

**The beginnings of S-shaped temple rings in Bohemia
from the perspective of archaeological analysis
and radiocarbon dating**

Nikola Košťová – Kateřina Tomková – Naďa Profantová – Petr Limburský

**A child, twelve goats, three sheep, a cow, and a horse:
An unusual grave from the Late Eneolithic in Brno-Slatina
(South Moravia, Czech Republic)**

*František Trampota – Jarmila Bříšková – Jiří Kala – Petr Kos –
Míriam Nývltová Fišáková – David Parma*

**Social networks around the Orońsko flint mining area
(Central-Southern Poland) during the Late Palaeolithic:
The first results of the SEM-EDS analysis of flints
and pigments**

*Katarzyna Kerner-Gubała – Julia Kościuk-Zatupka –
Dominik Gurba – Mateusz Słoniewski*

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*Viktorie Čiřáková – Zdeněk Beneš – Zuzana Zlámalová Čílová –
Pavel Horník – Šárka Msallamová – Šárka Matoušková –
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EDITORIAL

Starting in 2025, *Archeologické rozhledy* established cooperation with the Peer Community in Archaeology (PCI Archaeology) – a non-profit organisation dedicated to the principles of open research and striving to reshape the distorted landscape of current academic publishing. In general, the idea of the PCI project is to provide community peer review. Papers submitted to PCI are rigorously scrutinised by volunteer scholars, who offer their expertise in peer review or recommendation of scientific articles. PCI Archaeology now comprises more than 160 researchers from around the world. They may recommend that submissions be made complete, reliable, and citable articles, without the need for publication in ‘traditional’ journals.

Hearing that, one might regard the PCI initiative as a competing element on the field of academic publishing, but we do not see it this way. As a Diamond Open Access journal, we think that the goals of PCI are converging with principles promoted by our journal. Moreover, authors who wish to publish their PCI-recommended article in a traditional way can submit it to PCI-friendly journals, now including *Archeologické rozhledy*. We joined as a category 2 journal, meaning that we do not automatically accept PCI-recommended articles, but have agreed to provide authors with a response within five days. Our decision can involve acceptance with minor modifications and no further peer review, standard peer review before acceptance, but also rejection of the paper if it is not in line with the aims and scope of *Archeologické rozhledy*.

The beginning of 2025 also brought changes to our social media communication, as we launched a new account on Bluesky (@archrozhlady.bsky.social). Given the current situation, this social network appears as a more suitable environment to present an academic journal. Along with that, we terminated our X (formerly Twitter) account for political reasons. We believe that science should stay apolitical in terms of political parties; nevertheless, there are general principles of democracy and academic freedoms at stake – principles that the string-pullers of X are apparently determined to suppress. What ‘interesting times’ we are living in!

As usual, this issue of *Archeologické rozhledy* offers four new research articles dealing with the archaeology of Central Europe. It opens with a study by Nikola Košťová and colleagues on the chronology of early medieval S-shaped temple rings in Bohemia. As in her previous papers, Nikola Košťová challenges the long-standing archaeological schemes with radiocarbon dating. This method was previously rather omitted by early medieval archaeologists, who pointed to its unreliability and vague results. However, the authors show that a rigorous approach involving planned sampling, offset assessment, and Bayesian modelling can bring relevant results.

The paper delivered by František Trampota and colleagues addresses the currently emerging topic of Central European Neolithic archaeology. After much attention was paid to the Corded Ware phenomenon, which most archaeologists and geneticists link with the arrival of Indo-Europeans, the focus is now turning to the processes and indigenous Central European social environment that preceded or were parallel with this migration. The extraordinary deposition from Brno-Slatina presented by František Trampota and his team thus enriches the debate with interesting new data on burial practices, which are still rare for this period and region.

The two studies that follow widely employ archaeometric approaches. Katarzyna Kerner-Gubała and her colleagues address social networks in the Paleolithic by inspecting the composition of chocolate silicites and ochres from outcrops in the Orońsko mining area in South-Central Poland. Although the paper presents the first results of an ongoing research project, it reveals that some of the flint and ochre may have been transported from Orońsko to the contemporaneous sites of Rydno and Całowanie, which are located outside the chocolate silicite outcrop zone. On the other hand, the transport of ochre in the opposite direction from Rydno to Orońsko remains unlikely, as the analyses showed no similarities. The research presented by the authors thus helped to adjust previous assumptions on Paleolithic distribution networks and promises even more new insights in the future.

Interesting new results also come from the study by Viktoria Čisťáková and her co-authors, which examines various artefacts with mosaic or millefiori enamel decoration from the 2nd and 3rd centuries AD found in Bohemia. Employing multiple methodological approaches that produced extensive datasets, the authors delivered a comprehensive archaeometric assessment, which is still rare in the Central European context and for these types of artefacts. They concluded that enamel-decorated objects were produced for the barbarian market by various provincial workshops located primarily on the Roman Limes. On a more general level, the study thus explores relationships between the Roman Empire and regions outside its borders that, rather than following a simple dichotomy of civilised and barbarian worlds, were complexly entangled.

Václav Vondrovský

RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

The beginnings of S-shaped temple rings in Bohemia from the perspective of archaeological analysis and radiocarbon dating

Počátky esovitých záušnic v Čechách pohledem
archeologické analýzy a radiokarbonového datování

Nikola Koštová – Kateřina Tomková – Naďa Profantová –
Petr Limburský

Jewellery represents important evidence not only for the reconstruction of fashion and cultural development but also provides significant support for the chronology of the periods studied. This paper is focused on the issue of dating the beginning of the appearance of early medieval S-shaped temple rings. It summarises the existing idea of dating from an archaeological perspective, mainly based on a comparative analysis of the occurrence of S-shaped temple rings with other chronologically distinctive objects, stratigraphic observations and burial rite. Entirely independently of this approach, the results of radiocarbon dating of selected graves from Central Bohemia were evaluated to provide an alternative perspective. Some other types of wire jewellery were also radiocarbon dated: meander-shaped earrings, temple rings with an eyelet, or hybrid types, especially earrings of the Jízdárna type. Several graves were repeatedly dated, and therefore the issue of repeated radiocarbon dating is addressed. The crossover of traditional archaeological dating with the results of the radiocarbon method and its implications are discussed.

Early Middle Ages – Bohemia – S-shaped temple rings – radiocarbon dating – chronology

Šperky představují významný pramen nejen pro rekonstrukci módy a kulturního vývoje, ale také významně podporují chronologii studovaných období. Předložený text otevírá otázku datování počátku výskytu raně středověkých esovitých záušnic v Čechách. Shrnutá je dosavadní představa datování založená na archeologickém pohledu, tedy především na srovnávací analýze výskytu esovitých záušnic s dalšími chronologicky citlivými předměty, stratigrafických pozorováních a pohřebním ritu. Zcela nezávisle na tomto konceptu byly vyhodnoceny výsledky radiouhlíkového datování vybraných hrobových celků ze středních Čech, které poskytují alternativní pohled. Radiouhlíkovou metodou byly datovány také některé další typy drátěného šperku: meandrovité náušnice, záušnice s očkem, nebo hybridní typy, především náušnice typu Jízdárna. Několik hrobů bylo datováno opakovaně, z toho důvodu je v textu řešena také problematika opakovaných radiouhlíkových datování. Diskutován je průnik tradičního archeologického datování s výsledky radiouhlíkové metody a důsledky, které z toho vyplývají.

raný středověk – Čechy – esovité záušnice – radiokarbonové datování – chronologie

Introduction

Since entering Bohemian and European archaeology as early as in the 19th century, S-shaped temple rings have become an integral part of the study of early medieval jewellery. This simple wire head ornament occurs in different subtypes and size variants (cf. *Krumphanzlová 1974; Profantová et al. 2015; Tomková et al. 2020a*) (Fig. 1: 1–4). It is known mainly from burial grounds, where these temple rings are found in graves as single items, in pairs,

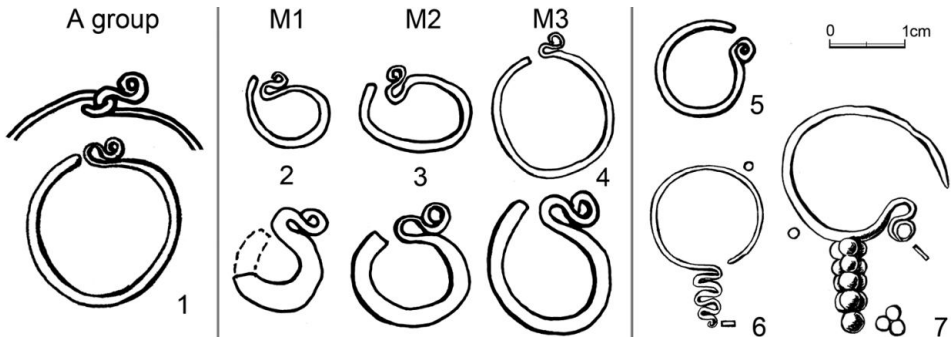


Fig. 1. Types of analysed jewellery. 1–4 – S-shaped temple rings; 5 – temple ring with an eyelet; 6 – meander-shaped earring; 7 – earring of Jízdárna type (after Tomková et al. 2020a, Fig. 94, 95, 98, 102, and 112, modified).

and in larger sets. They were made from precious metals, silver and in rare cases even gold, as well as from copper alloys, bronze, brass, and in a small number of cases even from lead, tin, or iron. In some cases, the surface of temple rings made of cheaper materials was enhanced with silver plating and other silver surface treatments.

The chronology of individual S-shaped temple ring subtypes and variants remains an important issue in early medieval archaeology. Determining the origin of their occurrence in the Central European or Southern European (Croatia) regions is closely tied to opinions on the genesis and directions of the spread of these ornaments. In this study, we focus on the territory of Bohemia in the 9th–10th century, specifically on the question of how finds from Bohemia help explain the origin of simple S-shaped temple rings, i.e. smooth wire rings with one flat-cut end and the other in the form of an S-shaped flattened end. We confront the existing conclusions of archaeological analysis with the results of radiocarbon dating and subsequently compare these results with radiocarbon dating of hybrid earrings combining a ring with S-shaped loop with elements formed by granulation (mainly earrings of the Jízdárna type, Fig. 1: 7), and other simple wire jewellery consisting of an arc hammered at one end and bent one or more times (temple rings with an eyelet, meander type of earrings, Fig. 1: 5, 6). At least briefly, we also address issues related to the development of S-shaped temple rings in the 10th–11th century.

The beginnings of S-shaped temple rings in Bohemia from an archaeological perspective

Since the 19th century, the initial phase of S-shaped temple rings (Fig. 2) has mostly been dated to the 10th century – with various explanations. For J. L. Píč, the occurrence of inhumation burials from the 10th century was important (Píč 1909, 75–76), as Bohemian burial grounds were the most frequent source of their finds. Besides, Píč was aware of an older origin, which he placed in the context of relics of ‘a provincial culture from lands south of the Danube’ (Píč 1909, 83, 131). In his concept, S-shaped temple rings appeared at the same time as earrings of ‘oriental origin’, by which are meant earrings with a grape pendant and other ornaments decorated with filigree and granulation.

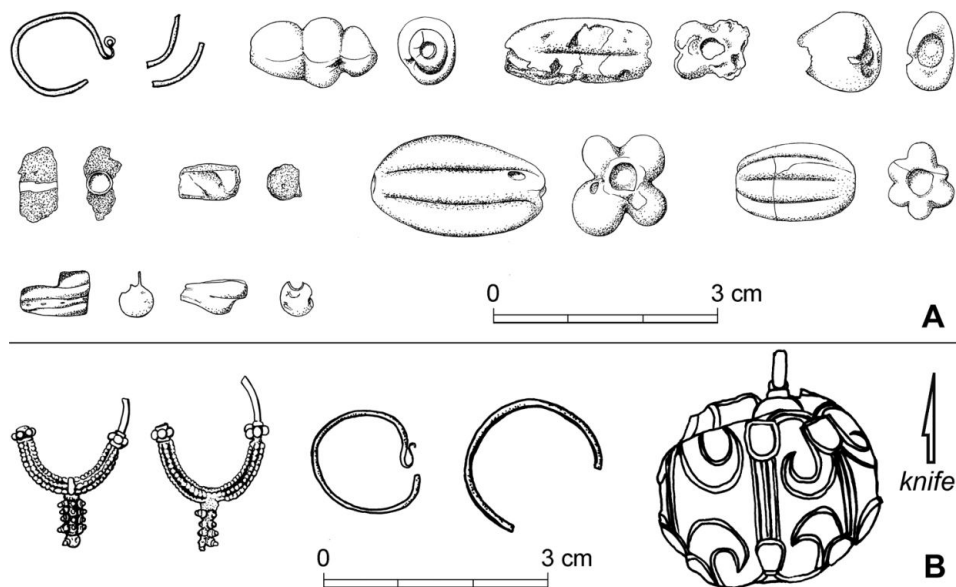


Fig. 2. Grave goods of radiocarbon-dated graves with S-shaped temple rings from Prague – Milady Horákové Street. A – grave 48; B – grave 83 (drawn by V. Pincová and M. Housková).

Niederle (1894, 194–209), the author of the first inventory of S-shaped temple rings from Bohemia and Moravia, assessed them against the background of other types of temple rings – temple rings with an eyelet and meander-shaped earrings. He dated the S-shaped temple rings to the 10th–12th century, among other things, with regard to their occurrence with coin finds, although this could not be documented until the 11th century. In the same article, however, with regard to possible precursors of S-shaped temple rings, he already formulated an opinion about the earlier dating of S-shaped temple rings and inhumation burials in Bohemia preceding the 10th century (*Niederle 1894*, 204–205). Later, he updated knowledge of S-shaped temple rings and slightly modified his views (*Niederle 1913*, 592–593), but for the most part this did not concern the dating of finds from Bohemia.

Both J. L. Přč and L. Niederle distinguished between the period in which S-shaped temple rings formed a significant part of the Western Slavic (especially Bohemian) archaeological find inventory and the issue of their genesis. Though referring to different justifications and different prototypes, this was located in the (Pannonian) Danube region and was dated to the period preceding the 10th century with reference to the Roman-provincial area. The same is true for the studies by *Borkovský* (1940; 1956), who was aware of *Reinecke's* knowledge of the occurrence of rings with an S-shaped end in High and Late Merovingian graves. It is important to realise that the opinions of both L. Niederle and I. Borkovský on S-shaped temple rings strongly reflected knowledge of other types of temple rings (temple rings with an eyelet and meander-shaped earrings), between which the boundaries were not as sharp as they are today. When Borkovský wrote about S-shaped temple rings in the 1940s, he sometimes confused them with other types of temple rings and even with other types of earrings with an S-shaped end. Based on that, he situated the origin of S-shaped temple rings – like Niederle and Přč – in the Carpathian Basin

(Borkovský 1940, 58). The different developmental line, indicated by P. Reinecke and arguing for an origin west of Bohemia, was developed by Dinklage (1940; 1941, 199), but this had virtually no impact on the chronology for dating the finds from Bohemia.

After the Second World War, Eisner (1947) in his study on early medieval jewellery, with an awareness of the opinions of his predecessors and with respect to the opinions of K. Dinklage, noted that there was no evidence for continuity from the Avar period to the middle of the 10th century and that: ‘Perhaps some of the now known sites with typical Slavic temple rings are older than the period around 950, but the beginning of the continuous development of the Slavic temple ring can hardly be assumed before the 10th century according to our current knowledge’ (Eisner 1947, 152). He continued to date S-shaped temple rings to the 10th century in his following study (Eisner 1955, 223). Šolle (1959, 436, 438) also formulated his conclusions in a similar way within the framework of the analysis of the burial ground in Stará Kouřim, when he stated that it is not possible to prove the dating of these ornaments to the 9th century.

At the same time, from the mid-1940s, a line of opinion also developed that saw the beginnings of S-shaped temple rings in Bohemia in the period preceding the 10th century. This hypothesis was justified in a variety of ways: R. Turek’s pre-war dating of the burial ground in Žižice (Turek 1939) and the beginnings of burial in Želenice as well as a theoretical consideration of potentially missing finds when assessing existing ones up to the 10th century led Knor (1953, 226, 225/235) to the early dating of the beginnings of the burial ground in Stehelčevě to the end of the 8th century and to the opinion that S-shaped temple rings were used long before the 10th century. R. Turek dated S-shaped temple rings even before the 9th century, referring to their co-occurrence with meander-shaped earrings in burial mound II in Pňovice (Turek 1946, 110–112, 119). Setting aside the change of opinion on the dating of burial mounds (Lutovský et al. 2023), it should be noted that R. Turek did not take into account that meander-shaped earrings were located in the lower part of the mound, while S-shaped temple rings were in its upper part. In the case of burial mounds, we can mention the find of an S-shaped temple ring in Údraž at the ‘U Obrázku’ site in a vessel of a subsequent cremation burial from the 9th century in a Hallstatt mound (Dubský 1930; 1949, 669–670). According to Borkovský, clues for an earlier dating of S-shaped temple rings came from finds that are tied to Prague Castle and its immediate surroundings. He dated the S-shaped temple ring from the burial ground in Jelení Street to the 8th century (Borkovský 1947, 151) based on the simultaneous occurrence with a meander-shaped earring. In a publication devoted to the beginnings of Prague Castle (Borkovský 1949, 73–74), he dated the S-shaped temple ring found ‘under the pavement’ to the end of the 9th and the beginning of the 10th century based on the incorrect assumption that it was a context beneath the floor of the Church of the Virgin Mary at Prague Castle founded by Prince Bořivoj (852/853? – 888/889). This was later refuted by his reclassification of the paving as belonging to a later annex (Borkovský 1953; Frolík 2015). In 1956, Borkovský entered the discussion about the dating of the beginnings of S-shaped temple rings with another idea – the connection of the symbolic meaning of the S-shaped end and Christianisation (Borkovský 1956, 151, 154). Considering the Christianisation of Bohemia during the 9th century, he assumed that S-shaped temple rings already appeared in this period.

In the early 1960s, J. Sláma concluded that S-shaped temple rings were rarely worn in Bohemia before the middle of the 10th century, though the previous century cannot be ruled out. Sláma drew attention to the fact that all potential inspirations, i.e. Great Moravian

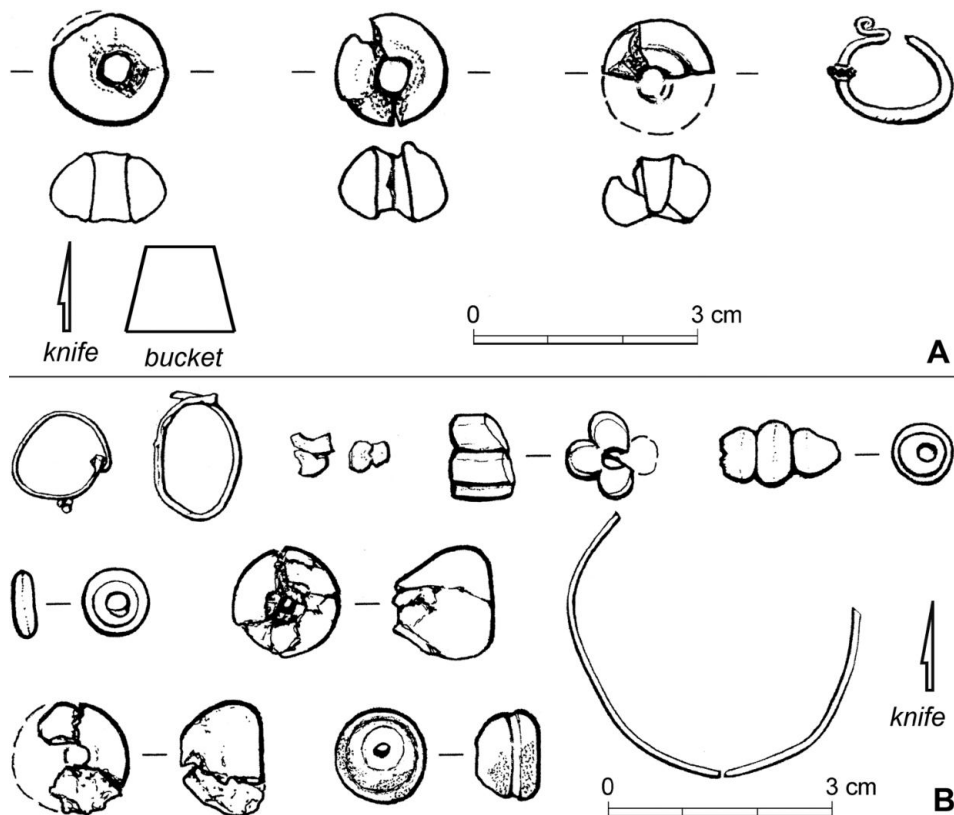


Fig. 3. Grave goods of radiocarbon-dated graves with hybrid earrings from Prague-Lahovice. A – grave 30-1/55; B – grave 389 (after *Krumphanzlová et al. 2013*, tab. 55, 94, modified by M. Housková).

jewellery with granulation or filigree and an S-shaped end on the arc of earrings, meander-type earrings, and ‘western’ (i.e. occurring west of Bohemia) large S-shaped temple rings with one end hooked into an unsplit S-shaped loop were used in Bohemia in the 9th century (*Sláma 1963*, 248). *Šolle (1966*, 162) also suggested an earlier beginning for S-shaped temple rings. The specific formulations of the aforementioned authors reflect their awareness of the difference between the well-documented horizon of the high frequency of S-shaped temple rings in the 10th century (especially in its second half) and the relative uniqueness of earlier artefacts.

In the 1970s, *Krumphanzlová (1974*, 52, fig. 1) recapitulated the previous opinions in the context of current knowledge and finds from Prague-Lahovice. *Krumphanzlová* included the hybrid S-shaped ‘earring’ from grave 30-1/55 from Prague-Lahovice (*Fig. 3: A*) among evidence for the earlier dating of the beginnings of S-shaped temple rings in Bohemia before the year 900. Since then, the dating of the beginnings of S-shaped temple rings has oscillated from the late 9th/last third of the 9th century to the first third of the 10th century or mid-10th century (*Profantová 2005*, Abb. 3; 2011; 2013; *Profantová et al. 2015*, 95–96, 157–160; *Tomková 2005*, 263; 2008, 95; 2011; *Štefan 2010*, 176; Tab. 2). Already in the aforementioned studies, grave units in which S-shaped temple rings appear with

jewellery of Great Moravian origin or tradition began to be used in the discussion about the chronology of S-shaped temple rings in Bohemia.

