photo J. Janová); i-unmelted patch of solder, SEM micrograph, SE image, photo D. Janová. (Photo E. Ottenwelter).

Chased *gombik* 1897/57 (246/š)

This small *gombik* was found on the surface at Mikulčice-Valy. It is complete and in a good condition.

This piece is a small *gombik* with a total height of 17 mm, a diameter of 16 mm, and a weight of 3.7 g. It consists of a single globe, a collar and a two elements suspension system (split

loop-ring) (Fig. 5a). The wire used to form the split loop was hammered to a square 0.8 mm wide section (Fig. 5b). A round section wire (0.8 mm diameter) was used to manufacture the ring.

The manufacture of this *gombik* required only four components (globe, collar, split loop, ring).

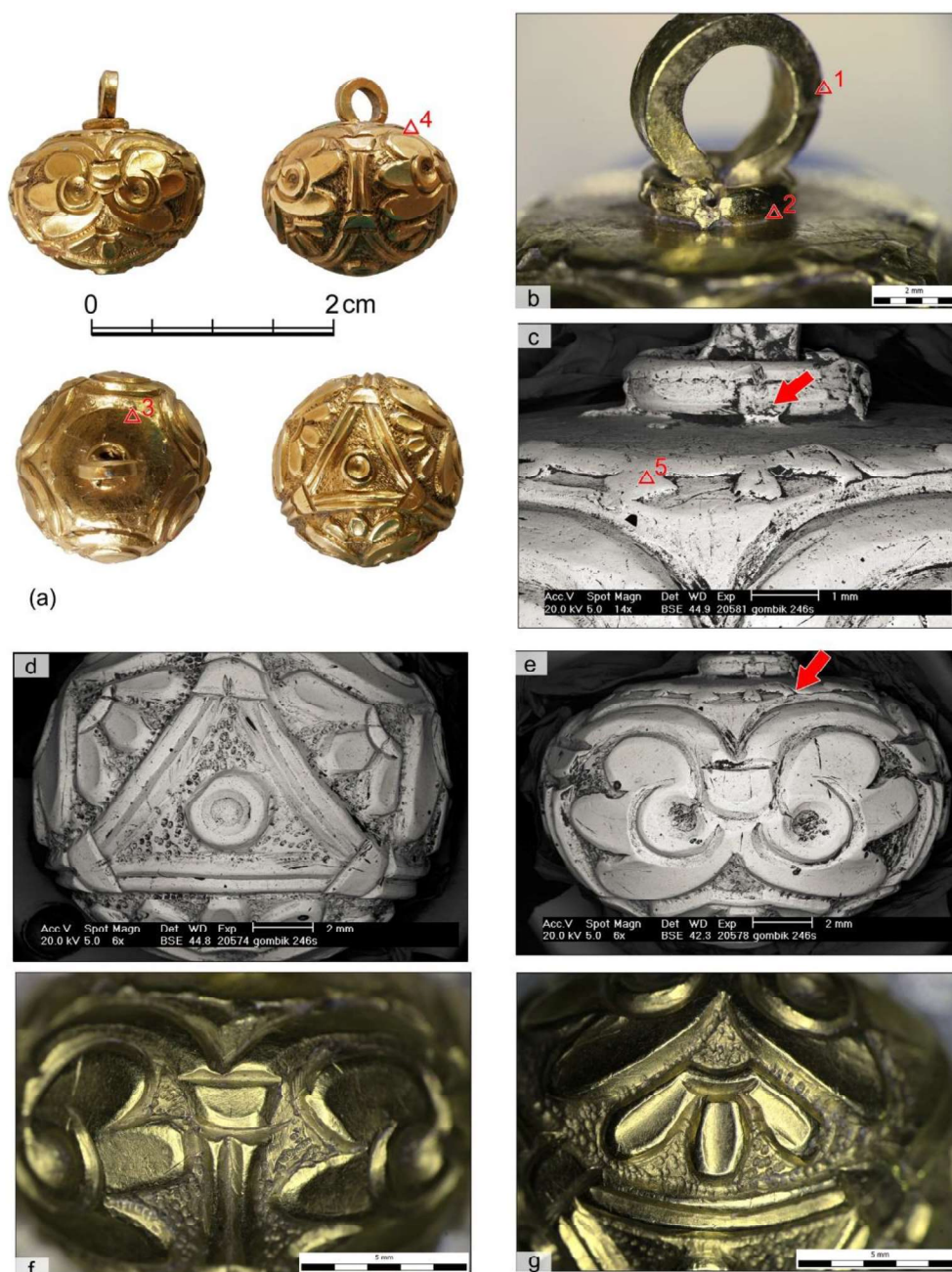


Fig. 5: *Gombik* 1897/57, Mikulčice: a-general view; b-detail of soldered loop; c-unmelted patches of solder, SEM micrograph (BSE image, photo J. Janová); d-detail of lower part, SEM micrograph (BSE image, photo D. Janová); e-unmelted patch of solder, SEM micrograph (BSE image, photo D. Janová); f-g-detail of the chased decoration on a dotted background. (photo E. Ottenwelter).

It is decorated by chasing with a motif of a single palmette between arcades on a dotted background (Fig. 5a, d, f, g).

The chased decoration was done after filling the globe with chaser's pitch. After the pitch was removed, the suspension system and the collar were soldered to the globe with patches of hard solder (see contribution of L. Barčáková in this volume).