Over the past decades, the publication of earlier excavations, especially the burial grounds in Prague – Lumbe Garden, Prague-Lahovice, and Levý Hradec, as well as new, published and unpublished, excavations (Klecany I and II, Žalov – Na Panenské, Prague-Vinoř – stronghold, Prague-Vinoř – V Žabokřiku, Přezletice) offer additional information that can be used along with earlier findings for understanding the studied topic.

For establishing the chronology of S-shaped temple rings, it is important to follow the relationships of succession or contemporaneity with other chronologically significant jewellery (Figs. 2–5). In our case, this includes simple wire jewellery (referred to, especially in Moravia, as jewellery of Danube origin), spherical buttons and jewellery with granulation or filigree representing the sphere of jewellery, the models of which are associated with the Byzantine-Oriental and Great Moravian culture (e.g. *Dostál 1966; Krumphanzlová 1974; Košta – Barčáková 2023; Ungerman 2023; Poláček et al. 2024*; for the primarily technological classification of jewellery, *Tomková et al. 2020a*). Some types of beads are also important chronological co-indicators. Fusiform, ribbed olive and G-beads represent the older horizon of early medieval necklaces in Bohemia, and amber beads indicate the later horizon (*Košta – Tomková 2011; 2012; Košta et al. 2011; Tomková 2012a; Tomková et al. 2023*).

Another important aspect in determining the chronology of the S-shaped temple rings is the stratigraphic relationships observed mainly due to the graves in superposition. They accompanied children's burial no. I in the upper part of mound II in Pňovice, as opposed to meander-shaped earrings from the grave in the lower part of the burial mound (*Turek 1946, 110–112*). At the burial ground near the rotunda of St Peter and Paul at the Budeč stronghold, grave 73 equipped with small S-shaped temple rings covered grave 71 with a pair of grape pendant earrings, glass beads (including olive beads), and a larger fragment of a cross fitting with masks as a pendant (*Šolle 1990, fig. 19, 21: 2*). Current excavations reflect similar stratigraphic observations. Unpublished grave burial 6/2017 from Klecany I containing S-shaped temple rings of thin wire and of a small diameter was intentionally placed above burial 8/2017 of a young woman furnished with 10 silver earrings/temple rings¹ with three sculptured ornaments in the form of a schematic rider decorated with filigree and granules on a flat oval, as well as 30 amber beads and a large number (over 120) of small glass beads and an iron knife. Amber and miniature glass beads suggest a dating to the second third or mid-10th century. The animal jewellery from this grave, probably made in Prague, can be dated to the first half of the 10th century, a dating that is also supported by radiocarbon analysis (*Profantová 2022*).² This makes it possible to date later grave 6/2017 to the period between the second half of the 10th to the first third of the 11th century, when burials in Klecany probably ended. At the same burial ground, a silver S-shaped temple ring was found in the later grave 32, while in earlier grave 32a an earring without a termi-

¹ The mentioned type of jewellery is usually traditionally classified as earrings in publications. However, a set of earrings from grave Kl-8/2017 indicates that they were used as temple rings.

² CRL-17_386, 1169 ± 21. The calibrated age at 95.4% probability 772–792 (15.4%), 801–812 (1.9%), 818–899 (61.9%), and 919–957 cal AD (16.2%). The most probable is the last calibrated interval. The data has been recalibrated according to the IntCal20 calibration curve.

Burial Ground	Grave	S-shaped temple ring	Meander-shaped earrings	Earring with a double-sided spiral pendant	Earring with a grape pendant	Spherical button (gombík)	Other types of earrings	Olive glass beads Amber beads	Other finds	References and notes
Prague 1 – Hradčany, Jelení street	1/1937 (male)	1	1					x	ceramic vessel with a simple rim; iron artefact; knife	<i>Borkovský 1947, 146–147; Tomková 2005, 82–83, obr. 3/8</i>
Klecany I	22/05 (male)	1		1					axe, knife, bucket, flint stone	<i>Profantová et al. 2015, 88–89; Profantová et al. 2010, Tab. 18–19</i>
Zákolany	4 (child)	2			2		Jízdárna type/2	x	2 earrings of unspecified type; pendant	<i>Šolle 1982, 185, 188, 19, obr. 11: 1–8; questionable finding context</i>
Prague 6 – Hradčany, Míladý Horákové	83/2013 (child)	1			2	1			knife, iron artefact	<i>unpublished</i>
Prague 1 – Hradčany, Lumbe garden	99 (9/75, child)	2+6 damaged				2			crystal bead; knife	<i>Frolík – Smetánka 2014, 165–167</i>
Prague 1 – Hradčany, Lumbe garden	84 (4/72, child)	2			6	2		14	finger ring; segmented glass beads; egg; knife	<i>Frolík – Smetánka 2014, 151–153</i>
Klecany II	28/2000 (child)	2			3		temple ring with an eyelet/4+2 damaged		miniature glass beads; middle size melon and barrel glass beads; knife	<i>Profantová et al. 2010, Tab. 97, Fototab. 81 a 94, Profantová et al. 2015, 144</i>
Kanín II	133 (female)	2+1 damaged			2		temple ring with an eyelet/2	2	segmented glass beads; sword set fitting; finger ring; bucket; knife	<i>Mařík 2009, 89–90, Tab. 42</i>

Tab. 1. Graves containing S-shaped temple rings with chronologically significant jewellery of the Danubian and Great Moravian style.

nal and one fragmented olive bead were deposited (*Profantová et al. 2010, tab. 21–32; Profantová et al. 2015, 95–96, 106–107*). In all of these cases, graves with S-shaped temple rings are later than graves with simple wire jewellery of the Danube tradition, jewellery decorated with filigree and granulation, and with olive beads. Although the stratigraphy confirms the development trend from the fashion represented by jewellery of the Danube and Great Moravian tradition to the fashion of S-shaped temple rings (*Eisner 1947; 1955; Krumphanzlová 1974; Tomková 2011; Profantová 2013; Tomková et al. 2020a*), it does not actually contribute to knowledge of the absolute chronology of the beginnings of S-shaped temple rings.

There are also graves in which S-shaped temple rings occur simultaneously with the aforementioned jewellery groups. Combinations with meander-shaped earrings, an earring with a double-sided spiral pendant, and olive beads (grave 1/1937 in Prague – Jelení Street, grave 22/05 in Klecany I) is less frequent than with jewellery of the Great Moravian style,³ with spherical buttons (gombíky) and earrings with a grape pendant decorated with gran-

³ Here, the Great Moravian style is synonymous with Great Moravian luxury jewellery/Veligrad jewellery (according to *Poláček et al. 2024*), jewellery of Great Moravian origin or tradition (*Tomková 2011; Tomková et al. 2020a*) or jewellery of the Great Moravian type (*Profantová 2003, 77; Profantová et al. 2015, 79, 85; Boháčová – Profantová 2014, 146, 148*).

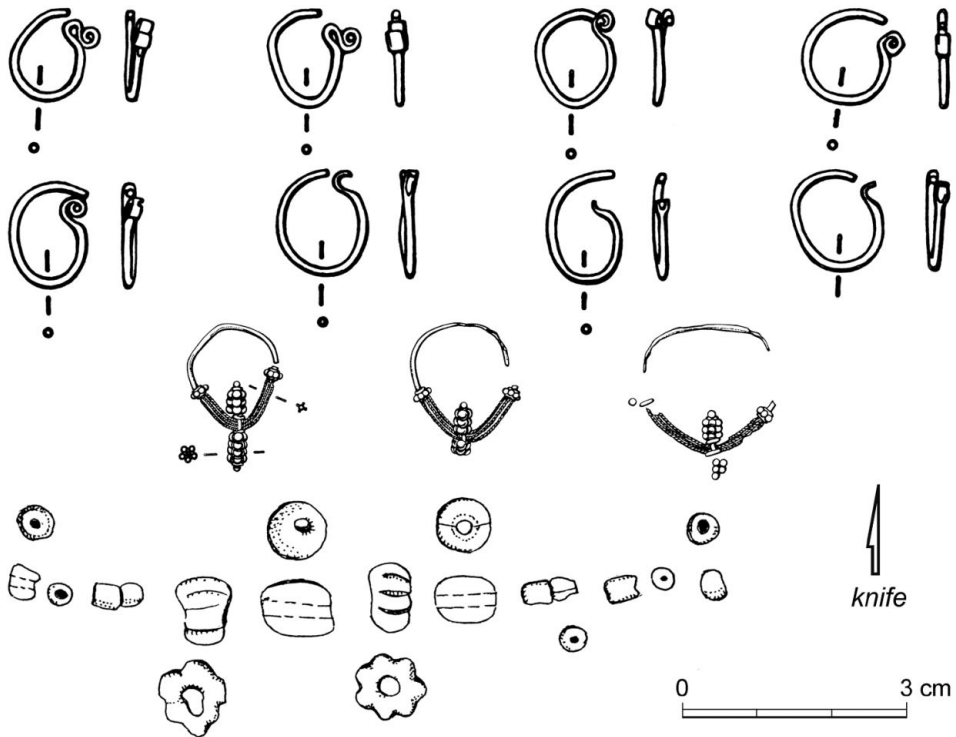


Fig. 4. Grave goods of grave 28 from Klecany II. Set combining S-shaped temple rings, temple rings with an eyelet, and granulated jewellery (after Profantová *et al.* 2010, Fig. 97, modified by L. Raslová).

ulation (grave 83/2013 in Prague – Milady Horákové Street, graves 99 and 84 in Prague – Lumbe Garden, grave 28/2000 in Klecany II, grave 4 in Zákolany,⁴ and grave 133 in Kanín II) (Tab. 1; Fig. 2B, 4).⁵

The archaeological dating of these contexts, as well as the stratigraphically earlier graves described above, follow a trajectory starting with the potentially oldest find from Prague – Jelení Street, whose dating before the year 900 was already assumed by I. Borkovský, to finds that can be dated according to the existing practice to the broader interval of the late 9th – first third/half of the 10th century, though without the possibility of defining their position within this interval more precisely.

⁴ Unfortunately, there are discrepancies in the publication, and due to the poor state of preservation, the S-shaped temple rings cannot be reliably identified in the figure. It is all the more unfortunate that the set also included simple wire earrings and olive beads (Šolle 1982, 185, 188, fig. 11: 1–8).

⁵ Some graves previously mentioned in publications (Štefan 2010, Tab. 2) should be rejected. In the case of grave 52/1913 from Žalov – cihelna A we cannot be sure that it contained what the excavator stated, but it may contain finds from more than one grave (cf. Tomková 2012a, 73–77). Grave 48 from Stará Kouřim does not contain a standard S-shaped temple ring, but meander-shaped earrings with a 1.5 S-shaped loop. Even though Krumphanzlová (1963, 110) argued for the occurrence of S-shaped temple rings and meander-shaped earrings in Prague-Lahovice, this was an error, since this reference is missing from a later study from the 1970s and as in the catalogue (Krumphanzlová 1974; Krumphanzlová *et al.* 2013).

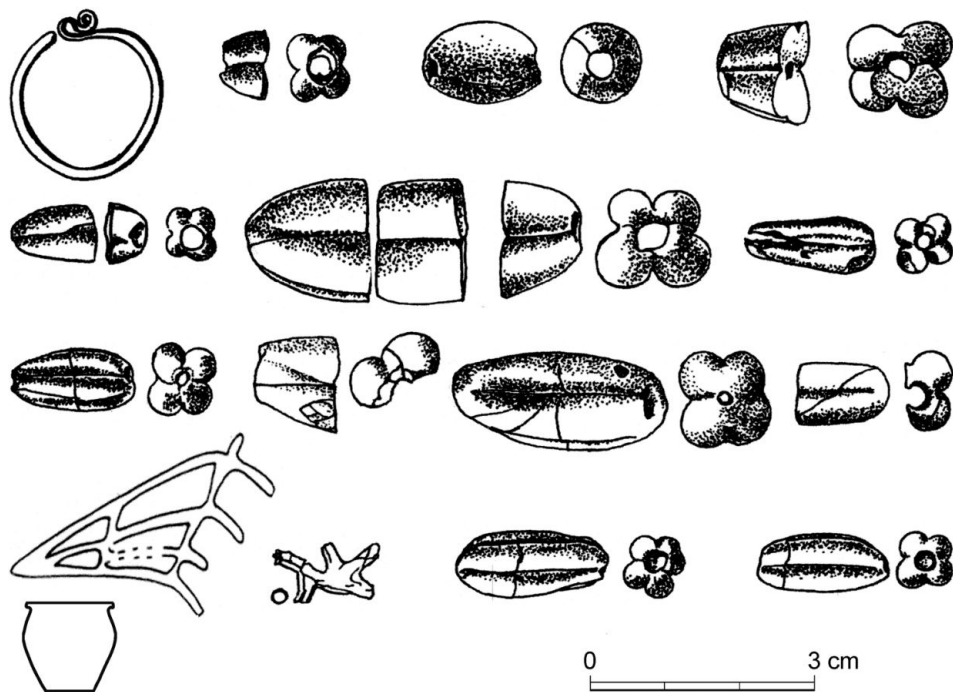


Fig. 5. Grave goods of radiocarbon-dated grave 33 from Žalov – Na Panenské containing S-shaped temple rings of group A (after Tomková 2012b, Fig. 157, modified by M. Housková).

Another stimulus in the study of S-shaped temple rings is the definition of a hypothetical A-group of S-shaped temple rings (Fig. 1: 1) with an assumed dating before the year 900. It has been proposed by K. Tomková based on an analysis of the burial grounds in Žalov linked to the residential area of the Levý Hradec stronghold (Tomková *et al.* 2020a, 185, 189, 191). S-shaped temple rings from Žalov – Na Panenské, the oldest burial ground in the Levý Hradec area, also belong to this group. Graves ŽAP-6/2003 and 33/2005 (Fig. 5) contained items with a diameter reaching or slightly exceeding 20 mm (group M3/S: the smaller of the diameters is beyond 15 mm and the other reaches or exceeds 20 mm; for the size variants of simple S-shaped temple rings, see Tomková *et al.* 2020a, 179–180), and are therefore larger than the temple rings occurring, according to the current state of knowledge, in the 10th century. They are accompanied by olive and fusiform beads and also ceramic vessels. In the first case a group E pot with relief shoulders was present, in the second a group A pot with an archaic appearance (Tomková *et al.* 2020a, Tab. 27). The S-shaped temple ring from the aforementioned grave 1/1937 from Prague – Jelení Street belongs to the same horizon (Tomková 2005, 82, Fig. 3/8). With regard to Bavarian finds close to Bohemia, a large S-shaped temple ring with a hook terminal at the other end from Žalov – Cihelna A, grave 52/1913, is also included in the A-group.

We can summarise that existing archaeological research allows us to assume the beginnings of S-shaped temple rings in Bohemia already before the year 900, but also does not rule out their later emergence. It also does not provide support for a more precise absolute dating in the 9th century.

Materials and methods

Considering the limits of archaeological analysis, we decided to use radiocarbon dating of human remains, which is independent of the classification of the grave goods, to reach a chronological framework alternative to traditional archaeological dating. We aimed to investigate whether and to what extent this analysis would confirm or refute the dating of the beginnings of S-shaped temple rings before the year 900. The analysed assemblage consisted of graves located in a vertical stratigraphy and equipped with other chronologically distinctive jewellery besides S-shaped temple rings. Looking for the beginnings of S-shaped temple rings in Bohemia, it is necessary to start analysing other graves containing S-shaped temple rings of a small diameter (up to a diameter of 20 mm) to understand their wider context and obtain dates for their firmer anchoring in the chronology of early medieval jewellery over a long period. With regard to possible connections, we also extended our attention to other head ornaments, both simple ones made of wire (i.e. meander-shaped earrings and temple rings with an eyelet), as well as hybrid earrings combining a ring with an S-shaped loop with elements, pendants, and knots formed by granulation. Therefore, the Jízdárna type earrings (*Fig. 6*) were also included (more about this type in *Tomková 2005*, 231, 233; *Profantová et al. 2015*, fig. 7.17; *Havrda – Ždárská 2017*, Fig. 25; *Tomková et al. 2020a*, 198–201, fig. 114) and some other ornaments.

The selection had to be narrowed down mainly for two reasons. The first was the state of bone preservation: the absence of anthropological material did not permit an analysis of the S-shaped temple ring with a hook terminal at the opposite end of the arc of assumed Bavarian origin from grave 52/1913 from Žalov – Cihelna A. It was also not possible to include grave 28 from Klecany II, because the fragmented skull of a child did not provide an adequate sample. An even more significant factor that can distort the results of radiocarbon dating is the conservation of some previously excavated anthropological collections (see *Bíšková et al. 2023*, 43; *Pachnerová Brabcová et al. 2024*, 213–215). This also affected the important burial ground of Prague – Lumbe Garden, where bones are preserved with polyvinyl acetate (PVA), a material that is very difficult to remove from bones, thus preventing the use of radiocarbon dating (*Brock et al. 2018*). Therefore, material without conservation obtained during archaeological excavations of burial sites in the last two decades was preferred. We focused on the burial grounds of Žalov – Na Panenské, Klecany I, Prague-Milady Horákové Street, Prague-Triangl, Prague-Klementinum, Prague-Vinoř – stronghold, Prague-Vinoř – V Žabokřiku (hereinafter referred to as Vinoř-stronghold, Vinoř – V Žabokřiku), and Přezletice. From earlier excavations, only samples from the tomb at Prague Castle – Church of the Virgin Mary, from the burial grounds of Prague-Lahovice, Prague – Dolní Chabry (hereinafter referred to as Dolní Chabry), Kováry – Na Týnici, Stará Kouřim, and Libice nad Cidlinou – stronghold were included on an exceptional basis. These sites have undergone or are undergoing revision evaluation in recent years and, in addition, this anthropological material was treated with agents that can be successfully removed for radiocarbon dating. The sites are situated mostly in the heartland of Central Bohemia (*Fig. 7*) and they have, except for Prague-Lahovice and Dolní Chabry, spatial connection with one of the early medieval strongholds in the region. They were located in their interior (Vinoř-stronghold, Libice-stronghold, Prague Castle – St. Mary's Church),

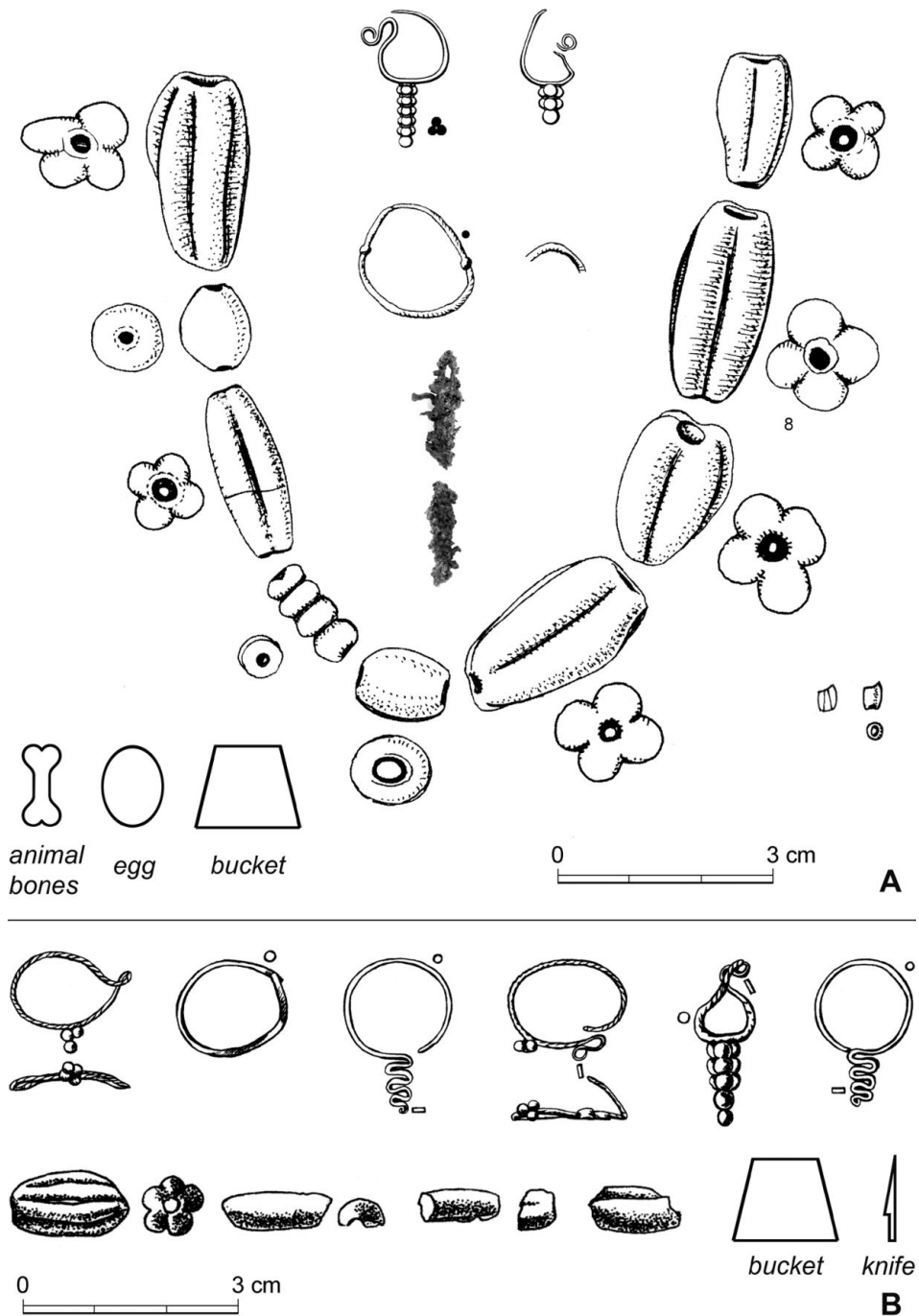


Fig. 6. Grave goods of radiocarbon-dated graves with Jízdárna-type earrings. A – Klecany I, grave 54; B – Žalov – Na Panenské, grave 24, also with meander-shaped earrings (after Profantová et al. 2010, Fig. 45 and Tomková 2012b, Fig. 149, modified by L. Raslová and M. Housková).

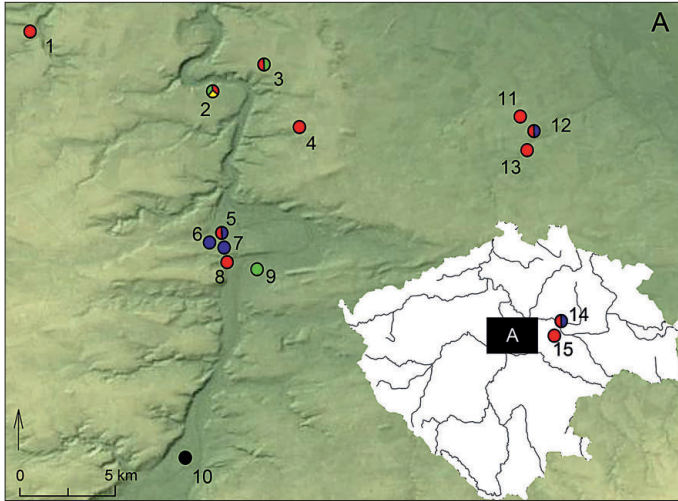


Fig. 7. Map of radiocarbon-dated sites. 1 – Kováry – Na Týnici; 2 – Žalov – Na Panenské, 3 – Klecany I; 4 – Dolní Chabry; 5 – Prague – Milady Horákové Street; 6 – Prague–Triangl; 7 – Prague Castle – Church of the Virgin Mary; 8 – Prague – Vratislav Palace; 9 – Prague-Klementinum; 10 – Prague–Lahovice; 11 – Přebetice; 12 – Prague-Vinoř – V Žabokřiku; 13 – Prague-Vinoř – stronghold; 14 – Libice nad Cidlinou; 15 – Stará Kouřim. Colours: red – S-shaped temple rings; blue – temple rings with an eyelet; green – Jízdárna-type earrings; yellow – meander-shaped earrings; black – hybrid type.

in the surrounding area (Žalov – Na Panenské, Klecany I,⁶ Kováry – Na Týnici, Prague – Vratislav Palace), or in the immediate vicinity of the stronghold (Prague – Milady Horákové Street, Prague-Triangl, Prague-Klementinum, Vnoř – V Žabokřiku, and Přebetice). The radiocarbon dates from the mass grave in Kováry – Na Týnici were not included in the catalogue (Štefan – Krutina 2009, 151, 157, 202, fig. 26: E, graph 8). Among the bones from the mass grave was a female skull with eight small S-shaped temple rings 12–16 mm in diameter. However, the published radiocarbon dates (1170 ± 30 and 1130 ± 30) do not come directly from this skull.

The resulting assemblage of graves (Tab. 2), which became the starting point of our study, was divided into three parts: grave units with S-shaped temple rings (Tab. 2: A), wire jewellery, one end of which is open (Tab. 2: B), and graves comprising hybrid forms or other potential prototypes of S-shaped temple rings (Tab. 2: C). The last group also comprised, in addition to hybrid earrings of the Jízdárna type, one silver S-shaped temple ring with a knot composed of a ring of granules surrounded by simple-wire rings from grave 30 and one silver earring with three granules on a ring and a hook fastener from grave 389 from the burial ground in Prague-Lahovice. The finds from grave 24/2003 from Žalov – Na Panenské, which contained a diverse set of jewellery (a pair of meander-shaped earrings, an earring from twisted wire with three granules and an unfinished S-shaped end, and earrings of the Jízdárna type deformed into a pendant), are therefore included in two tables (Tab. 2: B and C).

Selected samples were dated by the radiocarbon AMS method in the years 2017–2022. Most of the samples were processed in the Czech Radiocarbon Laboratory (CRL), while a smaller part of the samples, and especially the repeatedly dated samples, were analysed in the ETH Zurich laboratory in Switzerland or the AMS Laboratory of Kiel University

⁶ The unpublished graves from Klecany included in this study are spatially connected to the Klecany I burial ground and we can consider them part of it.

(KIA) in Germany; one sample comes from the Poznan Radiocarbon Laboratory in Poland. Most of the samples were analysed directly for the preparation of this study.

Human bones were sampled in all cases. When dating bone samples, the time of collagen formation is actually determined. In the case of children, juveniles, and young adults, the result will correspond fairly accurately to the time of their life. Data obtained from adult humans do not represent the time of death or childhood bone formation but reflect the process of bone remodelling (e.g. *Geyh 2001; Hedges et al. 2007; Ubelaker et al. 2015; 2022; Chmielewski et al. 2021*). This occurs at different rates in different parts of the skeleton (fastest in vertebrae and ribs, very slow in the skull base, for example). The exact timing of these processes depends on many unknowns: the lifespan of the individual, which we can only estimate, and it can also be influenced by diseases, lifestyle, or motherhood. Depending on the age of the individual and the type of bone, the sample may contain an isotope signal from several years or decades before death. For this reason, we have included a correction to compensate for the difference between the time of death and the time of bone collagen formation in the evaluation of the radiocarbon data (*Ubelaker et al. 2015*). This correction is explicitly expressed in the graphs (see *Fig. 10–14*) by a normal distribution with parameters given in brackets (equivalent to the Offset function of the OxCal program). Where the preservation of anthropological material allowed, we preferred ribs, mainly because of the relatively rapid remodelling of bone tissue (*Chmielewski et al. 2021*). For replicate measurements, we combined re-dating of the same sample with sampling of a different bone. In some cases, ultrafiltration was added to routine laboratory processing (see *Bířková et al. 2023, 43–45*). When evaluating the data, it is necessary to take into account the process of treatment of the radiocarbon data and the quality of the samples, as well as the whole set.

We dated only one sample for most of the burials. By this procedure, we aimed to obtain a larger set of data from different sites. We believe that this approach is sufficient to capture trends in the development of jewellery. If the obtained data did not correspond to the previous research, we made repeated measurements. Repeated measurements were also used for conserved bones to reveal possible effects on the dating results. Replication is a suitable strategy for reducing the risks associated with the radiocarbon dating of any sample set (see *Bayliss – Marshall 2019*).

OxCal v4.4 software (*Bronk Ramsey 2009*) and the IntCal20 calibration curve (*Reimer et al. 2020*) were used to model and calibrate the data. All previously published data were recalibrated according to the IntCal20 curve. The 95% probability level (sigma 2) was used in the evaluation. We employed the mutual combination of radiocarbon dates using the Combine function in OxCal when evaluating repeated dating of a single individual. While using radiocarbon data from different laboratories, processed by different procedures, the R_Combine command is not suitable for data combination. The Combine function, on the other hand, is more conservative and thus seems more appropriate. In this case, the radiocarbon data should not contradict the assumption of dating the same event. The diagnostic tools (A_{comb} coefficients and χ^2 tests) were used to evaluate the model representations and their agreement with the radiocarbon dates. The OxCal functions First and Last were used to formulate conclusions about the earliest or latest appearance of jewellery groups. Otherwise, only a single modelled date is used for the evaluation; this is done in cases where we did not have enough data for a statistical evaluation (it applies to a group of meander-shaped earrings and hybrid types from Prague-Lahovice).

A. S-shaped temple rings	Grave	Abbreviation	Grave goods	Anthropological determination	Anthropological inventory no., NM Prague	References
	Dolní Chabry, Church of the Beheading of St. John the Baptist H80/1974	Dch H80	1 silver S-shaped temple ring, Ø 16x18 mm, wire thickness 3–3,3 mm; necklace with an 1 fluorite and 9 glass beads	child (3–4 years)	unspecified	Dragoun – <i>Tryml</i> 2022, 208, Obr. 219, Tab. 2, 5; Havrda – <i>Tryml</i> 2021, 295, Obr. 85–87; Tab. 1
	Klecany I, H22/2005	KI H22	1 S-shaped temple ring made of copper alloy, Ø 9,5x11 mm, wire thickness 1 mm; 1 earring with a spiral pendant and wire knots; axe; bucket; knife; flint stone	male, maturus II (45–60 years)	P7A 40 732	Profaňová et al. 2010, Tab. 14, 15; Profaňová et al. 2015, 25, 26
	Klecany I, H70/2007	KI H70	2 silver S-shaped temple rings, Ø 13x15 and 13x14 mm, wire thickness 2 mm	female?, adultus II – maturus I (30–45 years)	P7A 41 586	Profaňová et al. 2010, Tab. 64; Profaňová et al. 2015, 36
	Klecany I, H89/2008	KI H89	2 silver S-shaped temple rings, Ø 11x14 mm and 10x12 mm, wire thickness 1 mm; fragments of a copper alloy ornament; fragments of a buckle; knife; ceramic vessel; egg	female, maturus I (40–50 years)	P7A 41 930	Profaňová et al. 2010, Tab. 80, 81; Profaňová et al. 2015, 40–41
	Klecany I, H1/2017	KI H1-17	4 S-shaped temple rings, Ø 10 mm (before conservation); wire thickness 1,8–2 mm (before conservation)	female, maturus I (35–50 years)	unspecified	unpublished
	Klecany I, H6/2017	KI H6-17	1 S-shaped temple ring (copper alloy ?), Ø 14x11 mm (before conservation), wire thickness ca. 2,2 mm (before conservation); 2 fragments of an iron artefact (a knife?)	female maturus I–II (40–55 years)	unspecified	unpublished
	Klecany I, H9/2017	KI H9-17	15 S-shaped temple rings, Ø 10–15 mm (before conservation), wire thickness 2 mm (before conservation); 1 knife	female, adultus I (20–30 years)	P7A 43 548	unpublished
	Klecany I, H14/2017	KI H14-17	4 S-shaped temple rings, Ø 12,6x13, 12x12, 13x14 and 14x12 mm, wire thickness 1 mm and 1,7–1,8 mm	female, adultus I–II (20–40 years)	P7A 43 551	unpublished
	Kováry – Na Týnici, H117/1987	KNT H117	1 S-shaped temple ring made of copper alloy, Ø 18x14 mm, wire thickness ca. 2 mm; fragments of a copper alloy artefact (S-shaped temple ring?)	infans II (5 years)	P7A 39 246	Štefan – <i>Krutina</i> 2009, 201
	Libice nad Cidlinou, stronghold, so-called acropolis H45/1950	Lib H45	1 damaged silver S-shaped temple rings (+1 unpreserved), Ø 13,5 x 11,7 mm, wire thickness 1,3 mm	child, infans II (6 years)	P7A 30 163	Košťová 2014, 146, Tab. 1; Turek 1978, 11–12
	Libice nad Cidlinou, stronghold, so-called acropolis H98a/1951	Lib H98a	7 S-shaped temple rings made of copper alloy (2 expliers are silver plated), Ø up to 20 mm, wire thickness 1,8–4 mm	juvenis (16 years)	P7A 30 220	Košťová 2014, 180–181, Tab. 3; Turek 1978, 32
	Libice nad Cidlinou, stronghold, so-called acropolis H159/1951	Lib H159	7 (+6 unpreserved) S-shaped temple rings, Ø up to 15 mm, wire thickness 1,4–1,6 mm; necklace with an amber cross and glass beads; 2 polyhedral, 2 round and 403 miniature; fragment of a corroded glass bead; amber biconical bead; iron fragments; 1 knife	child, infans I–II	P7A 31 113	Košťová 2014, 220–222, Tab. 7; Turek 1978, 62–64
	Prague 1 – Lesser Town, Vrátilslav Palace, Tržiště street No. 366/III, H80/1993	PVP H80	1 damaged gilded S-shaped temple ring, Ø 12/13 mm, wire thickness 2,5 mm	female, adultus I (20–30 years)	unspecified	Brejcha 2012, 126; Havrda – <i>Tryml</i> 2021, 223–226; Obr. 6–7, 17; Tab. 1
	Prague 6 – Hradčany, Mladý Horákové, H48/2011	MH H48	1 silver S-shaped temple ring, 11x13 mm, wire thickness 0,6/0,7 mm; 2 silver wires; glass beads; segmented (wound), flat oval, 3 olive and fragments of olive beads	female, maturus I–II (45–55 years)	P7A 42 280	unpublished
	Prague 6 – Hradčany, Mladý Horákové, H83/2013	MH H83	1 silver temple ring with an unfinished S-shape end, Ø 13x14 mm, wire thickness 0,7 mm; fragment of silver earring on temple ring, 2 silver earrings with a grape pendant; 1 silver damaged spherical button (gombik); 1 knife; iron artefact	child, infans II (6 years ± 24 months)	P7A 42 844	unpublished
	Prague 9 – Vinoř stronghold, so-called acropolis H2/2017	VA H2_CRL, VA H2_POZ	1 damaged gilded silver S-shaped temple ring, Ø 17 mm, wire thickness 2,6 mm; 4 gilded spherical buttons (gombik); 1 silver earring with three filigree baskets; 6 silver earrings with three sheet beads; fragments of another 2 earrings; 2 silver beads; silver ring, knife	juvenis (13 years)	unspecified	Štefan et al. 2024, 323–342, Fig. 5
	Prague 9 – Vinoř, V Žabokříku, H2/2009	VZ H2_CRL1, VZ H2_ETH, VZ H2_KIA	1 silver S-shaped temple ring, Ø 11,4x14,2 mm, wire thickness 1,3 mm; 2 amber and 7 glass beads; ring, knife	child, infans II (5 years)	P7A 42 062	unpublished; Unger 2014, 9
	Prague 9 – Vinoř, V Žabokříku, H23/2009	VZ H23_CRL1, VZ H23_CRL2, VZ H23_ETH, VZ H23_KIA	5 silver S-shaped temple rings, Ø 12,1–14 x 14,4–19,9 mm, wire thickness 1,9–2,4 mm; ceramic vessel; iron fitting with a spring bar; 3 bronze lumps	female?, adultus I–II (20–35 years)	P7A 42 081	unpublished; Unger 2014, 13
	Prezletice, H12/2015	Pre H12	5 S-shaped temple rings (silver and copper alloy); Ø up to 15 mm, wire thickness of silver items 1,7, 1,8 and 3,5 mm, wire thickness of copper alloy items 2,1 and 2,2 mm	juvenis (12–14 years)	P7A 43 562	Košťová et al. 2022, 231, obr. 12
	Prezletice, H21/2015	Pre H21	1 gilded S-shaped temple ring; Ø 17 mm, wire thickness 2,9 mm	female, adultus II – maturus I (30–59 years)	P7A 43 571	Košťová et al. 2022, 202, 233, obr. 12
	Prezletice, H53/2015	Pre H53	2 silver S-shaped temple rings, Ø up to 15 mm, wire thickness 2–2,1 mm	female (?), adultus I (20–29 years)	P7A 43 601	Košťová et al. 2022, 244–245, obr. 12
	Prezletice, H58/2015	Pre H58	2 S-shaped temple rings made of copper alloy, Ø up to 15 mm, wire thickness 1,7 mm	female, adultus I (20–29 years)	P7A 43 606	Košťová et al. 2022, 239–241, obr. 12
	Prezletice, H59/2015	Pre H59	5 S-shaped temple rings; Ø up to 15 mm (4 silver; 1 copper alloy), wire thickness 2,2–2,3 mm	female, adultus I (20–29 years)	P7A 43 607	Košťová et al. 2022, 246, obr. 12

Stará Koutřim, U Líbuše, H16/1956	StK H16	6 S-shaped temple rings made of copper alloy, Ø 13x13, 13x18, 12x17, 12x16, 16x16, 15x15 mm, wire thickness 2 mm	older child	P7A 31 796	Šolle 1966, 256
Stará Koutřim, U Líbuše, H19/1956	StK H19	2 silver S-shaped temple rings, Ø 13x14 mm, wire thickness 2 mm	adult female (?)	P7A 31 799	Šolle 1966, 257
Stará Koutřim, U Líbuše, H23/1956	StK H23	1 S-shaped temple ring made of copper alloy, Ø 13x13 mm, wire thickness 1 mm; necklace with an amber bead, 6 small melon, 2 rounded, 2 segmented, 70 small conical; headband made of linen and silk thread wrapped with silver thread	child	P7A 31 803	Šolle 1966, 257
Žalov – Na Panenské, H6/2003	ZP H6_CRL, ZP H6_KIA	2 S-shaped temple rings made of copper alloy, Ø 18x20 and 17x20 mm, wire thickness 1,3 mm; glass beads: 1 olive, 1 rounded and 2 polychrome (rounded and fr. of segmented with eyelets); 1 ceramic vessel	undetermined (female?), adultus II – maturus (35–45 years)	P7A 40 551 Ao 10 551	Tomková 2012b, 165, 166, obr. 126, 128
Žalov – Na Panenské, H33/2005	ZP H33_CRL, ZP H33_KIA	1 S-shaped temple ring made of copper alloy, Ø 20 mm, wire thickness ca. 1,5 mm (before conservation); glass beads: 11 olive, 1 fusiform; pendant (unpreserved); 1 ceramic vessel	child, infans II (approx. 4 years)	P7A 40 965 Ao 10 965	Tomková 2012b, 190, 191, obr. 157
B. Wire jewellery					
Libice nad Cidlinou, stronghold, so-called acropolis H268/1952	Lib H268	2 golden temple rings with an eyelet; 8 luxurious silver earrings with chains; 1 silver casket pendant (kaprota); 4 silver beads with granulation; 2 silver spherical buttons with bosses (gombik); 4 carnelian beads; 1 quartz-stone bead; 1 amber bead; 1 glass bead; 1 iron awl	female, adultus I (20–30 years)	P7A 31 100	Kostová 2014, 292–298, Tab. 17–18; Turek 1978, 121–124
Prague 1 – Hradčany, Church of the Virgin Mary, H IIN062	PH-IN H62	1 silver temple ring with an eyelet; 2 silver earrings with a grape pendant	female, maturus II (50+)	unspecified	Frolík 2015, 143–150; Frolík et al. 2020
Prague 6 – Hradčany, Milady Horákové, HZ/2011	MH H2	1 silver temple ring with an eyelet; 2 amber beads; 1 silver bead; 2 gilded spherical buttons; 1 knife; 1 bucket	child, infans II (9–10 years)	P7A 42 245	unpublished
Prague 6 – Sřešovice, Triangl H47/2012	Tri H47	14 silver temple rings with an eyelet; 3 silver earrings with three figural beads; 5 amber beads; 4 glass beads; 2 silver rings; 1 copper ring; 2 knives	female2, adultus II – maturus I (30–45 years)	unspecified	Frolíková-Kalitzová et al. 2023, 59–62, Obr. 29–31
Prague 9 – Vinoř, V Žabokřku, H24/2009	VZ H24_CRL, VZ H24_ETH, VZ H24_KIA	2 temple rings with an eyelet made of copper alloy; under the hull at the bottom of the grave pit 1 bronze lump	female, maturus I (40–50 years)	P7A 42 082	unpublished; Unger 2014, 13; Kostová et al. 2022, 216, graf 12
Žalov – Na Panenské, H8/2003	ZP H8	1 gilt copper meander-shaped earring; glass beads: 3 olive and 8 G-beads; 1 knife; ceramic vessel	undetermined (female?), maturus I–II (40–60 years)	P7A 40 553 Ao 10 553	Tomková 2012b, 167, obr. 127, 128
Žalov – Na Panenské, H24/2003	ZP H24_CRL, ZP H24_KIA	2 silver meander-shaped earrings; 1 copper-alloy ring-shaped earring; 1 silver earring with three granules and S-shape end; 1 silver earring with three granules; 1 gilded earring of Jizdárna type; 2 glass olive beads; 1 knife; 1 bucket	undetermined (female?), maturus I–II (40–60 years)	P7A 40 569 Ao 10 569	Tomková 2012b, 183, 184, obr. 149
C. Hybrid types					
Klecany I, H54/2005	KI H54	2 copper/gilded-copper earrings of Jizdárna type; 2 earrings with wire knots; glass beads: 6 olive; 1 segmented wound on tube; 2 fusiform; 1 miniature cylindrical bead; 1 iron needle, bucket; 1 egg; animal bones	female, adultus I (25–35 years)	unspecified	Profantová et al. 2010, Tab. 44–46; Fotabab. 39; Profantová et al. 2015, 32, 33
Prague 1 – Old Town, Klementinum, H32/2012	Pkt H32	1 gilded earring of Jizdárna type; 1 earring with two wire knots made of copper alloy; 1 simple earring with hook-shaped flattened end	child, 12 years	unspecified	Havrdá – Žďárská 2017, 108–109
Prague 16 – Lahovice, H30-1/1955	La H30_CRL, La H30_KIA	1 silver S-shaped temple ring with a knot composed of a ring of granules surrounded by simple-wire rings; 3 glass G-beads; 1 bucket; 1 knife	female, adultus II (35–50 years)	P7A 31 499	Krumphanzlová et al. 2013, 88, tab. 55
Prague 16 – Lahovice, H389-75/1960	La H389_CRL, La H389_KIA	1 silver earring with three granules on a ring and a hook fastener; 1 ring-shaped earring with knots made of copper alloy; 1 large silver (ear?) ring; glass beads: 1 olive, 2 flat oval, 1 segmented wound on metal tube; 3 G-beads; 1 knife	female2, adultus I (20–35 years)	P7A 32 770	Krumphanzlová et al. 2013, 164, tab. 94
Žalov – Na Panenské, H7/2003	ZP H7	2 gilded earrings of Jizdárna type; glass beads: 8 olive; 1 incomplete mille foiri bead; copper-alloy sheets from a pendant/ornament	undetermined (female?), juvenis-adultus	P7A 40 552 Ao 10 552	Tomková 2012b, 166–167, obr. 129
Žalov – Na Panenské, H20/2003	ZP H20	2 silver earrings of Jizdárna type; 1 silver earring with a grape pendant (unspecified); 3 glass olive beads; 1 knife; iron fragment	female, adultus I–II (25–30 years)	P7A 40 565 Ao 10 565	Tomková 2012b, 179–180, obr. 144
Žalov – Na Panenské, H22/2003	ZP H22	1 copper (gilded?) earring of Jizdárna type; bronze fragments of an earring; 1 lead pendant; glass beads: 13 olive, 5 fusiform, 1 with eyes; bottom of the ceramic vessel; spindle whorl; 1 knife with iron decorated handle; 1 iron needle; fragments of an iron ring; egg?	female, maturus I (40–50 years)	P7A 40 567 Ao 10 567	Tomková 2012b, 180–182, obr. 146–147
Žalov – Na Panenské, H24/2003	ZP H24_CRL, ZP H24_KIA	2 silver meander-shaped earrings; 1 copper-alloy ring-shaped earring; 1 silver earring with three granules and S-shape end; 1 silver earring with three granules; 1 gilded earring of Jizdárna type; 2 glass olive beads; 1 knife; 1 bucket	undetermined (female?), maturus I–II (40–60 years)	P7A 40 569 Ao 10 569	Tomková 2012b, 183, 184, obr. 149

Tab. 2. Graves with S-shaped temple rings (A), wire jewellery (B), and hybrid types with an S-shaped end (C) selected for radiocarbon dating. In the case of repeated dating, the laboratory code is appended to the abbreviation.