SEM/EDS elemental microanalysis carried out on the surface of the different components and solder localized in Figure 5 showed that the different parts were made from ternary alloys of Au-Ag-Cu with an average weight percentage of 79 wt. % Au, 17.5 wt. % Ag wt. 3.5 % Cu (Tab. 2, object 2). Hence a lower grade gold alloy was used to produce this *gombik*. Unmelted patches of solder are visible on the joining area between the hemisphere and the collar and between the ring and the collar (Fig. 5c). The analysis of the patches (point 5) revealed that a hard Au-Ag-Cu solder similar to the bulk metal but with a slightly higher percentage of Ag and Cu (72.5 wt. %, Au 22.7 wt. % Ag, 4.8 wt. % Cu) was used as solder material. The melting points of both materials are very similar, which explains why the patches were not melted entirely since the differential temperature between the bulk metal and the solder is only 30°C. The soldering process must have been particularly risky.

This *gombik* was made in a lower grade of gold to the previous *gombik*. The chemical composition of the solder revealed a bad choice of material to solder the different components safely and the stippled background is rather irregular and coarse. The goldsmith who produced this ornament was less skilled than the goldsmith who produced the previous *gombik*.

Silver

Twenty specimens in silver from Mikulčice were investigated. Two representative specimens are presented here in detail: a fine chased *gombik* and a *gombik* with rich granulation work.

Chased *gombik* 594-1300b/56 (63/š)

This *gombik* was found at Mikulčice-Valy, 3rd church (basilica), in grave 216, where an adult

female of 20-30 years of age was buried. Grave goods included a pair of identical silver *gombiky*, a third *gombik* and a knife (Klanica et. al 2019, 26, 177).

The *gombik* is not complete. 95% of the piece is preserved. The suspension system was missing and was completed with modern components. Part of the decoration (blue glass cabochons) is also missing.

This *gombik* has a diameter of 40-mm and a total height of 48 mm. It weighs 18.7 g.

Its construction is of type 1: two hemispheres (Fig. 6c) and a three-component suspension system (loop-staple-ring). The loop has a diameter of 9.6 mm. Its section is irregular and bears heavy traces of coarse filing (Fig. 6b). The staple is flat and 4 mm wide (Fig. 6b): it is a modern repair. Three rings of beaded wire of different diameter (9-6-5 mm) were soldered around the staple and inserted in a bezel of 8.2 mm diameter (Fig. 6b). The *gombik* was decorated by blue cabochons set in bezels and surrounded by a line of small granules.

A total of nine different components were manufactured to produce this *gombik* (hemisphere, loop, staple, three different diameter rings, bezel, blue cabochons, small granules), 6 constitutional components and approximately 300 decorative components (bezels, blue cabochons, granules, filigree rings).

A vent of 1.4 mm diameter was pierced in the upper hemisphere (Fig. 6d, Fig. 6f) to avoid bursting of the two hemispheres during soldering.

The entire surface of the *gombik* is decorated by chasing (Fig. 6a). It is divided in nine fields by ribbons (three on the upper hemisphere, three on the joining area and three on the lower hemisphere). The nine fields on the upper and lower hemispheres are decorated with 8 petal flowers (Fig. 6i), except one field which is decorated with a 12 petal flower (Fig. 6f). The fields on the joining area are decorated by a floral motif with four petals (Fig. 6a), and divided by ribbons defining rhomboids. A blue glass cabochon was originally set in a bezel at the four corners of the rhomboid (in total 10). The cabochons are still preserved on the other *gombik* from the pair, but are missing on this specimen. A line of granules (0.4 mm diameter) and a filigree ring decorate the bezels (Fig. 6e,

g). A regularly stippled background can be seen around the chased motifs.

Ternary alloys Ag-Cu-Au and binary Ag-Cu alloys were used in the manufacture of the different *gombik* parts as shown in Table 2

object 3. The average composition of alloys used is 93 wt. % Ag, 6 wt. % Cu and 1.7 wt. % Au. A hard Ag-Cu hard solder, close to the eutectic composition was used to solder the two hemispheres together (point 12).