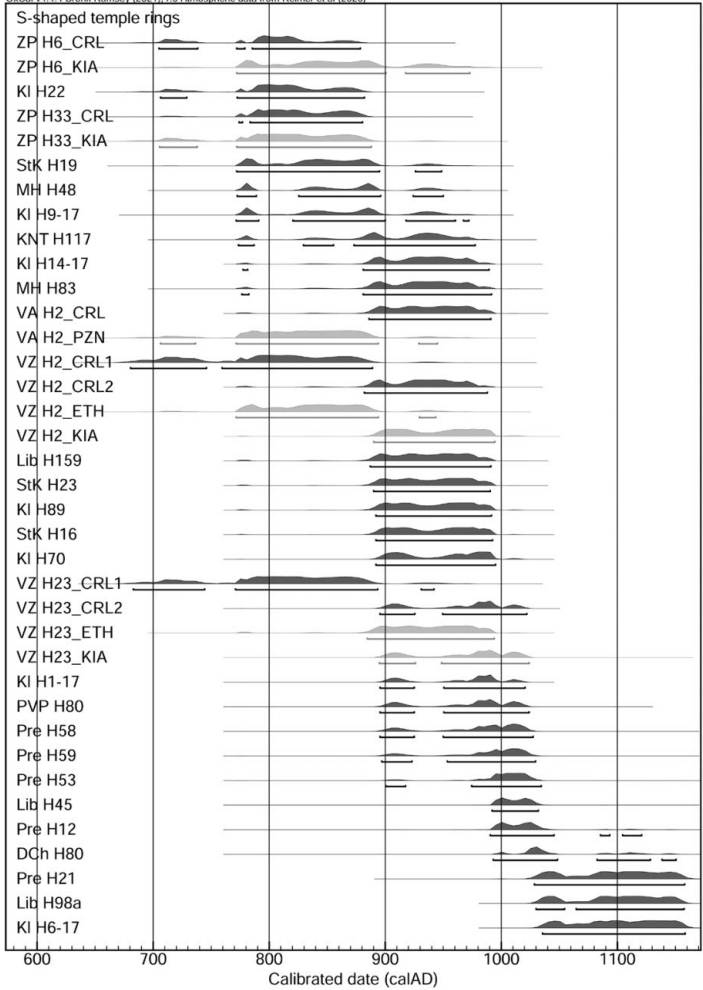
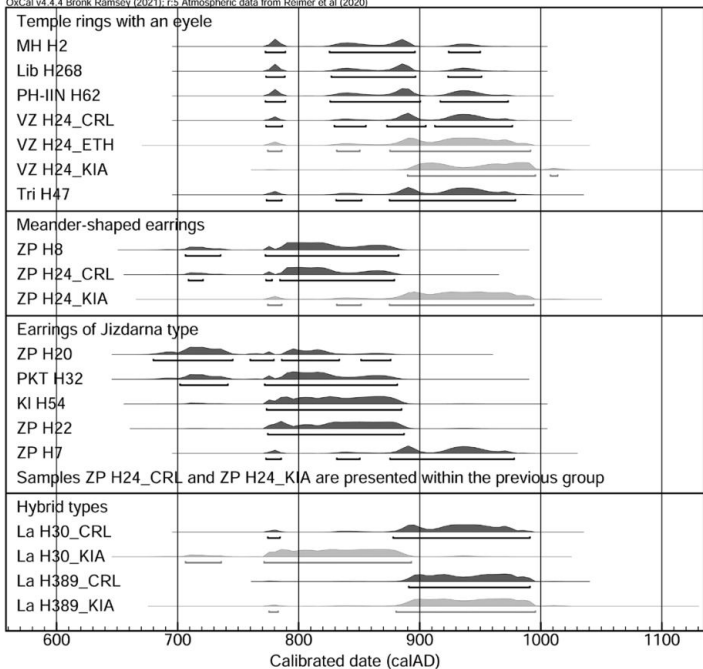


Fig. 8AB. Calibration of all radiocarbon dates before modelling. CRL lab in black, other radiocarbon laboratories in grey.

A



B

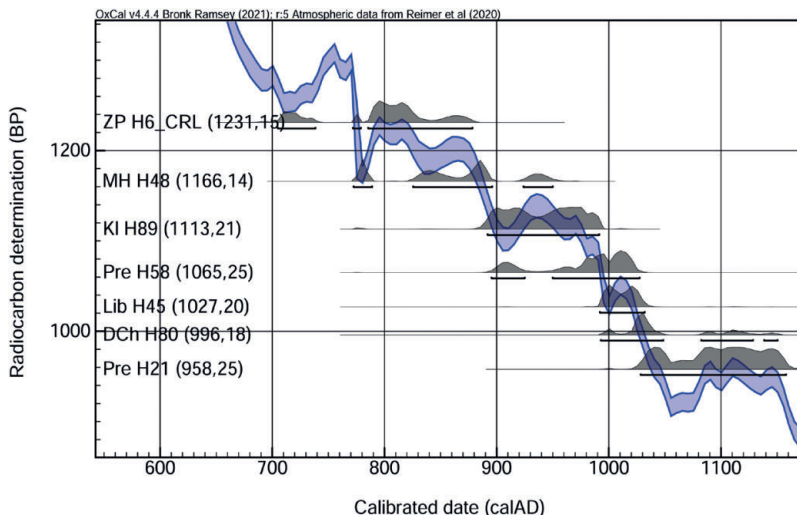


Fig. 9. The course of the calibration curve directly affects the resulting calibrated age.

Results

The results of the radiocarbon dating are evaluated separately for each group of jewellery (*Tab. 3; Fig. 8; Online Supplementary Material 1*). Radiocarbon dates are not calendar dates – they are time intervals. The possibilities of formulating conclusions are thus influenced by the shape of the calibration curve. It mostly does not allow for fixing the occurrence of jewellery groups in narrower periods, such as decades within the 9th or 10th century. In general, the individual radiocarbon dates for the 9th and 10th centuries fall into two-time segments (*Fig. 9*). The first covers almost the entire 9th century with an overlap into the late 8th century. The second covers the 10th century. The shape of the calibration curve offers a way for working with the data. We take advantage of the steep section on the calibration curve in 880–910 AD, which was caused by a relatively rapid increase in atmospheric $^{14}\text{CO}_2$ activity. For dates falling only in the 9th century, we can determine the latest event at which these jewels were part of the living culture. This information suggests that sometime prior to this event the jewels were already in use and therefore appear in graves. The latest parts of the radiocarbon age intervals for the 9th century can be understood in this context as an *ante quem* event. On the other hand, we will ask which categories of jewellery appear only in the 10th century.

S-shaped temple rings

For the radiocarbon dating of S-shaped temple rings, we used 37 samples related to 28 graves from 11 sites (*Tab. 3: A; Fig. 10: A, B*). Only in seven cases were the individuals older than *adultus II*. The other samples were from individuals aged *adultus I–II*, juveniles, and children. Where sex could be determined, they were females or probably females (12 cases), or the female sex was inferred from grave furnishings, which also applies to individuals of *juvenile* age. Only K1 H22 was anthropologically determined to be male;

A. S-shaped temple rings					
Grave	Abbreviation	Sample code	C ¹⁴ age BP	±	AD cal after correction and modelling (95.4% probability)
Dolní Chabry, Church of the Beheading of St. John the Baptist, H80/1974	DCh H80	CRL-17350	996	18	992–1048 (95.4%)
Klecany I, H22/2005	KI H22	CRL-220382R	1223	19	820–894 (95.4%)
Klecany I, H70/2007	KI H70	CRL-220383R	1096	19	906–1017 (95.4%)
Klecany I, H89/2008	KI H89	CRL-220384R	1113	21	899–989 (95.4%)
Klecany I, H1/2017	KI H1-17	CRL-17081A	1079	16	907–946 (26.0%); 964–1041 (69.4%)
Klecany I, H6/2017	KI H6-17	CRL-17509	949	20	1031–1102 (95.4%)
Klecany I, H9/2017	KI H9-17	CRL-220378R	1166	19	835–909 (66.7%); 925–969 (28.7%)
Klecany I, H14/2017	KI H14-17	CRL-220379R	1133	19	891–989 (95.4%)
Kováry – Na Týnici, H117/1987	KNT H117	CRL-20040	1149	19	840–850 (1.5%); 868–979 (93.9%)
Libice nad Cidlinou, stronghold, so-called acropolis, H45/1950	Lib H45	CRL-220550Rr	1027	20	992–1032 (95.4%)
Libice nad Cidlinou, stronghold, so-called acropolis, H98a/1951	Lib H98a	CRL-220553R	957	20	1024–1096 (95.4%)
Libice nad Cidlinou, stronghold, so-called acropolis, H159/1951	Lib H159	CRL-220549R	1123	21	888–987 (95.4%)
Prague 1 – Lesser Town, Vratislav Palace, Tržiště street No. 366/III, H80/1993-02	PVP H80	CRL-19598	1074	20	908–939 (22.4%); 963–1038 (73.0%)
Prague 6 – Hradčany, Milady Horákové, H48/2011	MH H48	CRL-21557	1166	14	842–973 (95.4%)
Prague 6 – Hradčany, Milady Horákové, H83/2013	MH H83	CRL-21558	1132	21	883–984 (95.4%)
Prague 9 – Vinoř stronghold, so-called acropolis, H2/2017	VA H2_POZ	number not specified	1200	30	Combine: 836–852 (2.5%); 871–905 (33.8%); 912–977 (59.1%)
	VA H2_CRL	CRL-220386R	1124	21	
Prague 9 – Vinoř, V Žabokřiku, H2/2009	VZ H2_CRL1	CRL-20124	1224	35	Combine: 877–900 (40.1%); 920–958 (55.4%)
	VZ H2_CRL2	CRL-220372R	1133	18	
	VZ H2_ETH	ETH-124635	1191	25	
	VZ H2_KIA	KIA-56337	1105	24	
Prague 9 – Vinoř, V Žabokřiku, H23/2009	VZ H23_CRL1	CRL-20125	1213	35	Combine: 901–943 (45.7%); 953–1006 (49.7%)
	VZ H23_CRL2	CRL-220373R	1078	19	
	VZ H23_ETH	KIA-56338	1119	25	
	VZ H23_KIA	ETH-124633	1074	24	
Přezletice, H12/2015	Pre H12	CRL-19293	1020	24	990–1039 (95.4%)
Přezletice, H21/2015	Pre H21	CRL-19297	958	25	1027–1104 (95.4%)
Přezletice, H53/2015	Pre H53	CRL-19300	1044	25	908–925 (3.7%); 982–1042 (91.8%)
Přezletice, H58/2015	Pre H58	CRL-19296	1065	25	903–933 (16.7%); 958–1036 (78.8%)
Přezletice, H59/2015	Pre H59	CRL-19292	1058	26	904–930 (11.8%); 962–1037 (83.7%)
Stará Kouřim, U Libuše, H16/1956	StK H16	ETH-131370	1110	21	892–991 (95.4%)
Stará Kouřim, U Libuše, H19/1956	StK H19	ETH-131371	1179	22	829–914 (82.2%); 929–969 (13.2%)
Stará Kouřim, U Libuše, H23/1956	StK H23	ETH-131372	1118	21	890–988 (95.4%)
Žalov – Na Panenské, H6/2003	ZP H6_CRL	CRL-21559	1231	15	Combine: 823–903 (95.4%)
	ZP H6_KIA	KIA-56866	1175	30	
Žalov – Na Panenské, H33/2005	ZP H33_CRL	CRL-21561	1213	15	Combine: 818–885 (95.4%)
	ZP H33_KIA	KIA-56868	1214	27	

B. Wire jewellery					
Grave	Abbreviation	Sample code	C ¹⁴ age BP	±	After correction and modelling (95.4% probability)
Libice nad Cidlinou, stronghold, so-called acropolis, H268/1952	Lib H268	CRL-21547R	1 163	13	847–915 (42.7%); 926–967 (52.7%)
Prague 1 – Hradčany, Church of the Virgin Mary, H IIN062	PH-IIN H62	CRL-17193	1158	17	860–981 (95.4%)
Prague 6 – Hradčany, Milady Horákové, H2/2011	MH H2	CRL-21556	1166	14	834–900 (38.2%); 920–962 (57.2%)
Prague 6 – Střešovice, „Triangl“ H47/2012	Tri H47	CRL-19535	1146	19	880–986 (95.4%)
Prague 9 – Vinoř, V Žabokříku, H24/2009	VZ H24_CRL	CRL-20126	1150	17	Combine: 892–976 (95.4%)
	VZ H24_ETH	ETH-124634	1139	25	
	VZ H24_KIA	KIA-56339	1097	26	
Žalov – Na Panenské, H8/2003	ZP H8	CRL-220377R	1222	20	735–753 (2.3%); 788–917 (93.2%)
Žalov – Na Panenské, H24/2003	ZP H24_CRL	CRL-21560	1222	15	Combine: 792–913 (95.4%)
	ZP H24_KIA	KIA-56867	1130	30	
C. Hybrid types					
Grave	Abbreviation	Sample code	C ¹⁴ age BP	±	After correction and modelling (95.4% probability)
Klecany I, H54/2005	KI H54	CRL-16155	1205	20	793–894 (95.4%)
Prague 1 – Staré Město, Klementinum, H32/2012	PKt H32	CRL-17159R	1230	22	786–886 (95.4%)
Prague 16 – Lahovice, H30-1/1955	La H30_CRL	CRL-220520R	1136	21	Combine: 783–799 (3.6%); 836–916 (49.1%); 823–979 (42.8%)
	La H30_KIA	KIA-56873	1202	28	
Prague 16 – Lahovice, H389-75/1960	La H389_CRL	CRL-220521R	1116	20	Combine: 897–995 (95.4%)
	La H389_KIA	KIA-56874	1115	29	
Žalov – Na Panenské, H7/2003	ZP H7	CRL-17203	1147	17	774–787 (5.5%); 822–904 (82.4%); 916–948 (7.8%)
Žalov – Na Panenské, H20/2003	ZP H20	CRL-220380R	1245	19	728–746 (2.2%); 777–895 (93.3%)
Žalov – Na Panenské, H22/2003	ZP H22	CRL-220381R	1194	19	794–899 (95.4%)
Žalov – Na Panenské, H24/2003	ZP H24_CRL	CRL-21560	1222	15	see ZP H24
	ZP H24_KIA	KIA-56867	1130	30	Combine Table 3: B

Tab. 3. Results of radiocarbon dating of graves with S-shaped temple rings (A), wire jewellery (B), and hybrid types with an S-shaped end (C). In case of repeated dating, the laboratory code is appended to the abbreviation. See details in *Online Supplementary Material 1*.

the jewellery was placed on the deceased's coffin at the time of burial and does not represent a later intrusion (*Profantová et al. 2015, 25–26*). Ultrafiltration was used on almost two-thirds of the samples. The quality of the bone samples was average, with only four samples showing lower values (VZ H2_CRL1, VZ H23_CRL2, KI H70, and KI H9-17).

Calibrated and modelled radiocarbon dating shows that the first jewellery of this type appeared before the end of the 9th century (KI H22 and ZP H33) or around 900 at the latest (ZP H6). Samples from Žalov were analysed repeatedly, and the combined data fall only in the 9th century. The finds from Žalov – Na Panenské are representatives of the A group, i.e. S-shaped temple rings with a diameter of up to 20 mm (for the exact definition, see above); the artefact from Klecany is an M1 temple ring with a diameter of up to 15 mm. The other grave goods of graves ZP H6 and ZP H33 are olive beads.

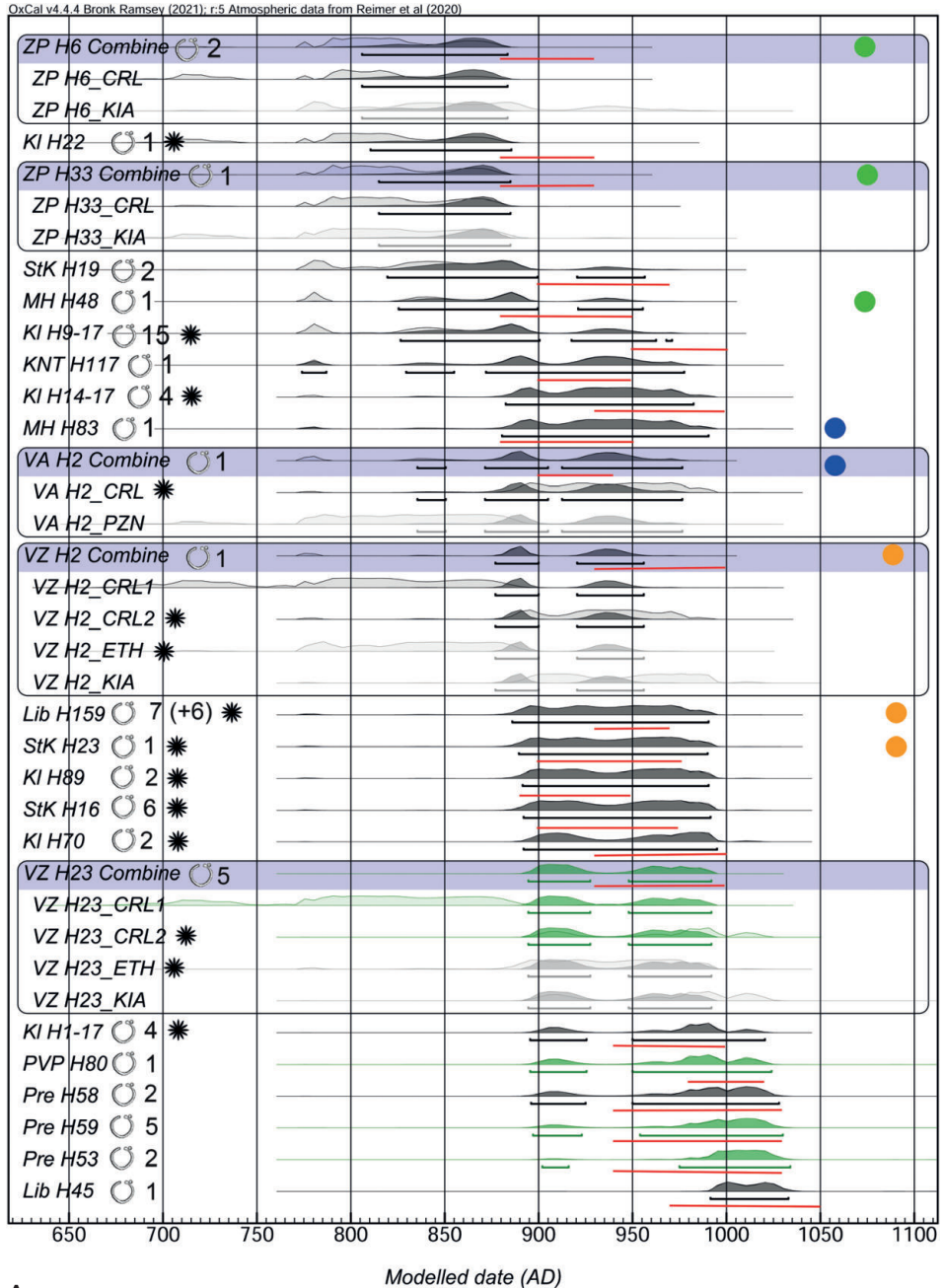


Fig. 10A. One-phase model for S-shaped temple rings. Grey – laboratory other than CRL (laboratory code is given after the sample abbreviation); black – wire thickness up to 2 mm; green – wire thickness more than 2 mm; blue – wire thickness more than 3 mm. The red line indicates the archaeological dating. Chronologically significant grave goods: 1 – jewel decorated with granulation; 2 – olive beads; 3 – G-beads; 4 – amber. Other attributes: 5 – ultrafiltration; 6 – number of temple rings in the set; C – combined dates.

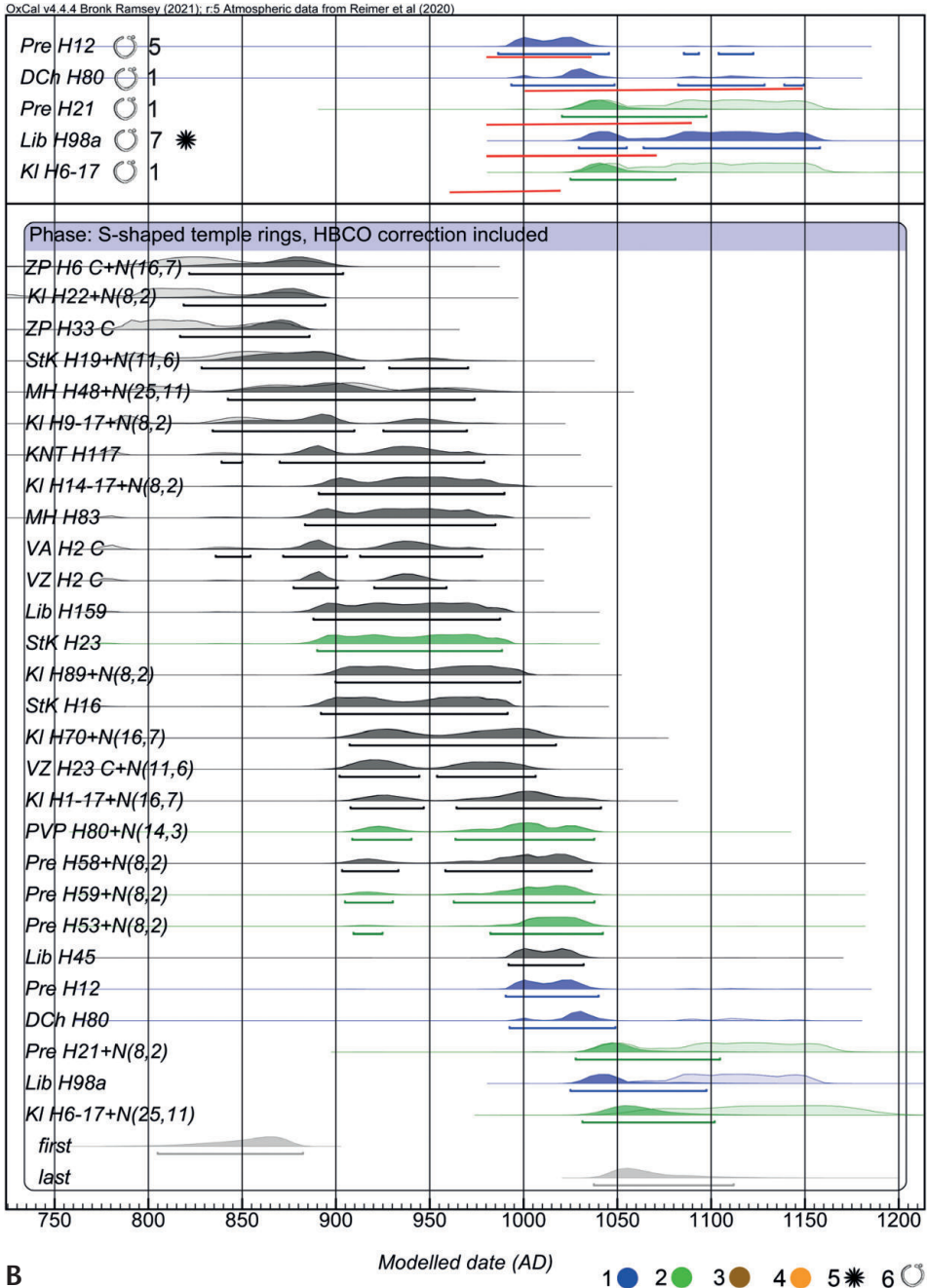


Fig. 10B. One-phase model for S-shaped temple rings. Grey – laboratory other than CRL (laboratory code is given after the sample abbreviation); black – wire thickness up to 2 mm; green – wire thickness more than 2 mm; blue – wire thickness more than 3 mm. The red line indicates the archaeological dating. Chronologically significant grave goods: 1 – jewel decorated with granulation; 2 – olive beads; 3 – G-beads; 4 – amber. Other attributes: 5 – ultrafiltration; 6 – number of temple rings in the set; C – combined dates.

Besides the samples from the 9th century, the analysed set includes S-shaped temple rings M1–M3 with a diameter of up to 20 mm (*Fig. 1: 2–4*), whose calibrated and modelled intervals cover the 9th but mostly the 10th century, and, in some cases, also the 11th to 12th century (see below). The period of the 9th and 10th centuries is represented by S-shaped temple rings from several burial sites: Prague – Milady Horákové Street, Klecany I, Kováry – Na Týnici, Vinoř–stronghold, Vinoř – V Žabokřiku, Stará Kouřim, and Libice nad Cidlinou. The grave goods are represented by jewellery with granulation and also amber, in the case of the burial of MH H48 only by olive beads. This group of radiocarbon dates was affected by high variability between repeated measurements. In the case of burial VZ H2, the evaluation of repeated radiocarbon measurements demonstrates the illustrative nature of the data obtained. On the basis of the archaeological analysis, it is possible to lean clearly towards a dating in the 10th century, especially when considering the occurrence of amber beads in Bohemia and the overall character of the Vinoř – V Žabokřiku burial site. The evaluation of the different measurements of the ‘princess grave’ VA H2 leads us to the conclusion that the actual age is expressed by the combination of both dates with a result of 873–975 cal AD on a probability level of 79%. Also, in this case, we can rely on archaeological evidence: grave goods include jewellery that could have been made as early as the 9th century but also earrings with three baskets, which were made of filigree pretzel pieces combined with granulation. They are currently known from contexts dated to the 10th and early 11th century (*Tomková et al. 2020a*, 209–210, fig. 143), while they were not found in 9th-century contexts in Bohemia or elsewhere in Central Europe.

Other radiocarbon dates for temple rings of M1–M3 size dating to the 10th–11th century, were obtained from the burial sites of Klecany I, Libice nad Cidlinou, Přezletice, and Dolní Chabry. These burial grounds also featured finds of S-shaped temple rings dated to the 11th–12th century. The real dating of these objects, which was determined on the basis of the find situation and a comparison with other radiocarbon dates, likely belongs to the older sections of the resulting probability distributions, i.e. to the first two-thirds of the 11th century. The overlap into the 12th century is a reflection of the shape of the calibration curve. Thus, the analyses confirm most of the small S-shaped temple rings up to 20 mm in diameter after the year 1000.

If we consider not only the diameter but also the thickness of the wire, we can see that after 950 the number of S-shaped temple rings made of thin wire decreased in favour of thicker wire (2 to 2.9 mm). Samples VZ 23 and PVP H 80 show that the occurrence of S-shaped temple rings made of thicker wire (around 2 mm) should be considered already in the first half of the 10th century. As far as S-shaped temple rings made of 3–3.9 mm thick wire are concerned, our analysis indicates that these jewels were produced from the 11th century onwards.

The analysed assemblage, which can be considered representative, documents the beginning of this type of jewellery at the latest before 900 and its continuation in the following century. It confirms that the S-shaped temple rings of the A-group belong to this earliest horizon. In accordance with the archaeological evidence, the results show the continuation of small diameter (up to 20 mm) S-shaped temple rings into the following period and indicate the chronological significance of the wire thickness for the later development of S-shaped temple rings in the 11th and 12th centuries. The set of radiocarbon dates provides the first independent evidence confirming the chronological significance. Nevertheless,

due to the small number of samples, the results are not representative for the 11th and 12th centuries. In the future, however, it may be possible to correlate it with the radiocarbon dates for S-shaped temple rings of a larger diameter published by *Havrda* and *Tryml* (2021, Tab. 1).

Wire jewellery – meander-shaped earrings and temple rings with an eyelet

Although the meander-shaped earrings and the temple rings with an eyelet are not well represented in the radiocarbon-dated graves, the intervals show similarities within each type of jewellery when compared after calibration and correction (Tab. 3: B).

Two individuals with meander-shaped earrings from Žalov – Na Panenské (ZP H8 and ZP H24) were analysed. Due to the poor state of preservation of the anthropological material, it was necessary to sample a fragment of a lower limb bone. The age of both individuals (females?) is estimated to be *maturus I–II*. The modelled data show that the meander-shaped earring from grave ZP H8 is dated with 95.4% probability to the 9th century, or to the first decades of the 10th century at the latest (Fig. 11: A). However, bone quality as well as the collagen yield is low in the ZP H8 sample. A similar interval was shown by the measurement of sample ZP H24_CRL. However, there is a discrepancy with the repeated measurement of ZP H24_K1A from the Kiel laboratory. Evaluation of both measurements showed that they represent outlying measurements of an illustrative nature. Based on archaeological evidence, we would date grave ZP H24 from Žalov – Na Panenské approximately to the interval 860–930. The indicator of dating to the 9th century is represented by the meander-shaped earrings in combination with other grave goods comprising the olive beads, and by the whole character of the set, which speaks of the experimenting spirit of the jeweller, who also created a variant of the earring with three granules on the arc. This type of earring was found in Moravia (*Dostál* 1966, fig. 8: 2, 35); in grave 108 from Mikulčice south of the second church, a closed ring ornament with three granules was found together with two ornaments of the Late Avar type and other Early Carolingian fittings (*Profantová* 1992, Taf. 22A). Similar finds come from Austria: in grave 195 in Edelstal dated back to the second third of the 8th century, they were deposited together with melon-core shaped beads (=melounového jádra), and other come from grave 98 in Mistelbach dated to the second or third of the 8th century (*Distelberger* 1996, taf. 31:4; *Lobinger* 2016, 93, Taf. 45 B1, Taf. 5: 15).

A group of temple rings with an eyelet, covered by a total of seven radiocarbon dates from five different sites (MH H2, Lib H268, PH-IIN H62f; Tri H47, and VZ H24) shows internal consistency, even for re-dated burial VZ H24 (Fig. 11: B). With the exception of the child from MH H2, all samples belong to adult females of *adultus I – maturus* age. Except for Lib H268, collagen was processed without ultrafiltration. Based on the modelled radiocarbon age intervals, these finds can be dated to the first and second third of the 10th century, but their occurrence before 900 cannot be ruled out. The dating to the end of the 9th century is also supported by a series of simulated radiocarbon age intervals that we have generated in the OxCal program (R_Simulate command). The simulated dates from the end of the 9th century are mostly similar to the intervals obtained for the temple rings with an eyelet; however, similar series of calibrated radiocarbon age intervals are also frequently found in the 930s and 940s. We can therefore consider the possible occurrence

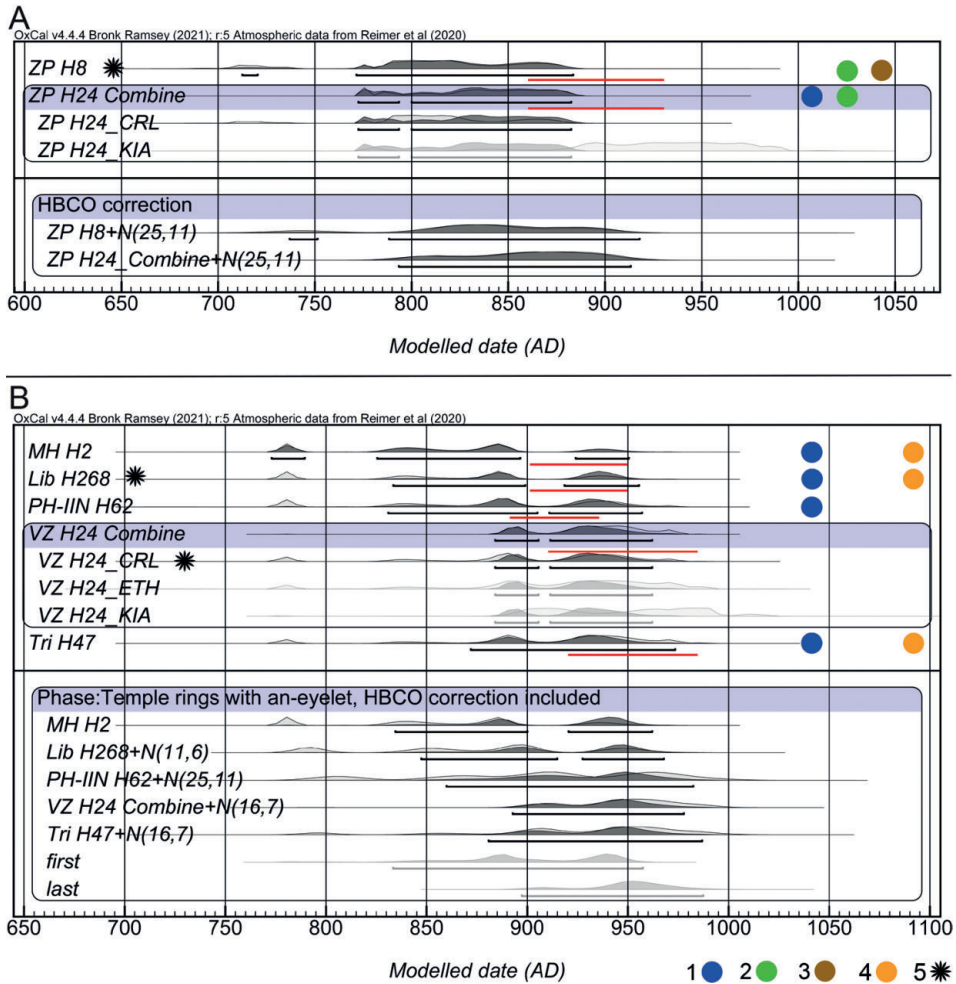


Fig. 11. One-phase model for wire jewellery: A – meander-shaped earrings; B – temple rings with eyelet. Grey – laboratory other than CRL (laboratory code is given after the sample abbreviation). The red line indicates the archaeological dating. Chronologically significant grave goods: 1 – jewel decorated with granulation, 2 – olive beads, 3 – G-beads, 4 – amber. Other attributes: 5 – ultrafiltration.

of the first eyelet earrings close to 900, but their popularity was mainly in the second third of the 10th century, after which their occurrence in graves declined. We have currently no data, even archaeological, to prove their occurrence after 1000. The other grave goods of radiocarbon-dated temple rings with an eyelet are jewellery with granulation and amber. The radiocarbon date for the temple rings with an eyelet is also known from Moravia. It comes from grave H117 from the church burial ground in the north-eastern suburb at Pohansko near Břeclav. Radiocarbon dates Poz-79826 (1145 ± 30) and Poz-79827 (1070 ± 30) date this grave to the 10th century. Grave H117 belongs to a later burial phase, which the authors date from the 920s to the 980s (Macháček et al. 2018, 328–337; 340–341; tab. 1; abb. 15, 19, and 22).

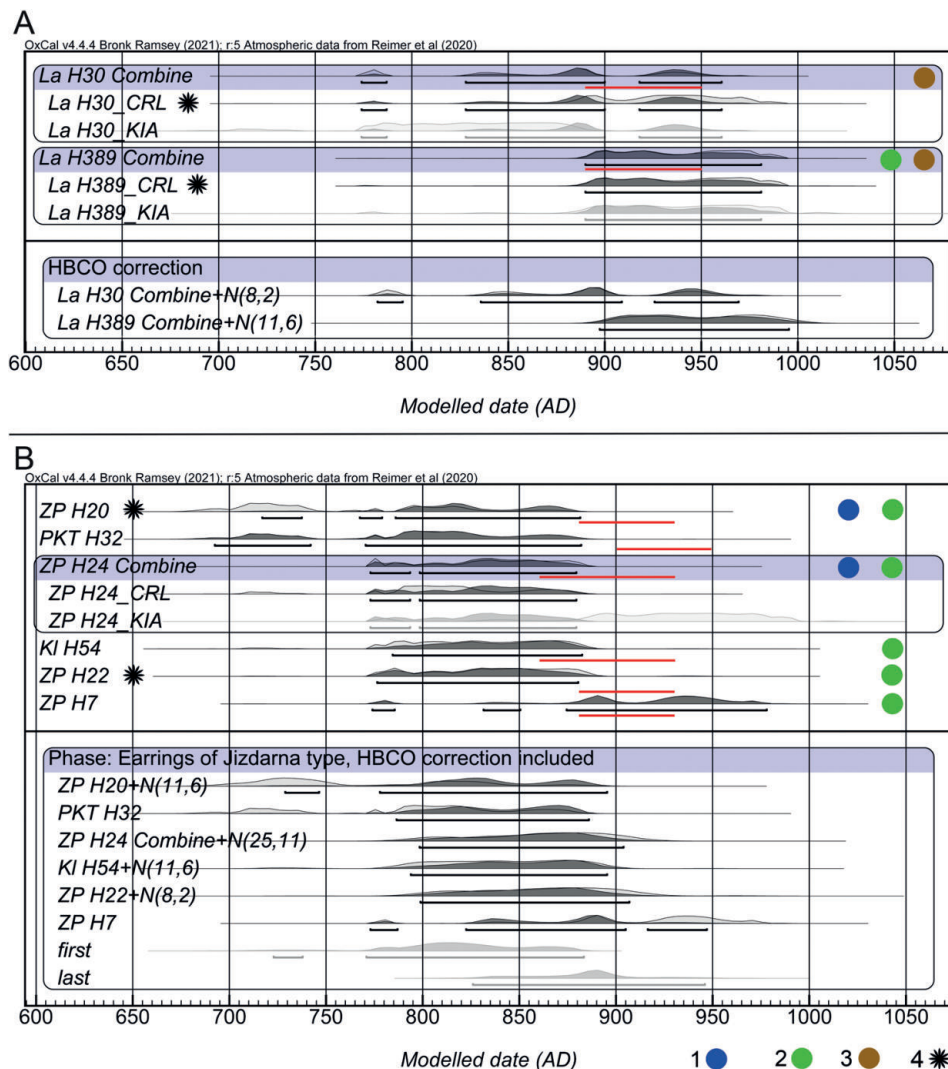


Fig. 12. One-phase model for hybrid types/earrings and other potential prototypes. A – samples from the Prague-Lahovice; B – Jízdárna-type earrings. Grey – laboratory other than CRL (laboratory code is given after the sample abbreviation). The red line indicates the archaeological dating. Chronologically significant grave goods: 1 – jewel decorated with granulation; 2 – olive beads; 3 – G-beads. Other attributes: 4 – ultrafiltration.

Hybrid types with an S-shaped end

The group of hybrid types with an S-shaped end includes earrings of the Jízdárna type and hybrid earrings from Prague-Lahovice (Tab. 3: C). Six graves with earrings of the Jízdárna type were analysed from three sites Klecany, Žalov – Na Panenské and Prague-Klementinum (KI H54, ZP H7, ZP H20, ZP H22, PKt H32, and repeatedly dated ZP H24) (Fig. 12: B). Except for an approximately 12-year-old child from PKt H32 and a *juvenis* –

Burial Ground	N	before calibration		after calibration				cal AD (95.4%)
		χ^2 test		χ^2 test		OxCal diagnostic		
		T	test	T	test	A _{comb}	test	
Vinoř-stronghold, grave 2: VA H2 (df=1; A _n =50)	2	4.3	N	3.5	Y	44	N	?
Žalov – Na Panenské, grave 6: ZP H6 (df=1; A _n =50)	2	2.8	Y	2.3	Y	83	Y	772–778 (3%)
								785–879 (91%)
Žalov – Na Panenské, grave 33: ZP H33 (df=1; A _n =50)	2	0	Y	0	Y	115	Y	784–879 (95%)
Žalov – Na Panenské, grave 24: ZP H24 (df=1; A _n =50)	2	7.5	N	5.2	N	22	N	?
Prague-Lahovice, grave 30: La H30 (df=1; A _n =50)	2	3.6	Y	2.8	Y	54	Y	771–789 (15%)
								825–899 (56%)
								920–956 (24%)
Prague-Lahovice, grave 389: La H389 (df=1; A _n =50)	2	0	Y	0	Y	109	Y	892–989 (95%)
Vinoř – V Žabokřiku, grave 24: VZ H24 (df=2; A _n =40)	3	2.9	Y	1.2	Y	119	Y	903–991 (95%)
Vinoř – V Žabokřiku, grave 2: VZ H2, H2/2009 (df=3; A _n =35)	4	11.6		9.8	N	20	N	?
Vinoř – V Žabokřiku, grave 23: VZ H23 (df=3; A _n =35)	4	13.6		9.6	N	20	N	?

Tab. 4. Test results and values of χ^2 test statistics before and after calibration of repeatedly dated individuals. Critical values: df=1, $T_{(0.05)}=3.8$; df=2, $T_{(0.05)}=6$; df=3, $T_{(0.05)}=7.8$. OxCal diagnostic tool values are reported by A_{comb}; critical value as A_n. Test results: Y – not contradicts; N – test rejects.

adultus I aged individual from ZP H7, the assemblage consists of adult females of various ages. When bone quality was assessed, the samples were of good quality. Even after correction for age, the group is very consistent. With the exception of sample ZP H7, the modelled radiocarbon dates with a probability of 95.4% belong only to the 9th century, i.e. a time close to 900. The dating of the young individual from grave ZP H7 points to the persistence of this type of jewellery into the 10th century.

From the Prague-Lahovice site, we took samples from two graves dated by earlier research to the period of the beginning of S-shaped temple rings in Bohemia. Both samples were repeatedly analysed in Kiel and at the CRL laboratory, where ultrafiltration was used. The modelled data for La H30 can be dated with a 95.4% probability to the whole span of the 9th century as well as to the second and third quarters of the following century. The female *adultus I* from grave La H389 belongs to the very end of the 9th century or to the whole of the 10th century. The quality of the bones as well as the collagen concentration of the La H389 sample are low and do not allow a generalisation of the obtained conclusions (Fig. 12: A).