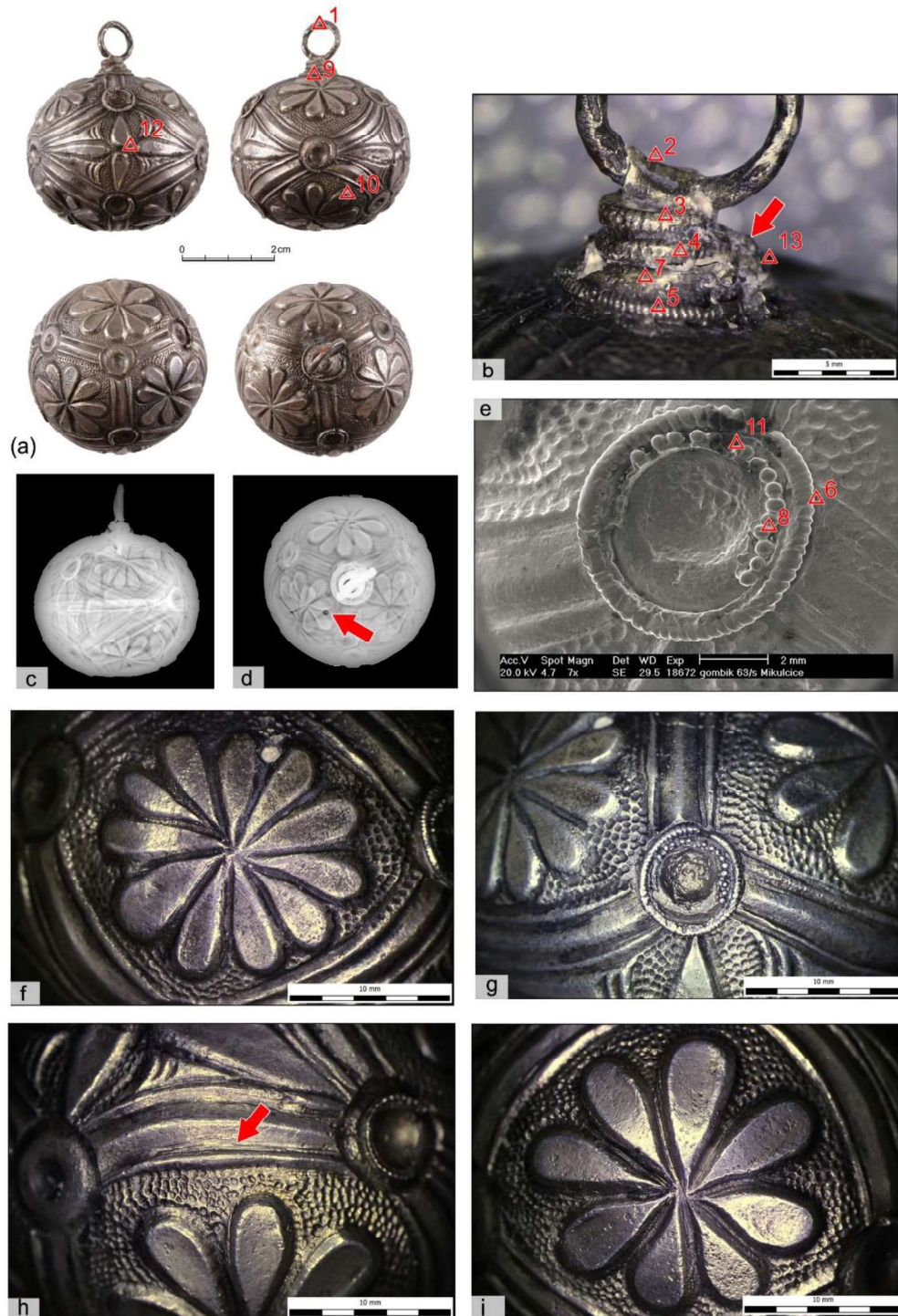


Fig. 6: *Gombik* 594-1300b/56, Mikulčice: a-general view; b-detail of suspension system; c-X-ray radiographs of the *gombik*; e-filigree ring and line of granules around missing glass cabochon, SEM micrograph, SE image (photo. D. Janová); f-12 petals flower; g- bezel with missing cabochon; h-chasing grooves; i-eight petal flower (photo. E. Ottenwelter).

The gold content here can be linked to the use of a gold-rich silver. Where the gold content is higher (3-10wt%), it can be due to recycling of outmoded jewellery or scrap metal including gilt silver pieces (Merkel 2016, 69). Gold-rich silver alloys are quite typical of Moravian silver elite jewellery (Machaček et al. 2016, 90-93; Ottenwelter 2019, 2020).

A modern repair (Fig. 6b) using a modern alloy containing Ni and Zn was identified on the suspension loop system (point 13). The staple is probably modern as well.

The *gombik* has an indifferent quality of chasing, as the motifs, and in particular the flowers, are rather irregular. The suspension

loop system was coarsely repaired in modern times and is probably far from its original look.

***Gombik* 1124b/57 (181/š) with granulation work**

This *gombik* was found at Mikulčice-Valy, in grave 505, church 3 (basilica), together with the first *gombik* made of gold presented in this study.

It is a medium sized *gombik* of 25 mm in diameter with a total length of 34 mm (Fig. 7a) and a weight of 17.4 g. The *gombik* is complete but several granules are missing.