Discussion

The issue of repeated dating of selected individuals

A fundamental question from the point of view of archaeologists is how to deal with the results of repeated measurements, or those that provide data that do not match. In the analysed dataset, nine buried individuals were repeatedly dated in this way: two measurements were obtained from six burials (Vinoř-stronghold: VA H2; Žalov – Na Panenské:

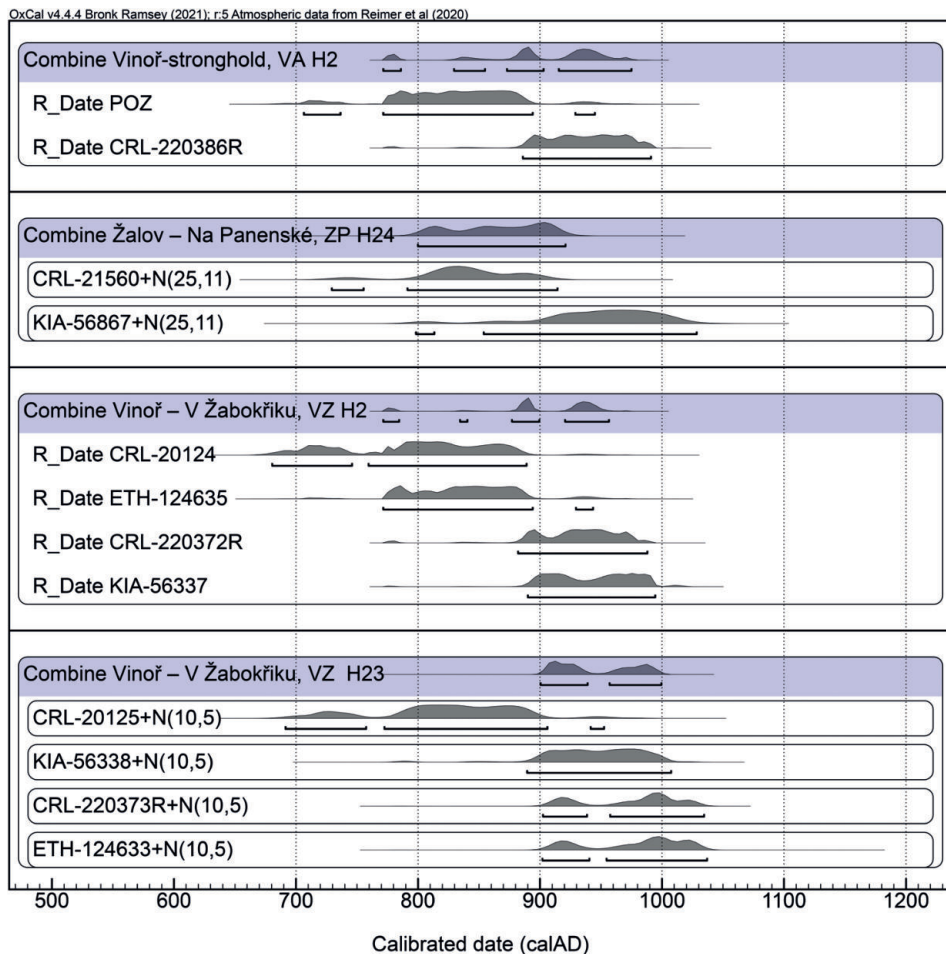


Fig. 13. Evaluation of repeated measurements (graphic differences with outliers).

ZP H6, ZP H24, ZP H33; Prague-Lahovice: La H30 and La H389), three measurements came from a single skeleton buried at Vinoř – V Žabokřiku (VZ H24), and four repeated measurements were made on burials from two graves (Vinoř – V Žabokřiku: VZ H2, VZ H23). We compared the paired results taking into account the shift caused by different tissue remodelling related to the age of the sampled individual (Tab. 4).

The dataset contains at least five outliers out of 23 measurements (21%) which, at 95% confidence of learning the age of the dated samples, exceeds the occurrence of expected outliers due to statistical reasons by more than four times. Special care must be taken in the interpretation of these results and their use (Fig. 13).

Different results of repeated measurements cannot be completely ruled out using the radiocarbon dating method. Particularly for samples with lower measured activities, differences are accentuated and can reach several hundred conventional years (cf. e.g. Higham et al. 2006; Devìese et al. 2019). Due to the technological complexity of the whole radio-

carbon dating procedure, differences can arise for multiple reasons and cannot always be reasonably quantified. Leaving aside gross processing errors, differences in results are usually sought in the inhomogeneity of the sample and its varying degrees of contamination, the chosen processing procedure, and the corresponding evaluation of influences of the accuracy of the result. Other issues then arise from the statistical character of the results and are mainly reflected in the correct representation on a calendar timeline. It cannot be overlooked that, for example, inter-laboratory comparisons have long shown an incidence of outliers of around 10% in sets of repeated bone measurements, which corresponds to approximately twice the expected frequency and points to the need for critical discussion of all radiocarbon data (e.g. *Scott et al. 2010*, 856).

When discussing differences in the results of repeated measurements in our processed ^{14}C data sets, it is important whether the dates allow us to distinguish outliers, whether we are able to identify these outliers based on additional information, or whether all these measurements should be excluded due to low validity. In the case of comparison of measured activities of conventional radiocarbon age, the differences of the obtained results are either tangential at the 2σ interval (Žalov – Na Panenské: ZP H24; Vinoř – V Žabokřiku: VZ H23) or overlapping (Vinoř-stronghold: VA H2).

In the case of the overlapping of these intervals (Vinoř-stronghold: VA H2), it cannot be ruled out that both measurements reflect the actual identical ^{14}C content in both samples, although this hypothesis was rejected on the basis of the χ^2 test. After calibration, this test no longer rejects the hypothesis that the ages of the two samples are the same, but the distribution of acceptable sample ages does not match the model representation of the OxCal diagnostic. In the case of the VA H2 sample from Vinoř-stronghold, the diagnostics prefer time periods with a steep calibration curve (880–891 AD) less. Thus, it is very likely that the actual age of the individual from Vinoř-stronghold VA H2 is expressed by the combination of both dates. Due to the ultrafiltration performed on the younger sample, more emphasis can be placed on this date, which is in agreement with the numerical expression of the combination of both dates with a result of 873–975 cal AD at a probability level of 79%.

A similar, although more extreme situation is shown by the repeated dating of the burial of ZP H24 from Žalov – Na Panenské and the burials of VZ H2 and VZ H23 from Vinoř – V Žabokřiku. Despite the slight overlapping of the probability density distributions of some dates, χ^2 tests and OxCal diagnostics reject chronological contemporaneity. It would be possible to formulate a justification analogous to the previous case, but with different validity. More likely, these assemblages do not meet the assumption of the same ^{14}C content prior to measurement for individual samples from the same individual.

Variation in ^{14}C content prior to measurement may not only be caused by the inhomogeneity of the sampled material but could also be due to the preparation of the samples taken prior to measurement. Sample preparation and pre-treatment aim to cleanse the samples of possible contamination or to select those chemical compounds that can be assumed to have a low probability of contamination by both recent or fossil carbon. Each pretreatment has its own limits of applicability and sample requirements, while at the same time procedures in different laboratories often differ in detail (cf. *Deviése et al. 2019*; *Bířková et al. 2023*).

The differences in the results from Žalov – Na Panenské ZP H24 cannot be reasonably explained with respect to pretreatment or measurement method. It is not possible to

decide on the basis of additional information which of the results represents the outlier and both measurements are therefore only illustrative. It can be assumed that the reason for the difference is either due to sampling, sample inhomogeneity, or a gross processing error.

Re-dating of samples from Vinoř – V Žabokřiku VZ H23 resulted in three measurements with statistically insignificant differences and one different measurement (CRL-20125). Due to the agreement of the three results, one of which underwent a different pre-treatment, it can be assumed that measurement CRL-20125 probably deviates due to weak fossil carbon contamination. The resulting ages after calibration are in the intervals 905–934 cal AD (32% probability) and 962–1007 cal AD (63% probability).

The four dates of the skeleton from Vinoř – V Žabokřiku VZ H2 can be divided into two groups, within which the results do not show statistically significant differences when compared (first group: CRL-20124 and ETH-124635, second group: CRL-220372R and KIA-56337). The anthropological determination of the dated individual identifies it as a child of about five years of age, which rules out variation in the ^{14}C content of the bones due to its different rate of tissue remodelling. The grouping is not solely determined by the sample pretreatment performed (ultrafiltration, see *Bíšková et al. 2023*, 43–45), nor by the choice of laboratory (*Tab. 3: A*). It can be assumed that the differences between the groups of results are due to the different levels of contamination of the dated bones from which the samples were taken. It is not possible to deduce from the set of measurements or the accompanying context which of the groups of dates represent outlying dating results and thus all samples are purely illustrative. The above evaluation of specific cases of repeated measurements shows that it is necessary to take an individual approach to their processing.

Archaeological vs. radiocarbon dating

In the following part of the discussion, we will compare archaeological and radiocarbon dating and address the stimuli that radiocarbon dating brings to the archaeological analysis of early medieval jewellery or other contexts. The graphs (*Fig. 10–12*) not only represent the measurement results but also illustrate the degree of agreement between radiocarbon dating and the archaeologically presumed dating, based not only on the dating of the jewellery in question, but also on the entire grave goods and socio-chronological context of individual burial grounds integrating knowledge of the organisation of the burial grounds, funeral rites and material culture as a whole. The differences between the two types of dating are essentially partial in nature and do not affect the general dating of the analysed jewellery types, with two exceptions. The greatest differences appear for dates from the graves with the oldest S-shaped temple rings and also in the case of graves containing earrings of the Jízdárna type with dates before the year 900.

We attempted to collect a group that would have sufficient informative value. We were successful in this regard with S-shaped temple rings, while the other groups of jewellery are represented by a much smaller number of samples and are hence of a more preliminary character. To evaluate the radiocarbon dates, we use modelled dates only for groups of jewellery that are at least a partially representative set: S-shaped temple rings, temple rings with an eyelet, and earrings of the Jízdárna type. The other groups do not comprise a sufficient number of samples, and for an overall comparison we use basic calibrated dates, or

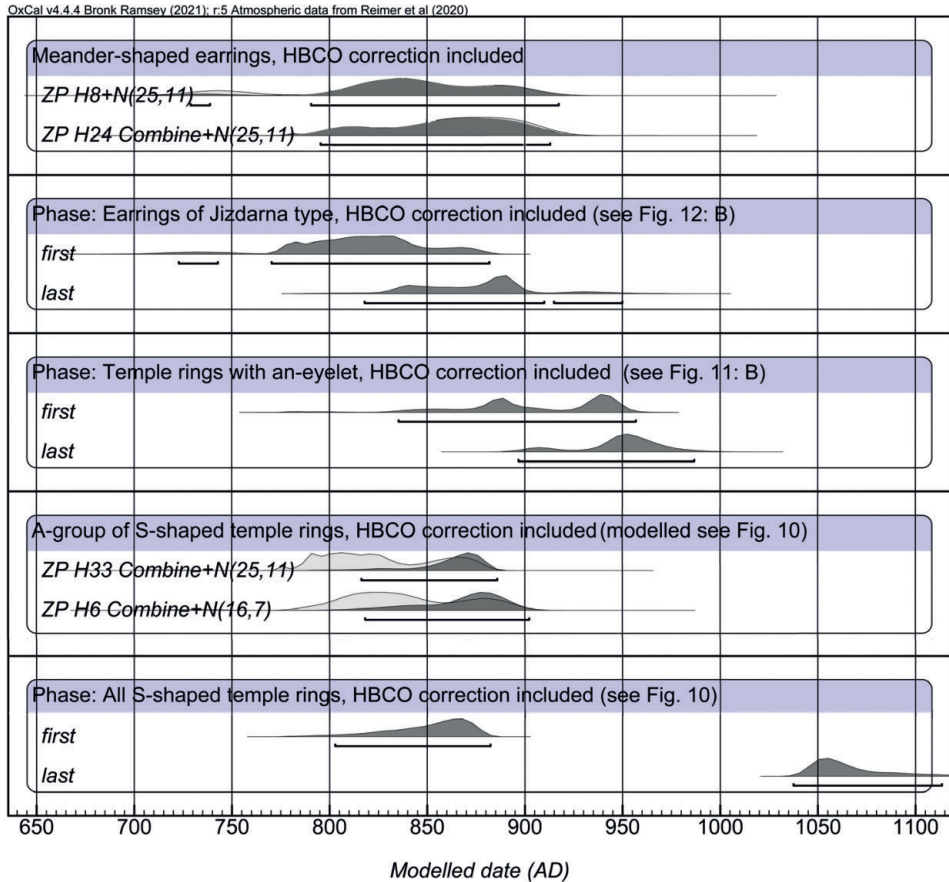


Fig. 14. Comparison of radiocarbon dating of different types of jewellery. Correction of bone tissue remodelling is included.

combined dates (if burials were dated repeatedly) with human bone collagen offset (HBCO) correction. The informative value of these groups is indeed much lower than the first mentioned case. However, it should be noted that even the group of temple rings with an eyelet and earrings of the Jízdárna type strongly manifest tendencies in dating that cannot be regarded as completely random. When processing a similar assemblage, we must not forget that an essential role is played by the actual selection of samples for radiocarbon dating, which is strongly biased. It is not a random group, but all samples entered the analysis intentionally.

The modelled radiocarbon dating of selected jewellery finds indicates (Fig. 14) that in the 9th century all analysed types of jewellery with an arc hammered flat on one end and then formed in various ways – meander-shaped earrings, earrings of the Jízdárna type, S-shaped temple rings of the A-group, the oldest S-shaped temple rings of small diameters, and likely also temple rings with an eyelet (somewhat after the end of the 9th century or probably at the beginning of the 10th century) – coexisted or could have coexisted in Bohemia. It confirms the hypothesis of the dating of the oldest S-shaped temple rings in Bohemia

before the year 900 formulated both by members of the earlier research generation, i.e. *Turek (1946)* and *Borkovský (1947)*, and recently by *Tomková et al. (2020a, 185, 191, 257)* in the context of the hypothetical A-group.

A substantial part of the results does not contradict archaeological observations regarding the simultaneous occurrence of S-shaped temple rings with other types of simple wire jewellery, jewellery of the Danube type, jewellery with filigree and granulation (jewellery of Great Moravian origin or style), as well as various mutual combinations of the studied types of jewellery in graves. The results of radiocarbon dating are not in conflict with the concept of two phases of occurrence of S-shaped temple rings. The early phase, covering the 9th century and the first half of the 10th century, featured the isolated occurrence of S-shaped temple rings within the framework of other types of simple wire jewellery (jewellery of the Danube type) and jewellery with filigree and granulation (jewellery of Great Moravian style origin). The second phase, when S-shaped temple rings became a leading fashion element for more than two centuries, started from around the middle of the 10th century (*Tomková et al. 2020a, 191–193*). In Moravia, parallels to the first phase are provided by finds of type 7-7, for which B. Dostál and Š. Ungerman use the term S-shaped earrings in contrast to ornaments from the 10th–11th century called – similar to Bohemia – S-shaped temple-rings (*Dostál 1966, fig. 7; Ungerman 2023, 149–151*).

In phase 1, S-shaped temple rings were not yet an ornament stabilised in terms of form, size, and function. Their relatively low quantity and frequency compared to other jewellery of the Danube and Great Moravian traditions is characteristic, and it is no coincidence that hybrid forms occur in this phase. Standardisation came in phase 2, when, among other things, larger sets of S-shaped temple rings appeared in graves, as is also confirmed by analysed find from the burial grounds in Stará Kouřim, Klecany, Libice nad Cidlinou, Vinoř – V Žabokřiku, and Přezletice. The challenge for the future is to expand knowledge of the chronology of technological details, such as the thickness of the wire used in the production of these ornaments, either from one type of material or plated with another metal.

Earrings of the Jízdárna type marked a major change. While in the past these ornaments were dated to the late 9th and early 10th century (*Krumphanzlová 1974, 44*), radiocarbon dates push their existence back deeper into the 9th century. The indication of occurrence already in the 9th century means that these earrings cannot be considered a ‘later derivative’ of more decorative earrings with a grape pendant (with multi-grain pendant attached to the arch on the bottom, or on the bottom and top side) rather as a type of jewellery associated with the beginnings of early medieval Bohemian jewellery earlier in the 9th century (*Fig. 12; Fig. 14*). At the same time, a potential overlap of the dating of the sample from grave ZP H7 to the first half of the 10th century cannot be ruled out. The fact that this type of earring was placed in graves even in the first half of the 10th century is evidenced by the burial of a child from grave 66/1952 at Žalov – Cihelna (*Tomková 2012b, 119–120*). The jewellery grave goods consisted of earrings of the Jízdárna type chain-like connected with temple rings with an eyelet, which were put together in a finger-ring with circumferential grooves. Although these rings are typical for the area of the so-called Bijelo Brdo culture in the second half of the 10th century, there is also evidence of their occurrence in the period preceding the beginning of this culture and the mid-10th century (see *Tomková et al. 2020a, 227–228*). The atypical position of the earrings in the grave also supports a later dating during the first half of the 10th century.

Radiocarbon dating – results and consequences

In addition to the aforementioned conclusions concerning the analysed jewellery, the consequences for other topics related to the development of early medieval jewellery and burials in Bohemia must also be considered.

The genesis of the S-shaped temple rings

Radiocarbon dating of groups of jewellery with a hammered and further shaped end of the arc contributes to the discussion on the sources of inspiration for their design and sheds new light on the origin of S-shaped temple rings. In previous publications, both meander-shaped earrings and earrings from Bavaria, which are characterised by large diameters, or jewellery with granulation or filigree with an S-shaped arc terminal, have been noted as inspirations for the S-shaped temple rings in Bohemia (*Eisner 1955; Borkovský 1956; Tomková et al. 2020a*, 191, 391, 401 on the importance of this type of earring for the genesis of earrings from a Hungarian perspective, see *Mesterházy 2023*, 35–47). Without questioning these sources of inspiration, it seems to us that the search for primary internal or external inspiration in the simplest forms of wire jewellery and S-shaped temple rings can be misleading for S-shaped temple ring studies. Multiple independent processes could have contributed to the variability of very simple ornaments found in Bohemia or generally in Central Europe, and coincidence could also have played a role with them.

Dating of accompanying jewellery

Although the article focuses on S-shaped temple rings, important data was also obtained for other types of jewellery accompanying the analysed jewellery (*Fig. 10–12*). It has been confirmed that the current archaeological dating of olive beads and G-beads to the 9th and the first half of the 10th century does not collide with radiocarbon dates (cf. *Košta – Tomková 2012*). These beads are linked in grave goods to meander-shaped earrings, hybrid jewellery including earrings of the Jízdárna type and the oldest S-shaped temple rings.

Similarly, other arguments were obtained for the fact that amber beads reached Bohemia already during the first half of the 10th century and thus contacts with Polish territory can already be considered in this period (cf. *Tomková 2012a*, 169, fig. 4). In our assemblage, amber is linked only to eyelet temple rings and S-shaped temple rings in the second phase of their development (*Fig. 10; Fig. 11: B*).

Consequences for the beginnings of jewellery production in Bohemia

The shift in the dating of earrings of the Jízdárna type to the 9th century provides further evidence for the thus far only hypothetically defined first phase of early medieval jewellery production in Bohemia, to which the jewellery from grave 24 from Žalov – Na Panenské (ZP H24), earrings of the Jízdárna type, some olive beads, G-beads, and some jewellery from Stará Kouřim have been assigned (*Tomková et al. 2020a*, 399; *Košta – Barčáková 2023*, 198–216). The earrings of the Jízdárna type primarily occurred in the middle part of central Bohemia, especially at the Žalov – Na Panenské and Klecany I burial grounds (*Profantová et al. 2015*, 80–86, 127; *Tomková et al. 2020a*), which brings new stimuli to the discourse on the status and meaning of the central part of Bohemia in the 9th century.

Implications for dating burial grounds and changes of burial rite

The results of the radiocarbon analysis also have implications for the dating of burial grounds and the burial rite. They confirm the assumed burial activities already during the 9th century at Žalov – Na Panenské and the beginning of burials in the 9th century at Klecany I. The resulting probability distributions also extends into the first half of the 9th century. In the case of Žalov – Na Panenské, this does not contradict current knowledge about the history of settlement in Levý Hradec based on research over the last two decades (Tomková 2020; Tomková et al. 2020b). We can assume a similar development in the case of Klecany with respect to the dating of samples Kl H22 and H54. The dating of sample Kl H6-17 is solid proof of the continuation of Klecany I into the 11th century.

In the case of these burial grounds and some other samples, we also see sections of calibrated age intervals that even predate the year 800. These intervals are a reflection of the calibration curve, which is not linear and exhibits many local inequalities (Bířková et al. 2023, 45–49), which is how the intervals found before the year 800 can be explained (Fig. 9). The calibration curve in the period at the end of the 8th and almost the entire 9th century forms a ‘plateau’. At this time, the activity of atmospheric ^{14}C slowly decreased at a rate close to that of ^{14}C due to its radioactive transformation. The result of the calibration is thus a very long interval. At the moment, we cannot reliably comment on the possible occurrence of the observed jewellery groups for the period close to the year 800. Addressing this issue is important because at least those segments of the curve that directly follow the dates from the 9th century can broaden the discussion concerning the beginnings of inhumation burial in Bohemia prior to the middle of the 9th century (for the chronology of inhumation burial, cf. Krumphanzlová 1974; Štefan 2007; Košta – Barčáková 2023). The results of the radiocarbon analysis for this period need to be correlated with the archaeological findings, which are based on a detailed study of the find situation. The actual results of radiocarbon dating, which cover the mentioned plateau, do not provide an adequately robust basis for the question of the beginning of the inhumation rite.

The overlap of calibrated dates up to the 12th century for samples from Přezletice, Libice nad Cidlinou, Klecany, and Dolní Chabry can be explained by analogy. The calibration curve for this period unfortunately does not allow the determination of a narrower interval, and the obtained intervals break up into several segments. Even in these cases, the find situation needs to be considered during the final interpretation. Based on the find situation and reflection with other radiocarbon dates from the same sites, we assume that these specific samples date to the first two-thirds of the 11th century at the latest.

Conclusion

This study presents the results of radiocarbon measurements of an intentionally selected burials furnished with S-shaped temple rings and other jewellery that is or has been associated with the origin of S-shaped temple rings. Based on a critical evaluation of our radiocarbon data in the archaeological analysis, it is possible to prove the occurrence of S-shaped temple rings before the year 900 and their parallel use with meander-shaped earrings and earrings of the Jízdárna type. Early dating of this type of grape earring proved that it is not a late derivative, but an adornment associated with the beginnings of Bohemian jewellery

making earlier in the 9th century. The presented results raise new questions concerning the beginnings of jewellery production and the beginnings of inhumation in Bohemia, specifically in its central part.