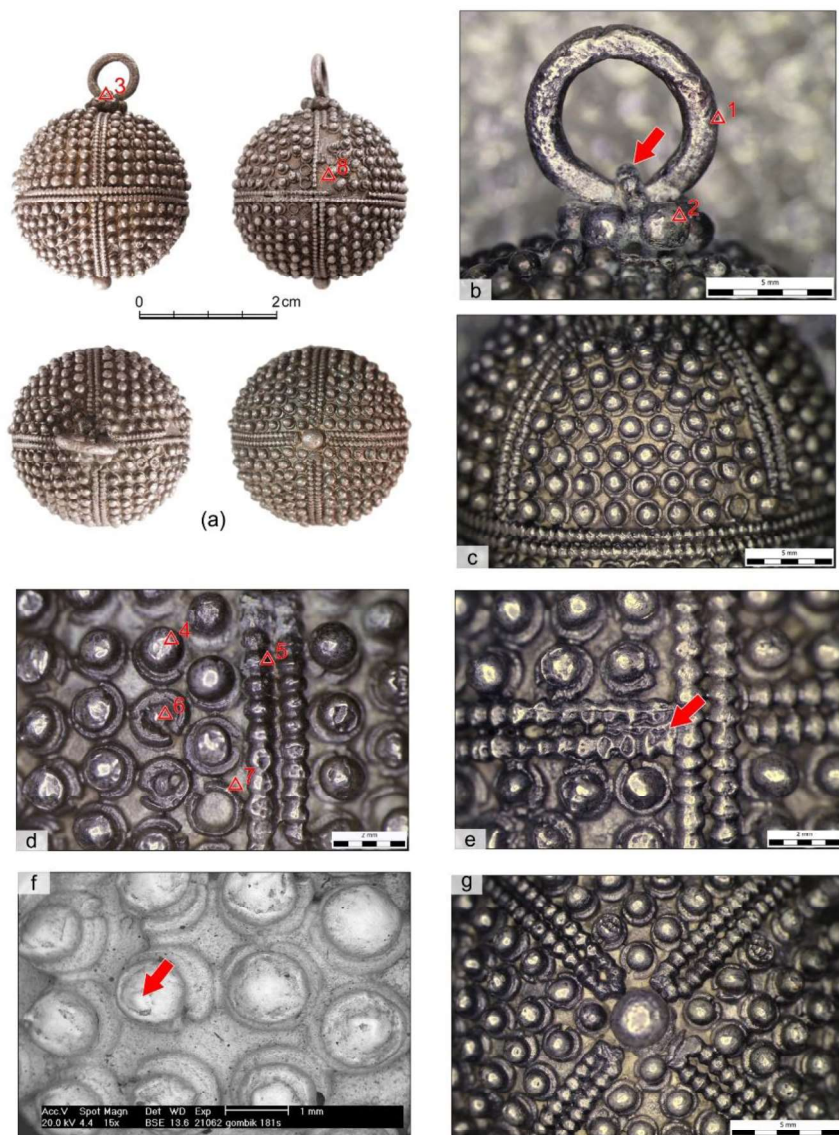


Fig. 7: *Gombik* 1124b/57, Mikulčice: a-general view; b- detail of suspension system; c-detail of granulation work; d-detail of granulation and missing granules; e-detail of beaded wires; f-detail of half molten solder fragments on granules; g-detail of large granule in the centre of the lower hemisphere of the *gombik*. Photo E.

Ottenwelter

Its construction is of type 1: two hemispheres, a split loop of 7.5 mm diameter with a round section of 1.5 mm (Fig. 7b). The ring is made of a ring of granules of 2 mm diameter (6 in total). There is no staple, but a fragment of beaded wire of 0.8 mm diameter closes the split loop (Fig. 7b). The *gombik* is decorated with double lines of beaded wire that divide the hemispheres into quarters (Fig. 7a). Each quarter is decorated with granules of 1.3 mm diameter set on a tiny plain filigree ring of 1.6 mm diameter. A larger granule (2.7 mm diameter) set on a beaded wire ring of 3 mm diameter decorates the centre of the lower hemisphere (Fig. 7g). The *gombik* is made of 5 components (two hemispheres, a split loop, a ring of 6 granules, and a fragment of beaded wire) and 939 decorative components (beaded wires, granules and filigree rings).

Ag-Cu-Au ternary alloys with an average composition of 94.8 wt % Ag, 3.8 wt. % Cu, and 1.4 wt. % Au were used to manufacture the different components of the *gombik* as shown in Table 2, object 4.

The gold content measured on the different components fluctuates on this *gombik* more than in the previous one. It is probable that the different pieces were made from recycled silver including gilt silver. A higher percentage of copper (4% higher than in the item) was detected in the solder area where granules are missing (point 6). A hard Ag-Cu solder, probably applied as fine filings was used to solder the different components including the granules, since small half-molten pieces are still visible on the surface of the granules (Fig. 7f) and molten beaded wires are visible (Fig. 7e). A modern solder was used to solder the granules forming the ring (point 3).

This *gombik* is a fine jewel. The granulation work is regular, nevertheless, several granules have fallen off and the soldering technique is rather coarse. The beaded wires may have been made in a swage block.

Gilded copper

Twelve gilded copper *gombiky* from Mikulčice were investigated (Ottenwelter et al. 2020). Here two specimens of chased *gombiky* will be presented in detail.

Chased *gombik* 594-976a/58 (220/š)

The *gombik* was found in grave 662, Mikulčice-Valy, in the graveyard of church 3 (basilica). It was a grave of a female child aged 4 years, which contained two *gombiky* made of gilded copper, one silver *gombik*, and one silver grape-shaped earring.

The condition of the object is very good. It is sound and complete.

This *gombik* has a total height of 33 mm, and a diameter of 28.6 mm diameter. It weighs 9 g. It consists of two hemispheres soldered together (Fig. 8a, e). The suspension system is made of three elements (Fig. 8b); a loop, a staple and a ring. The staple is inserted in the upper hemisphere through a hole and surrounded by a small ring made of a tightly twisted strip (Fig. 8b). The loop was hammered (Fig. 8b). The decoration was produced by chasing (see the contribution by L. Barčáková in this volume for the description of the different steps of manufacture).

The *gombik* is made of five components in total (two hemispheres, a loop, a staple and a ring).

The upper hemisphere was repaired during the manufacture of the object (Fig. 8c, 8e). The *gombik* was gilded after soldering of all the components and chasing.

The entire surface of the *gombik* is decorated. It is divided into six medallions, four around the equator of the *gombik*, one on the top, and one on the lower pole. All medallions, with the exception of the one at the top, show a flower with six symmetrical petals (Fig. 8a).

The hemispheres of the *gombik* are made from unalloyed copper (Tab. 2, object 5). Tin was evidenced in the staple suggesting that another material was used to produce the staple. An Ag-Cu hard solder was used to join the two hemispheres together. The joining area is well visible on the X-ray radiography (Fig. 8e). The solder usually smears around the joining area and should not be interpreted as a silver plating (Ottenwelter 2014, 173). Ag-Cu hard solders have a lower melting temperature than the components to be joined which allows safe soldering. Ag-Cu solders were commonly used to join copper alloys but also silver alloys components.

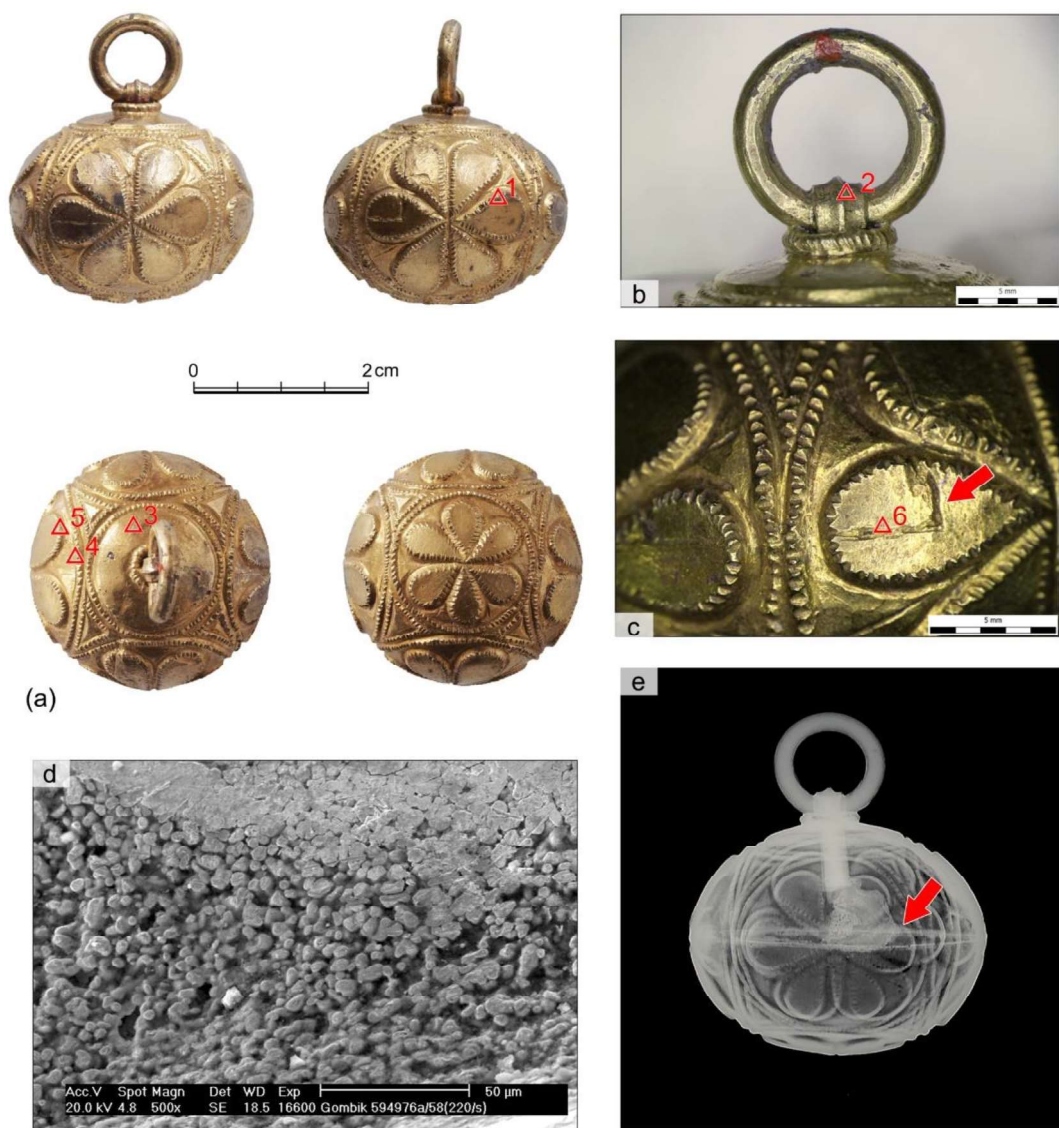


Fig. 8: *Gombik* 594-976a/58, Mikulčice: a-general view; b- detail of suspension system; c-detail of repair; d-detail of unburnished gilding layer observed in a recess; e-X-ray radiograph of the *gombik* (L. Barčáková). Photo E. Ottenwelter.

Gilding was performed by fire-gilding (mercury was determined in the gilding). The typical granular structure of fire-gilding after evaporation of the mercury is visible in recesses (Fig. 8d). Silver is also present in the gilding layer.

This *gombik* shows an extremely precise chased decoration and is of high-quality work.