As part of the dialogue between archaeology and archaeometry, the methodological limits of radiocarbon dating were defined and respected – the accessibility, selection and quality of the sample (amount of collagen, various types of conservation measures), ultra-filtration, bone remodelling, and the shape of the curve in the given period. The different representativeness of the analysed jewellery groups was reflected in a similar way. In this regard, we believe that we have managed to collect an assemblage whose informative value is sufficient to clarify the origins of S-shaped temple rings. In contrast, the other groups of jewellery were represented by a much smaller number of samples. Although the informative value is lower in this case, it can be stated that even for temple rings with an eyelet and earrings of the Jízdárna type we find strongly manifested tendencies in dating that cannot be considered entirely random. In any case, we consider both assemblages as a starting point for further analyses, which will help verify and refine the findings of both this study and advance the understanding of S-shaped temple rings, emblematic adornments for the later phases of the Early Middle Ages.

We paid special attention to the evaluation of repeated measurements. In this context, the question could be raised as to the validity of the dating of other samples for which we do not have these measurements. Our aim is not to diminish the importance of radiocarbon dating but to point out that its results should be treated with great circumspection. We must be aware that these are not dates that we should perceive as final and absolute, but as dates that are partial reference points on a much longer path of archaeological knowledge and, last but not least, as dates that must be interpreted in the context of archaeological knowledge.

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References

- Bayliss, A. – Marshall, P. 2019: Confessions of a Serial Polygamist: The Reality of Radiocarbon Reproducibility in Archaeological Samples. *Radiocarbon* 61, 1143–1158. <https://doi.org/10.1017/RDC.2019.55>
- Bířková, J. – Brychová, V. – Demján, P. – Dreslerová, D. – Frank Danielisová, A. et al. 2023: Capabilities and limits of radiocarbon dating with a focus on untypical archaeological samples. *Archeologické rozhledy* 75, 40–67. <https://doi.org/10.35686/AR.2023.4>
- Boháčová, I. – Profantová, N. 2014: Bohemia and Great Moravia – archaeological evidence. In: P. Kouřil (ed.). *Great Moravia and the Beginnings of Christianity*. Brno: Archeologický ústav AV ČR, Brno, 143–154.
- Borkovský, I. 1940: Staroslovanská keramika ve střední Evropě. Studie k počátkům slovanské kultury. Praha: Borkovský.
- Borkovský, I. 1947: Staročeské pohřebiště poblíže Pražského hradu. *Historica Slovaca* 5, 145–152, 225, 235.
- Borkovský, I. 1949: O počátcích Pražského hradu a nejstarším kostele v Praze. Praha: Orbis.
- Borkovský, I. 1953: Kostel Panny Marie na Pražském hradě. *Památky archeologické* 44, 129–200.

- Borkovský, I. 1956: Esovité záušnice, jejich původ a význam. In: Referáty o pracovních výsledcích československých archeologů za rok 1955. Liblice: Československá akademie věd, 148–158.
- Brejcha, R. 2012: Pohřebiště ve Vratislavském paláci v kontextu raně středověkých funerálních aktivit malostranského suburbia. Plzeň: Západočeská univerzita v Plzni. Unpublished MA thesis.
- Brock, F. – Higham, T. – Ditchfield, P. – Bronk Ramsey, C. 2018: Testing the effectiveness of protocols for removal of common conservation treatments for radiocarbon dating. *Radiocarbon*, 60, 35–50. <https://doi.org/10.1017/RDC.2017.68>
- Bronk Ramsey, C. 2009: Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337–360. <https://doi.org/10.1017/S0033822200033865>
- Chmielewski, T. – Hatuszko, A. – Goslar, T. – Cheronet, O. – Hajdu, T. – Szeniczey, T. – Virag, C. 2021: Increase in ¹⁴C dating accuracy of prehistoric skeletal remains by optimised bone sampling: Chronometric studies on Eneolithic burials from Mikulin 9 (Poland) and Urziceni-Vada Ret (Romania). *Geochronometria* 47, 196–208. <https://doi.org/10.2478/geochr-2020-0026>
- Devišev, T. – Comeskey, D. – McCullagh, J. – Bronk Ramsey, C – Higham, T. 2019: Compound-specific radiocarbon dating and mitochondrial DNA analysis of the Pleistocene hominin from Salkhit Mongolia. *Nature Communications* 10, 274. <https://doi.org/10.1038/s41467-018-08018-8>
- Dinklage, K. 1940: Studien zur Frühgeschichte des deutschen Südostens. *Südost-Forschungen* 5, 158–159.
- Dinklage, K. 1941: Zur deutschen Frühgeschichte Thüringens. *Mannus* 33, 408–507.
- Distelberger, A. 1996: Das awarische Gräberfeld von Mistelbach (Niederösterreich). Innsbruck: Universitätsverlag Wagner.
- Dostál, B. 1966: Slovanská pohřebiště ze střední doby hradištní na Moravě. Praha: Academia.
- Dragoun, Z. – Tryml, M. 2022: Románský kostel v Dolních Chabrech a jeho předchůdci. Praha: Nová Tiskárna Pelhřimov, spol. s r.o. – Národní památkový ústav, územní odborné pracoviště v Praze – Občanské sdružení pro ochranu památek v Dolních Chabrech.
- Dubský, B. 1930: Mohyly z poslední doby pohanské u Údraže na Písecku. *Památky archeologické* 36, 92–93.
- Dubský, B. 1949: Pravěk jižních Čech. Blatná: Bratři Římsové.
- Eisner, J. 1947: K dějinám našeho hradištního šperku. *Časopis Národního muzea – oddíl duchovědný* 116, 142–162.
- Eisner, J. 1955: Počátky českého šperku. *Památky archeologické* 46, 215–225.
- Frolík, J. 2015: Pohřebiště u kostela Panny Marie a na II. nádvoří Pražského hradu. Díl I. Katalog. *Castrum Pragense* 14. Praha: Archeologický ústav AV ČR Praha.
- Frolík, J. – Smetánka, Z. 2014: Pohřebiště v Lumbeho zahradě na Pražském hradě I. Katalog. *Castrum Pragense* 12. Praha: Archeologický ústav AV ČR Praha.
- Frolík, J. – Šneberger, J. – Světlík, I. – Dřítkolová Kaupová, S. – Pachnerová Brabcová, K. – Ovsonková, Z. A. 2020: The oldest rulers of early medieval Bohemia and radiocarbon data. *Radiocarbon* 62, 1529–1542. <https://doi.org/10.1017/RDC.2020.62>
- Frolíková-Kalíšková, D. et al. 2023: Raně středověké pohřebiště Triangl v Praze-Střešovicích. Praha: Archeologický ústav AV ČR Praha.
- Geyh, M. 2001: Bomb Radiocarbon Dating of Animal Tissues and Hair. *Radiocarbon* 43, 723–730. <https://doi.org/10.1017/S0033822200041382>
- Havrdá, J. – Tryml, M. 2021: Pohřbívání na sklonku raného středověku. Pohřební areály v pražské předlokační aglomeraci v 11. až 1. polovině 13. století. *Archeologie ve středních Čechách* 25, 217–326.
- Havrdá, J. – Žďárská, A. 2017: K pohřbívání v pravobřežní části pražské předlokační aglomerace v 9. a 10. století. *Staletá Praha* 33/2, 94–134.
- Hedges, R. E. M. – Clement, J. G. – David, C. – Thomas, L. – O'Connell, T. C. 2007: Collagen turnover in the adult femoral mid-shaft: Modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* 133, 808–816. <https://doi.org/10.1002/ajpa.20598>
- Higham, T. – Ramsey, C. B. – Karavanić, I. – Smith, F. H. – Trinkaus, E. 2006: Revised direct radiocarbon dating of the Vindija G1 Upper Paleolithic Neandertals. *Proceedings of the National Academy of Sciences* 103, 553–557. <https://doi.org/10.1073/pnas.0510005103>
- Knor, A. 1953: Nové hroby ze starší doby hradištní ve středních Čechách. *Památky archeologické* 44, 220–228.
- Košta, J. – Barčáková, L. 2023: Šperk za časů gombiků. Příběh luxusních ženských ozdob 9. a 10. století v Čechách. Praha: Národní muzeum.
- Košta, J. – Tomková, K. 2011: Olivovité korálky v raně středověkých Čechách a jejich postavení ve středoevropském kontextu. *Památky archeologické* 102, 307–354.

- Košta, J. – Tomková, K. 2012:* Olivenperlen – ein gemeinsames Kapitel der Geschichte der frühmittelalterlichen Kultur in Böhmen und Bayern. *Fines transire* 21, 199–214.
- Košta, J. – Tomková, K. – Hulínský, V. – Závřel, J. 2011:* G-kořály v raně středověkých náhrdelnicích z Čech v kontextu evropské sklářské produkce přelomu 9. a 10. století. *Archeologické rozhledy* 63, 586–607.
- Košťová, N. 2014:* Pohřebiště na akropoli libického hradiště. Nové zhodnocení archeologického výzkumu. Praha: Univerzita Karlova. Unpublished MA thesis.
- Košťová, N. – Kapustka, K. – Zazvonilová, E. – Křivánek, R. – Drtikolová Kaupová, S. – Vondrová, H. – Bajer, A. – Kočárová, R. 2022:* Raně středověké pohřebiště v Přezleticích (okr. Praha-východ). *Památky archeologické* 113, 183–255. <https://doi.org/10.35686/PA2022.4>
- Krumphanzlová, Z. 1963:* Příspěvek v vývoji lidového šperku 10. století v Čechách. *Památky archeologické* 54, 87–113.
- Krumphanzlová, Z. 1974:* Chronologie pohřebního inventáře vesnických hřbitovů 9.–11. věku v Čechách. *Památky archeologické* 65, 34–110.
- Krumphanzlová, Z. et al. 2013:* Raně středověké pohřebiště v Praze-Lahovicích. Praha: Muzeum hl. m. Prahy.
- Lobinger, Ch. 2016:* Das awarenzeitliche Gräberfeld von Edelstal (Nemesvölgy) im Burgenland. *Die Ausgrabungen Ágost Sötérs von 1884 bis 1887. Universitätsforschungen zur prähistorischen Archäologie* 288. Bonn: Verlag Dr. Rudolf Habelt.
- Lutovský, M. et al. 2023:* Raně středověké mohyly v Čechách. *Archeologie ve středních Čechách – Supplementum* 2. Praha: Ústav archeologické památkové péče středních Čech.
- Macháček, J. – Dresler, P. – Přichystalová, R. 2018:* Das Ende Großmährens – Überlegungen zur relativen und absoluten Chronologie des ostmitteleuropäischen Frühmittelalters. *Prähistorische Zeitschrift* 93, 307–348.
- Mařík, J. 2009:* Libická sídelní aglomerace a její zázemí v raném středověku. *Dissertationes archaeologicae Brunenses/Pragensesque* 7. Praha: Univerzita Karlova v Praze.
- Mesterházy, K. 2023:* Počiatky esovitých záušnic. In: M. Holeščák – J. Zábojník (eds.), *Medieval Stories. In Honor of Gabriel Fusek. Slovenská archeológia – Supplementum* 3. Nitra: Archeologický ústav SAV, 35–47. <https://doi.org/10.31577/slovarch.2023.suppl.3>
- Niederle, L. 1894:* Bemerkungen zu einigen Charakteristiken der altslawischen Gräber. *Mittheilungen der anthropologischen Gesellschaft in Wien*, N. F. 14, 194–209.
- Niederle, L. 1913:* Slovanské starožitnosti. Život starých Slovanů I. 2. Praha: Bursík & Kohout.
- Pachnerová Brabcová, K. – Brychová, V. – Golec Mírová, Z. – Košťová, N. – Kufnerová, J. – Lisá, L. – Světlík, I. 2024:* Time Travel with Radiocarbon Dating. *Interdisciplinaria Archaeologica – Natural Sciences in Archaeology* 15, 209–217. <https://doi.org/10.24916/iansa.2024.2.6>
- Piř, J. L. 1909:* Starožitnosti země České III. Čechy za doby knížecí. Praha.
- Poláček, L. – Ungerman, Š. – Krupičková, Š. – Galuška, L. – Pygawko, M. – Fořt, M. – Valášková, L. 2024:* Velkomoravský luxusní („veligradský“) šperk: současný stav výzkumu. *Přehled výzkumů* 65/2, 77–117.
- Profantová, N. 1992:* Awarische Funde aus den Gebieten nördlich der awarischen Siedlungsgrenzen. In: F. Daim (ed.), *Awarenforschungen II*. Wien: (Institut für Ur- und Frühgeschichte der Universität Wien, 605–778.
- Profantová, N. 2003:* Mikulčice – pohřebiště u 6. kostela: pokus o chronologické a sociální zhodnocení. In: N. Profantová – B. Kavánová, *Mikulčice – pohřebiště u 6. a 12. kostela. Spisy Archeologického ústavu AV ČR Brno* 22. Brno: Archeologický ústav AV ČR, Brno, 7–209.
- Profantová, N. 2005:* Die Elite im Spiegel der Kindergräber aus dem 9. und 10. Jahrhundert in Böhmen. In: P. Kouřil (ed.), *Die frühmittelalterliche Elite bei den Völkern des östlichen Mitteleuropas. Spisy Archeologického ústavu AV ČR Brno* 27. Brno: Archeologický ústav AV ČR, Brno, 313–334.
- Profantová, N. 2011:* New evidence concerning the dating, importance and hinterland of the early medieval hillfort of Klecany (District Prague-East). In: J. Macháček – Š. Ungerman (eds.), *Frühgeschichtliche Zentralorte in Mitteleuropa. Studien zur Archäologie Europas* 14. Bonn: Verlag Dr. Rudolf Habelt, 355–370.
- Profantová, N. 2013:* Ke změnám ve vývoji hmotné kultury 10. století v Čechách. *Archaeologia historica* 38, 27–44.
- Profantová, N. 2022:* A New Type of Animal Style Jewellery from the Klecany I Burial Ground and the so-called Prague “Silver Workshop”. In: F. Biermann – A. Kieseler – E. Pernicka, – J. von Richthofen (eds.), *Frühmittelalterliches Hack Silber im nördlichen westslawischen Raum. Archäologie und Archäometallurgie. Beiträge der internationalen Konferenz im Kulturhistorischen Museum Görlitz*, 18./19. Oktober 2019.

- Ergebnisse des Projektes „Hacksilberschätze im Oder-Neiße-Raum“ 1. Studien zur Archäologie Europas 36. Bonn: Verlag Dr. Rudolf Habelt, 263–279, 320–321.
- Profantová, N. et al. 2010: Klecany. Raně středověká pohřebiště II. Praha: Archeologický ústav AV ČR, Praha – Epocha.
- Profantová, N. et al. 2015: Klecany. Raně středověká pohřebiště I. Praha: Archeologický ústav AV ČR, Praha – Epocha.
- Reimer, P. – Austin, W. – Bard, E. – Bayliss, A. – Blackwell, P. et al. 2020: The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP). *Radiocarbon* 62, 725–757. <https://doi.org/10.1017/RDC.2020.41>
- Scott, E. M. – Cook, G. T. – Naysmith, P. 2010: A report on phase 2 of the Fifth International Radiocarbon Intercomparison (VIRI). *Radiocarbon* 52, 846–858. <https://doi.org/10.1017/S0033822200045938>
- Sláma, J. 1963: K česko-polským stykům v 10. a 11. století. Vznik a počátky Slovanů 4, 221–269.
- Šolle, M. 1959: Knižecí pohřebiště na Staré Kouřimi. *Památky archeologické* 50, 353–506.
- Šolle, M. 1966: Stará Kouřim a projevy velkomoravské hmotné kultury v Čechách. *Monumenta archaeologica* 15. Praha: Academia.
- Šolle, M. 1982: Slovanská pohřebiště pod Budčí. *Památky archeologické* 72, 174–216.
- Šolle, M. 1990: Rotunda sv. Petra a Pavla na Budčí. *Památky archeologické* 81, 140–207.
- Štefan, I. 2007: Změna pohřebního ritu v raném středověku jako archeologický a kulturně-antropologický problém. *Archeologické rozhledy* 59, 805–836.
- Štefan, I. 2010: Příspěvek k chronologii a výpovědním možnostem esovitých záušnic. *Studia mediaevalia Pragensia* 9, 171–207.
- Štefan, I. – Březinová, H. – Hasil, J. – Drtíková Kaupová, J. – Ottenwelter, E. – Vondrová, H. 2024: Bohatě vybavený pohřeb dívky H2 na hradišti v Praze-Vinoři. In: J. Klápště – T. Klír – I. Štefan (eds.), *Krajina středověké Prahy*. Praha: Academia, 323–342.
- Štefan, I. – Krutina, I. 2009: Raně středověké sídliště, hromadný hrob a pohřebiště na Budčí (poloha Na Týnici). Ke vztahu archeologie a „událostní historie“. *Památky archeologické* 100, 119–212.
- Tomková, K. 2005: Hmotná kultura raně středověkých pohřebišť Pražského hradu a jeho předpolí. In: K. Tomková (ed.), *Pohřbívání na Pražském hradě a jeho předpolích, Díl I.1. Castrum Pragense 7/1*. Praha: Archeologický ústav AV ČR Praha, 217–304.
- Tomková, K. 2008: Emma a šperk její doby v kontextu vývoje raně středověkého šperku. In: J. Kilián – L. Polanský (eds.), *Emma Regina – Civitas Melnic. Mělník: Regionální muzeum Mělník – Národní muzeum; Centrum medievalistických studií Akademie věd České republiky – Univerzity Karlovy v Praze – Česká numismatická společnost, pobočka Praha*, 89–105.
- Tomková, K. 2011: Der Kulturwandel des 10. Jahrhunderts in Böhmen aus archäologischer Sicht. In: F. Biermann (ed.), *Der Wandel um 1000. Beiträge zur Ur- und Frühgeschichte Mitteleuropas* 60. Langenweissbach: Beier & Beran, 199–208.
- Tomková, K. 2012a: Jantar jako doklad dálkových kontaktů v raně středověké střední Evropě. In: K. Grażawski – M. Dułinicz (eds.), *Pogranicze kulturowe w Europie średniowiecznej. Słowianie i ich sąsiedzi*. Brodnica – Warszawa – Olsztyn: Multi, 161–193.
- Tomková, K. 2012b: Pohřebiště na Levém Hradci a jeho předpolí. Katalog. In: K. Tomková et al., *Levý Hradec v zrcadle archeologických výzkumů. Pohřebiště. Díl I*. Praha: Archeologický ústav AV ČR Praha, 7–272.
- Tomková, K. 2020: Před branami a za branami Levého Hradce. In: J. Izdny a kol., *Ludmila. Kněžna a světička*. Praha: Archeologický ústav AV ČR Praha – Filozofická fakulta Univerzity Karlovy – Katolická teologická fakulta Univerzity Karlovy, 166–185.
- Tomková, K. et al. 2020a: Levý Hradec v zrcadle archeologických výzkumů. *Pohřebiště. Díl II* Praha: Archeologický ústav AV ČR Praha.
- Tomková, K. et al. 2020b: Levý Hradec: new excavations, analyses and questions. In: F. Biermann et al., *Burg, Herrschaft und Zentralörtlichkeit im nördlichen westslawischen Raum, Beiträge zur Ur- und Frühgeschichte Mitteleuropas* 92. Langenweissbach: Beier & Beran, 123–137.
- Tomková, K. – Křížová, Š. – Faltusová, V. – Schibille, N. – Vaculovič, T. 2023: Archaeological and chemical variability of glass beads: olive and fusiform beads in central Europe. *Archaeological and Anthropological Sciences* 15, 19. <https://doi.org/10.1007/s12520-023-01717-4>
- Turek, R. 1939: Staroslovanská pohřebiště na Slánsku. *Slánský obzor* 47, 11–15.
- Turek, R. 1946: Slovanské mohyly u Pňovic. *Památky archeologické* 42, 105–122.

- Turek, R. 1978: Libice. Hroby na vnitřním hradisku. Sborník Národního muzea v Praze, řada A – Historie 32, 1–150.
- Ubelaker, D. H. – Plens, C. R. – Pessoa Soriano, E. – Diniz, M. V. – de Almeida Junior, E. – Daruge Junior, E. – Francesquini Júnior, L. – Palhares Machado, C. E. 2022: Lag time of modern bomb-pulse radiocarbon in human bone tissues: New data from Brazil. *Forensic Science International* 331, 111143. <https://doi.org/10.1016/j.forsciint.2021.111143>
- Ubelaker, D. H. – Thomas, C. – Olson, J. E. 2015: The impact of age at death on the lag time of radiocarbon values in human bone. *Forensic Science International* 251, 56–60. <https://doi.org/10.1016/j.forsciint.2015.03.024>
- Unger, J. 2014: Vinoř 2009 – V Žabokřiku. Ploché kostrové pohřebiště z raného středověku na parcele RD 1337/219. Unpublished fieldwork report. Institute of Archaeology of the CAS, Prague.
- Unger, J. 2023: Raně středověké pohřebiště v Dolních Věstonicích – Na pískách. Díl I – Analýza. Spisy Archeologického ústavu AV ČR Brno 74. Brno: Archeologický ústav AV ČR Brno – Masarykova univerzita. <https://doi.org/10.47382/arub2023-04-1>

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RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

A child, twelve goats, three sheep, a cow, and a horse: An unusual grave from the Late Eneolithic in Brno-Slatina (South Moravia, Czech Republic)

Dítě, dvanáct koz, tři ovce, kráva a kůň:
Neobvyklý hrob z mladého eneolitu v Brně-Slatině

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Miriam Nývltová Fišáková – David Parma

The discovery of a child burial in Brno-Slatina containing both complete and disarticulated animal remains represents a unique funerary practice with no direct analogies. The grave was located near a prominent limestone crag; it had been secondarily opened, and no grave goods were found. Based on radiocarbon dating, its chronology corresponds to the Late Eneolithic. In addition to anthropological, zooarchaeological, and taphonomic analyses, the find was assessed within the larger spatial context of the Morava River basin, where new, specific settlement patterns, diverse burial practices, and three distinct pottery styles (Jevišovice, Bošáca, and Globular Amphora) emerged. In a broader sense, these burial practices can be interpreted as a reflection of the growing presence of steppe populations who came into contact with indigenous Neolithic societies.