***Gombik* 594-1038/57a (115/z)**

This *gombik* was found at Mikulčice-Valy, church 3 (basilica), in grave 508. A male (?) of 50-60 years of age was buried in the grave with

two pairs of gilded and chased *gombiky*, a pair of spurs, and perhaps a dagger (Klanica et al. 2019, 96-97, 271).

This piece is incomplete. The split loop is broken.

This example is small, with 15-mm diameter, and a weight of 2 g. It is consisting of two hemispheres, but with only two elements forming the suspension system (split loop-ring). The loop is broken (Fig. 9b) and only the legs inserted in the upper hemisphere are still present. They have a rectangular section of 1.7 mm and 0.5 mm. Two beaded rings of

different diameters (5.6 and 4 mm) are soldered around the loop remains. Three pellets were identified inside the body (Fig. 9d).

The *gombik* is composed of 8 components in total (a split loop, two beaded rings, two hemispheres and three pellets).

This piece is decorated by chasing (Fig. 9a). Three arcades define three medallions, in which birds of prey are represented on an irregularly stippled background (Fig. 9c). On the upper and the lower pole, vegetable motifs are represented in a triangle (Fig. 9f).

The different components were made of copper alloys (Tab. 2, object 6).

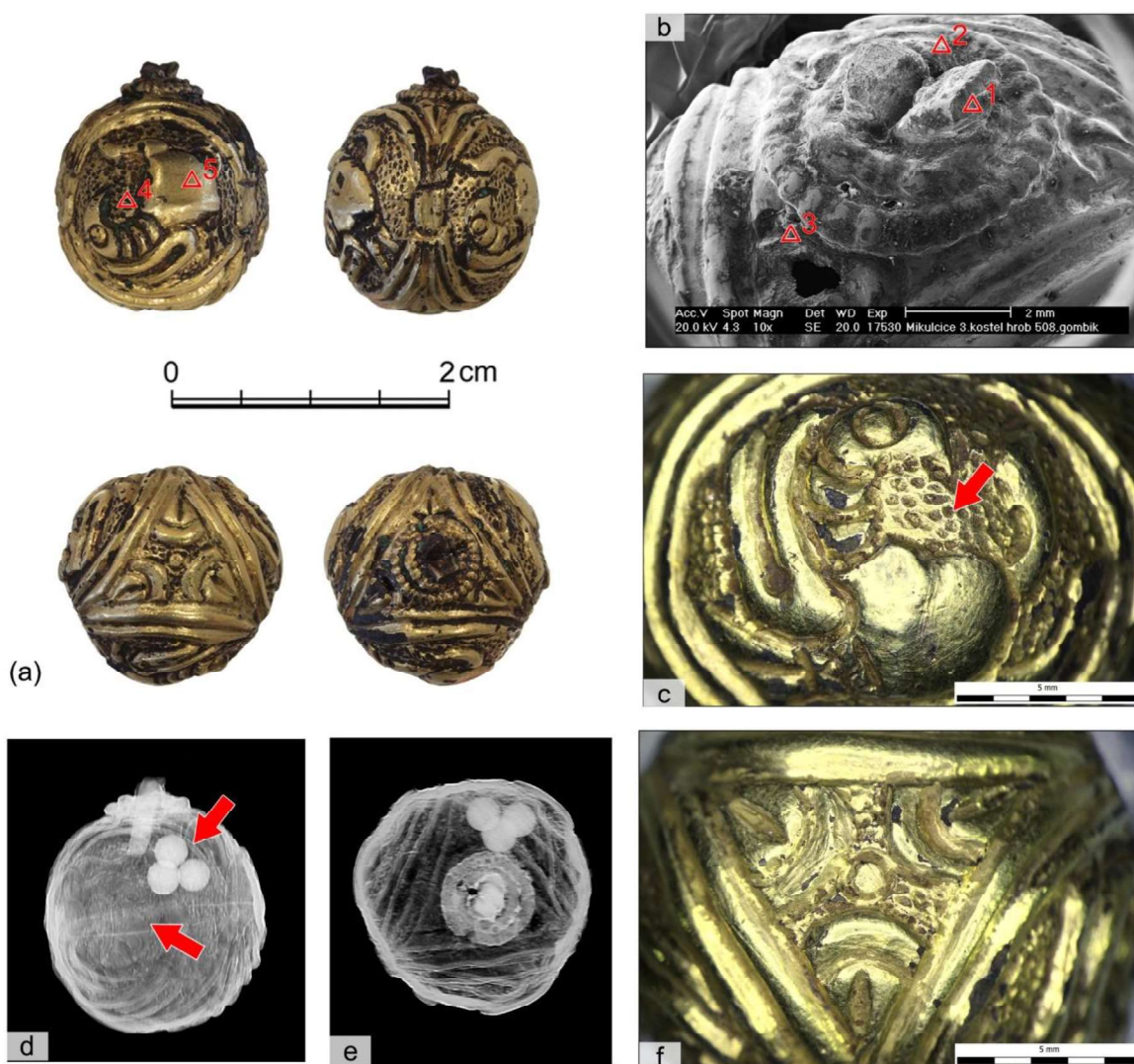


Fig. 9: *Gombik* 594-1038/57a, Mikulčice: a-general view; b-detail of suspension system, SEM micrograph, SE image (photo D. Janová); c-detail of bird of prey motif on the stippled background; d-e- X-ray radiographs revealing three pellets inside the *gombik* and joining area of the two hemispheres; f-detail of the chased motifs in a triangle on the lower pole (photo and X-ray radiographs by E. Ottenwelter).

Unalloyed copper was used for the ring (point 2), and copper with a small amount of Sn and Pb for the split loop (point 1) and the hemispheres (point 3). A Cu-Ag hard solder was employed to join the two hemispheres (Fig.9a, point 4). It is interesting to note that the

proportion of Ag and Cu are inverted from the eutectic composition. The *gombik* is gilded by fire-gilding (point 5). The high percentage of Ag detected in the gilding is due to the underlying Ag-Cu hard solder.

The chasing work is less skillful than on the previous *gombik*. The motifs are quite irregular and were not first sketched. The stippled background is coarse. Less skill in the use of alloys is evident as well. The hard solder composition is far from the eutectic point (Tab. 7). A peculiarity of this *gombik* is the presence of three pellets inside it (Fig. 9d).

Conclusion

The different *gombiky* can be distinguished by different parameters.

If we consider the size, we can observe that gold alloy *gombiky* are smaller than their counterparts in silver and gilded copper. Their size does not exceed 15 mm in diameter, while gilded copper *gombiky* fall in the range of 15 mm – 28 mm and 33 mm and silver *gombiky* reach larger sizes (33 mm – 40 mm – 44 mm).

As regards the construction, Type 1 (i.e. consisting of two hemispheres) is observed whatever the material used to manufacture the *gombiky*, while gold *gombiky* can either be of Type 1 or of Type 2 (single globe and collar). Type 3 (two hemispheres and collar) is only present in the group of gilded copper and silver *gombiky*.

Considering the decoration, we can observe that gold *gombiky* are usually plain, ribbed or decorated by filigree and granulation work. Chasing prevails in the group of *gombiky* made of gilded copper and in that of silver *gombiky*, but in the case of silver *gombiky* granulation and bosses are also often encountered.

Regarding the materials, gold *gombiky* are made of good quality gold alloys: ternary alloys Au-Ag-Cu with an average of 81 wt % Au, 14 wt % Ag and 5 wt % Cu. Differences in the purity of gold is observed suggesting that no standard was applied to gold jewellery (Ottenwelter 2020b). Recycling seems to have been a common practice as it was the case in the Scandinavian world (Armbruster et al. 2002, 199-200) Silver *gombiky* are made of good quality silver with a small amount of copper and gold. The average composition of silver *gombiky* is 96 wt % Ag, 1.6 wt % Au, 2.4 wt % Cu. The gold content in the silver alloys point to recycling of gilt silver. Gilded copper *gombiky* are made of pure copper or copper with a small amount of impurities such as Pb, Sn or

Ag (Ottenwelter et al. 2020). The gilding technique employed for the *gombiky* is always the fire-gilding method (Ottenwelter et al. 2020).

The joining of the components was mainly performed with hard soldering (Ottenwelter 2020b). Small patches of ternary alloy Au-Ag-Cu were used for gold, while Ag-Cu solders applied as filings or powder were used to solder the different components of gilded copper and silver *gombiky*. The use of hard solders was also evidenced on gold jewellery from Hedeby (Armbruster et al. 2002, 175).

The multidisciplinary approach combining archaeology, material sciences and experimental archaeology (see article of L. Barčáková in this volume) has allowed better understanding of the archaeological context, the steps of manufacture and identification of materials and manufacturing processes used to produce these enigmatic pieces of jewellery. It shed light on their different types of construction and decoration. It has shown that very fine pieces, produced by goldsmiths with a long tradition in filigree and granulation work as well as chasing, using high purity gold and silver alloys coexisted with more coarse pieces made by less skilled goldsmiths with lower grade materials. It also brought new discoveries about the complexity of the different types of *gombiky*, and new data about the time, weight and skills required to manufacture them.

Acknowledgments

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Typology: decoration type – description	Plain	Chased decoration	Soldered decoration
Percentage representation	4% (15 pcs)	ribbed: 4% (15 pcs), vegetable motifs: 26% (96 pcs), zoomorphic motifs: 5% (20 pcs), geometric motifs: 10% (36 pcs)	Granulation (all-around, geometrical motifs): 18% (68 pcs), Other filigree work (bosses, corrugated strips, etc.): 9% (33 pcs)
Prevailing material	Gilded copper alloy, but high percentage of gold	Copper alloy, but high percentage of silver	Silver
Prevailing size	1.12 cm	ribbed: 2.17 cm, vegetable motifs: 2.46 cm (69 pcs), zoomorphic motifs: 1.98 cm (9 pcs), zoomorphic motifs: 1.98 cm (9 pcs)	granulation: 2 cm (26 pcs), Other filigree work: 2.37 cm (13 pcs)
Prevailing construction type	Type II (collar + sphere), Type III (collar + 2 hemispheres)	Type I (2 hemispheres), Type II (collar + sphere), Type III (collar + 2 hemispheres)	Type I (2 hemispheres)
Figures of types			

Table 1: Typology, construction, size and material specification of *gombiky*.

Object	Gombik type	Inv. No.	Material	Analysed area	Remarks	Chemical composition [wt%]							
						Au	Ag	Cu	Sn	Pb	Zn	Hg	Ni
1	"Two layered" gombik	1122b/57, (177/§)	gold alloy	Loop, point 1	sub-surface	95.7	1.7	2.6	-	-	-	-	-
				Ring, point 2	surface	83.6	10.9	5.5	-	-	-	-	-
				Ring, point 3	sub-surface	88.3	7.3	4.4	-	-	-	-	-
				Ring, point 4	sub-surface	85.6	7.9	6.5	-	-	-	-	-
				Ring, point 5	sub-surface	89.9	4.7	5.4	-	-	-	-	-
				Granule, point 6	sub-surface	93.5	2.3	4.2	-	-	-	-	-
				Granule, point 7	sub-surface	90.7	4.5	4.8	-	-	-	-	-
				Omega strip, point 8	sub-surface	91.5	4.9	3.6	-	-	-	-	-
				Strip, point 9	sub-surface	91.6	3.2	5.2	-	-	-	-	-
				Boss, point 10	sub-surface	93.7	2.2	4.1	-	-	-	-	-
				Hemisphere, point 11	sub-surface	86.4	6.8	6.8	-	-	-	-	-
				Solder, unmelted patch, point 12	sub-surface	79.3	6.9	13.8	-	-	-	-	-
2	Chased gombik	1897/57, (246/§)	gold alloy	Loop, point 1	sub-surface	80.3	16.7	3.0	-	-	-	-	-
				Ring, point 2	sub-surface	76.0	19.5	4.5	-	-	-	-	-
				Collar, point 3	sub-surface	82.3	15.6	2.1	-	-	-	-	-
				Globe, point 4	sub-surface	77.6	18.2	4.2	-	-	-	-	-
				Solder, patch, point 5	sub-surface	72.5	22.7	4.8	-	-	-	-	-
3	Chased gombik	1300b/56, (63/§)	silver alloy	Loop, point 1	sub-surface	1.3	82.9	15.8	-	-	-	-	-
				Clamp, point 2	sub-surface	-	94.5	5.5	-	-	-	-	-
				Ring, point 3	surface	-	95.5	4.5	-	-	-	-	-
				Ring, point 4	sub-surface	-	95.2	4.8	-	-	-	-	-
				Ring, point 5	sub-surface	1.7	93.4	4.9	-	-	-	-	-
				Ring, point 6	sub-surface	1.8	93.9	4.3	-	-	-	-	-
				Boss, point 7	sub-surface	-	91.3	8.7	-	-	-	-	-
				Granule, point 8	sub-surface	1.4	96.3	2.3	-	-	-	-	-
				Hemisphere, point 9	sub-surface	2.2	93.1	4.7	-	-	-	-	-
				Hemisphere, point 10	sub-surface	1.9	93.2	4.9	-	-	-	-	-
				Solder area under granule, point 11	surface	-	91.9	8.1	-	-	-	-	-
				Solder area, hemisphere, point 12	sub-surface	-	68.4	31.6	-	-	-	-	-
				Modern solder, point 13	sub-surface	-	33.2	37.8	-	-	25.9	-	3.1
4	Granulated gombik	1124b/57, (181/§)	silver alloy	Loop, point 1	sub-surface	1.1	96.7	2.1	-	-	-	-	-
				Granule, point 2	sub-surface	-	85.9	9.7	-	-	4.4	-	-
				Solder, granule, point 3	sub-surface	-	67.9	23.7	-	-	8.4	-	-
				Granule, point 4	sub-surface	0.9	92.2	6.9	-	-	-	-	-
				Beaded wire, point 5	sub-surface	3.2	91.7	5.1	-	-	-	-	-
				Solder area, granule, point 6	sub-surface	-	92.2	7.8	-	-	-	-	-
				Filigree ring, point 7	sub-surface	1.9	96.0	2.1	-	-	-	-	-
				Hemisphere, point 8	sub-surface	-	97.3	2.7	-	-	-	-	-
5	Chased gombik	976a/58, 220/§	gilded copper	Hemisphere, point 1	sub-surface	-	-	100.0	-	-	-	-	-
				Clamp, point 2	sub-surface	-	-	96.5	3.5	-	-	-	-
				Gilding layer, point 3	surface	86.2	2.3	4.5	-	-	-	7.0	-
				Gilding layer, point 4	surface	86.2	1.6	2.4	-	-	-	9.8	-
				Gilding layer, point 5	surface	88.7	2.0	1.7	-	-	-	7.6	-
				Solder area, hemisphere, point 6	sub-surface	-	25.9	74.1	-	-	-	-	-
6	Chased gombik	1038/57a, 115/z	gilded copper	Loop, point 1	sub-surface	-	-	93.2	2.8	4.0	-	-	-
				Ring, point 2	sub-surface	-	-	100.0	-	-	-	-	-
				Hemisphere, point 3	sub-surface	-	-	96.4	1.6	2.0	-	-	-
				Solder area, point 4	sub-surface	-	28.8	71.2	-	-	-	-	-
				Gilding layer, point 5	surface	74.6	9.4	3.3	-	-	-	12.7	-

Table 2: Chemical composition of the different elements of analyzed *gombiky* and solder areas. SEM-EDS semi-quantitative surface analysis (normalized wt.%, carbon not considered). Numbers of analysis correspond to those reported on Figures 4, 5, 6, 7, 8 and 9 (from Ottenwelter 2020b).

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