Late Eneolithic – burial – child – zooarchaeology – secondary mortuary practices

Nález rozměrného hrobu dítěte v Brně-Slatině, obsahujícího kompletní i částečné zvířecí pozůstatky, představuje jedinečný funerální projev bez přímých paralel. Hrob byl situován v blízkosti výrazného vápencového bradla. Později byl sekundárně otevřen a nebyly v něm nalezeny žádné hrobové přídavky. Na základě radiokarbonového datování je možné jeho chronologické zařazení do mladého eneolitu. Kromě antropologických, zooarcheologických a tafonomických analýz byl náález vyhodnocen v širším kontextu regionu povodí Moravy, kde se objevily nové specifické sídelní projevy, rozmanité pohřební zvyklosti a tři odlišné keramické styly (jevišovický, bošácký a kulovitě amfory). V širším smyslu lze tyto pohřební praktiky interpretovat jako odraz narůstající přítomnosti stepních populací, které přicházely do kontaktu s původními neolitickými společnostmi.

mladý eneolit – pohřeb – dítě – zooarcheologie – druhotné pohřební praktiky

Introduction

The onset of the Late Eneolithic period in Moravia (c. 2950–2500 BC) represents a time when agricultural societies experienced a significant diversification of material culture for the first time in the history of the region. This phenomenon is evidenced by the presence of at least three distinct decorative pottery styles—Jevišovice, Bošáca, and Globular Amphora—which are traditionally interpreted as archaeological cultures. The differences among these groups were manifested not only in material terms but also in spatial distribution and settlement patterns. In addition to these groups, settlement assemblages have been identified with pottery that is not typologically distinct enough to be assigned to

a specific pottery style. These assemblages can only be classified as belonging to the Late Eneolithic. Settlements featuring Jevišovice-style pottery are primarily concentrated on the eastern edge of the Bohemian Massif, particularly in south Moravia and Lower Austria (Horváth 2022, fig. 4). Jevišovice pottery also appears, albeit less frequently, at settlements in east Moravia, southwest Slovakia (Mellnerová Šuteková 2015), and sporadically in Bohemia (Hrala 1959; Neustupný et al. 2013, 89) as well as in western Hungary (Régészeti Adatbázis).

Settlements with Globular Amphora pottery are confined to central Moravia and form a small settlement enclave (e.g. Šmíd 1999; also Fig. 8 in this article) that represents the southernmost extent of Globular Amphora distribution in Central Europe. Bošáca pottery is predominantly found in southwest Slovakia, with a smaller number of settlement sites in east Moravia and isolated occurrences in central and east Bohemia (Kalferst – Prostrředník 1998; Dobeš et al. 2013).

Beyond settlement finds, Peška (2023) has published probability densities of radiocarbon dates derived from graves, primarily in central Moravia. These graves are associated with the earliest Corded Ware pottery or other elements of material culture characteristic of populations from this period linked to the East European steppes.

The burial practices of the Late Eneolithic include the deposition of both cremated and uncremated bodies. Particularly in the case of inhumation burials, assigning individual graves to specific pottery styles (archaeological cultures) is often highly ambiguous. This issue is also exemplified by the specific grave discovery from Brno-Slatina that will be presented in this study. Despite the recovery of abundant zooarchaeological material, no artefacts were found, and the grave's chronological position is determined solely based on radiocarbon dating. We examine the find in light of knowledge of Late Eneolithic burial rituals and the spatial and landscape preferences of populations at the time.

The current state of knowledge has advanced significantly due to aDNA analyses of prehistoric populations, which allow for tracking the degree of social integration or isolation of communities based on specific haplogroups, or even more precisely through the reconstruction of direct lineage. Although a comprehensive genetic study of agricultural prehistory in Moravia has not yet been conducted, findings from other regions and periods highlight the inherent risks of directly correlating genetic relationships with material culture. The specifics of pottery production must be examined without the *a priori* assumption of rigidly defined social group boundaries. A similar approach is applied in interpreting an isolated burial situation within the Late Eneolithic, where settlement and burial structures do not necessarily produce a unified image of the society.

The site and its context

The rescue excavation in the northern foothills of Švédské šance Hill, located at the boundary between the municipal districts of Brno-Slatina and Brno-Tuřany (Fig. 1), was conducted by the Institute for Archaeological Heritage in Brno (hereinafter IAH Brno) in June and July 2006 under the direction of P. Kos. This excavation was part of a series of interventions in the gradually expanding new municipal industrial zone, designated as C1 in the investor's documentation. Adjacent to this area, to the south and east of the hill, lie areas labelled B1 and B2, while another archaeologically significant area, A1, is located

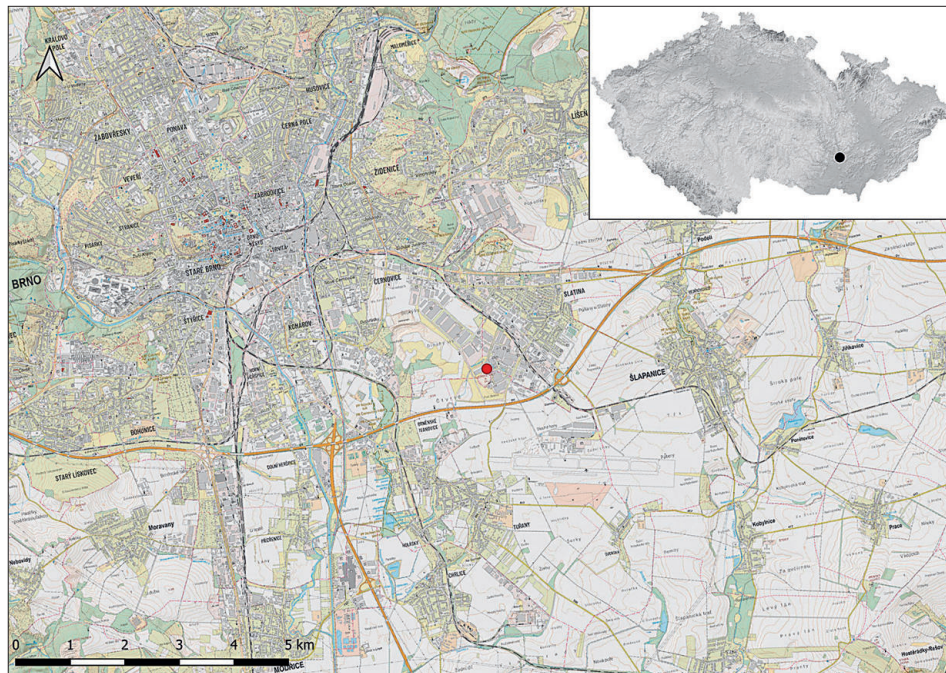


Fig. 1. Location of the site within the context of the city of Brno (Base Map of the Czech Republic 1:25,000).

c. 200 metres to the northeast (Fig. 2). Many other areas in the industrial zone were surveyed without identifying any archaeological features.

The excavation in area C1 uncovered a total of 361 pit features, the vast majority of which belonged to La Tène period settlements. Earlier activity is represented solely by feature 600 containing a Late Eneolithic child burial. In areas B1 and B2, sporadic Eneolithic settlement activities were identified alongside a prominent settlement and funerary component from the Early Bronze Age, as well as medieval and later activities (summarised in *Geislerová – Parma 2013*, 213–216).

Švédské šance Hill itself, originally reaching an elevation of 256 metres above sea level (*Oppenheimer 1907*, 222), is a crag (*klippe* in geological terminology). It was exploited as a quarry and subsequently significantly altered and elevated by a slag landfill during the 20th century. Švédské šance Hill rose approximately 20 metres above the surrounding landscape, forming a prominent landmark in the middle of the Tuřany Plateau. This plateau consists of Miocene and Pleistocene fluvial sediments from the Svratka and Svitava rivers, partially overlain with loess deposits. The crag itself is a remnant of Upper Jurassic limestones containing chert concretions up to 15 cm in size. It is therefore plausible that this natural monument also served in the past as a source of raw material for the production of chipped stone tools, which are not markedly different from the cherts of the Stránská skála type (*Přichystal 2013*, 76).

The landscape immediately surrounding the crag was only episodically used during prehistory. Intensive prehistoric settlement in the area is primarily concentrated near the Svratka River and close to the Říčka Valley. No evidence of Neolithic settlement activity

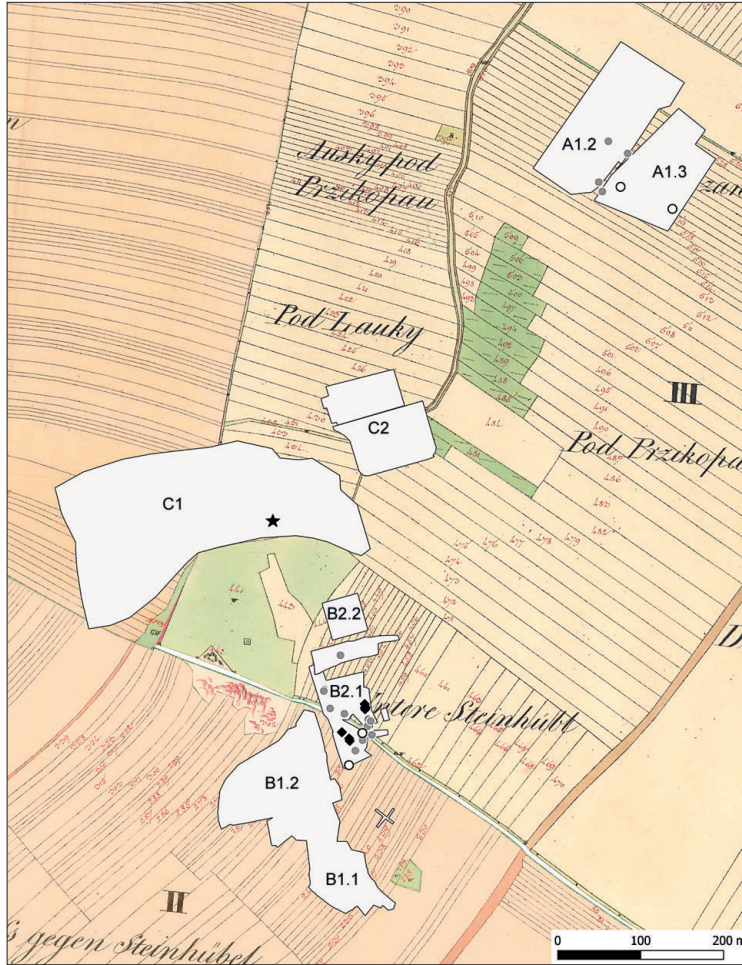


Fig. 2. Brno-Slatina. Location of the site based on the Stable Cadastre (1824–1836). The Švédské šance Crag is marked in red, situated between the excavated areas (white). Star – grave 800; rhombus – TRB feature; white circle – Baden feature; grey circle – Eneolithic feature (general).

is known in the immediate vicinity. During the Early Eneolithic, settlement features containing Funnel Beaker pottery (*Kos 2006b*) and classical Baden pottery (excavation by IAH Brno, *Kos 2005; 2006a; Geislerová – Parma 2013, 214*) have been documented directly beneath Švédské šance Crag. However, there is no evidence of settlement activity from the Late Eneolithic, and given the extent of the investigated areas, it is very likely that no contemporaneous graves were located near the child burial in feature 600.

The nearest evidence of settlement activity from this period comes from Šlapanice – Brněnská pole, 3.5 km away, which can only be generally attributed to the Late Neolithic (*Geislerová – Parma 2013, 293*). Similarly, at a comparable distance, the closest settlement at Brno-Židenice, Tovačovského Street yielded evidence of a Jevišovice settlement (*Čížmář 2019*), which was part of the zone in the lower Svitava River Valley densely occupied during the Late Eneolithic. In a broader chronological and spatial perspective, Brno and its surroundings ranked among the most densely settled regions in agrarian prehistory in Moravia.

Grave discovery context

The excavated grave featured a rectangular ground plan measuring 4.65×3.4 m with a depth of 1 m from the level of the overburden (the loess subsoil surface); its longer axis was oriented in a north-south direction. Shallow, step-like extensions protruded westwards and eastwards from the northern half.

The feature was manually cleaned on the surface and divided into four quadrants, which were excavated sequentially starting with sectors 1 and 3. In sector 1, human skeletal remains were encountered at a depth of 0.4 m. The situation was documented in detail. A dark fill layer (context 423) containing intact skeletal remains (skeleton 800) was identified near the walls of the pit, while a reddish-brown fill (context 421) in the central area contained only scattered animal bones.

The child's skeleton was laid in a stretched position, oriented north-south along the eastern wall of the grave pit. The upper limbs were flexed over the chest, with partial disarticulation likely caused by bioturbation (*Fig. 3; Fig. 4*). After the removal of skeleton 800, the remaining fill of sector 1 was cleared without any further finds discovered. After the bottom of sector 3 was excavated, only a few stones up to 0.2 m in size were found in the dark intact layer (contexts 423 and 425) at depths of 0.6–1 m. Sector 4 revealed a similar situation, again without significant finds.

In contrast, sector 2 at depths of 0.6–0.8 m in the dark fill layer (context 423) contained substantial parts of at least two animal skeletons, designated K1 and K2 (*Fig. 5*). Both were laid in the southwest corner, oriented north-south with their heads to the north and their abdomens facing each other; K2 was situated beneath K1. Further north, disarticulated remains of a third skeleton (K3) were discovered. The absence of skulls in all skeletons was likely due to the decomposition and consumption of these elements by osteophagous organisms.

After the skeletons were excavated, additional disarticulated animal bones (K3, K4, and K5) were found on another level at a depth of approximately 0.8 m. No further specific contexts were documented after these were removed from the pit. The excavation of the entire feature yielded only a small collection of prehistoric potsherds, which were insufficient for a precise dating.

The entire situation can be interpreted as a specific grave with a re-opening. The original grave fill, a dark layer (context 423), contained child's skeleton 800 near the centre of the eastern wall and the pair of animal skeletons K1 and K2 in the southwest corner. Besides a few stones as the only other finds in the northern half of the feature, these were all deposited within the fill rather than directly on the pit bottom, as is typical for burial contexts. The disarticulation of animal skeletons K3 to K5 indicates that the reddish-brown fill (context 421) resulted from a secondary disturbance of the original situation. However, no indications for dating this event exist. This grave re-opening is most evident in profiles E-F-G (sector 4) and D-B-H (sector 1) (*Fig. 6*). It likely also accounts for the extensions to the west and east in the northern part of the grave.

In the profiles of sectors 1 and 3, the dark fill (context 423) containing the skeletons is stratigraphically the oldest layer; it rests on the pit bottom and remains intact to a depth of 0.2 m above the base. Although no deposits or burials were directly placed on the bottom, the stratigraphic sequence in the northern part of sector 3 (profile A-B-C) shows that

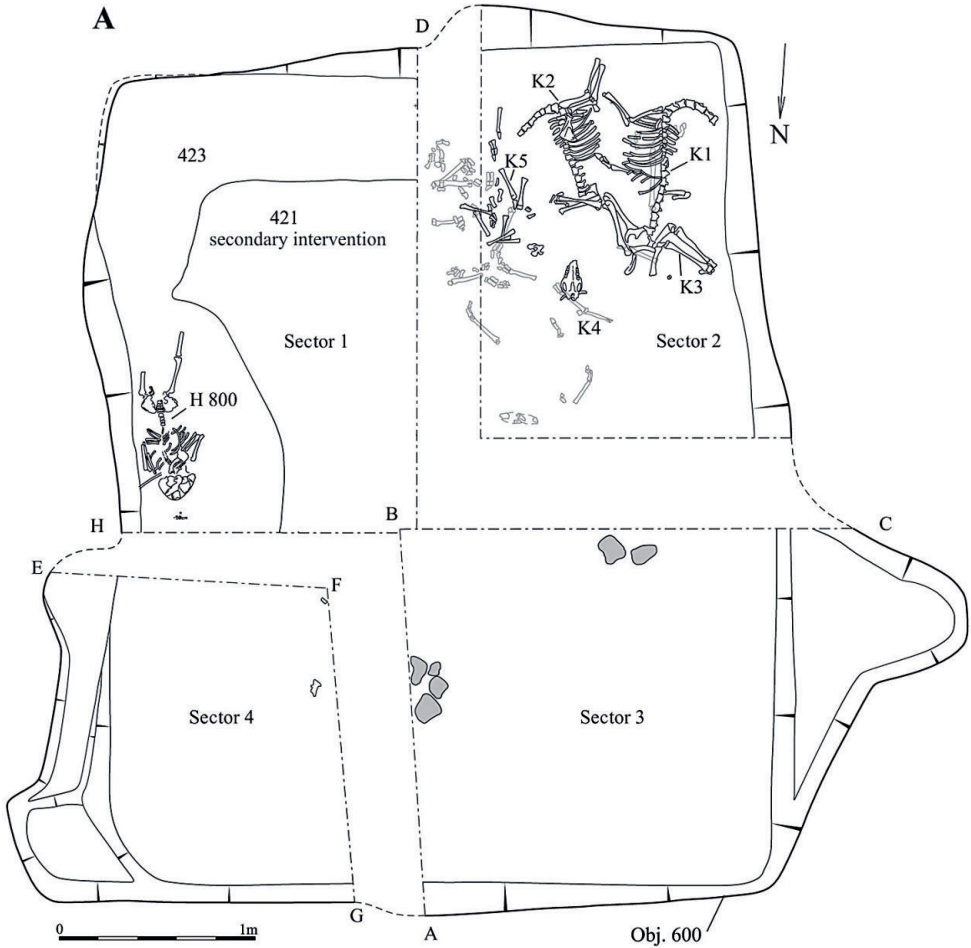


Fig. 3. Brno-Slatina. A – Overall ground plan of feature 600 showing all individual levels. B – Photo of the grave pit.

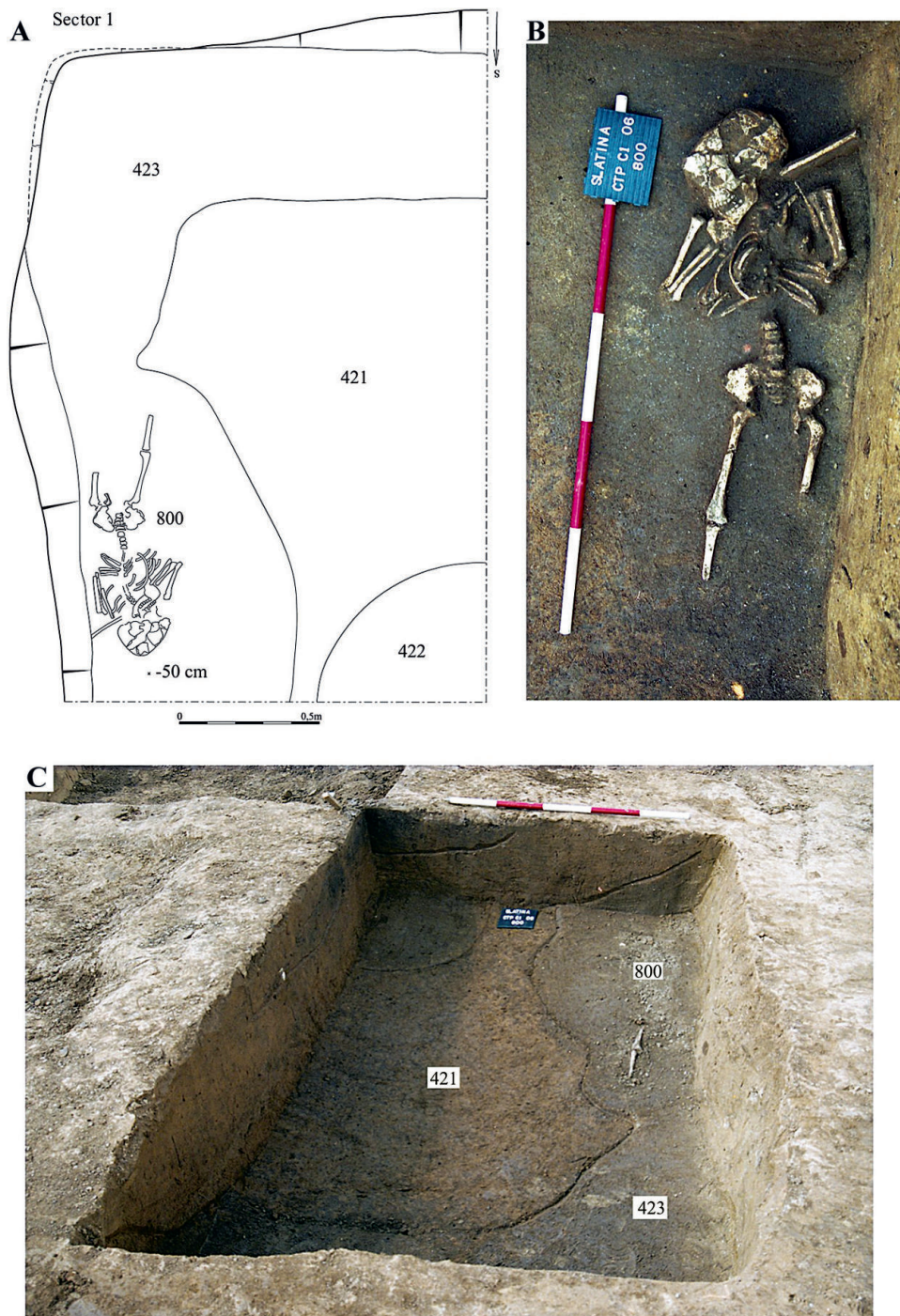


Fig. 4. Brno-Slatina. Feature 600, detail of sector 1. A – Ground plan of level 0.5 m showing the fill of grave re-opening context 421; B – Skeleton 800; C – Sector 1, level -0.5 m, view from the south.

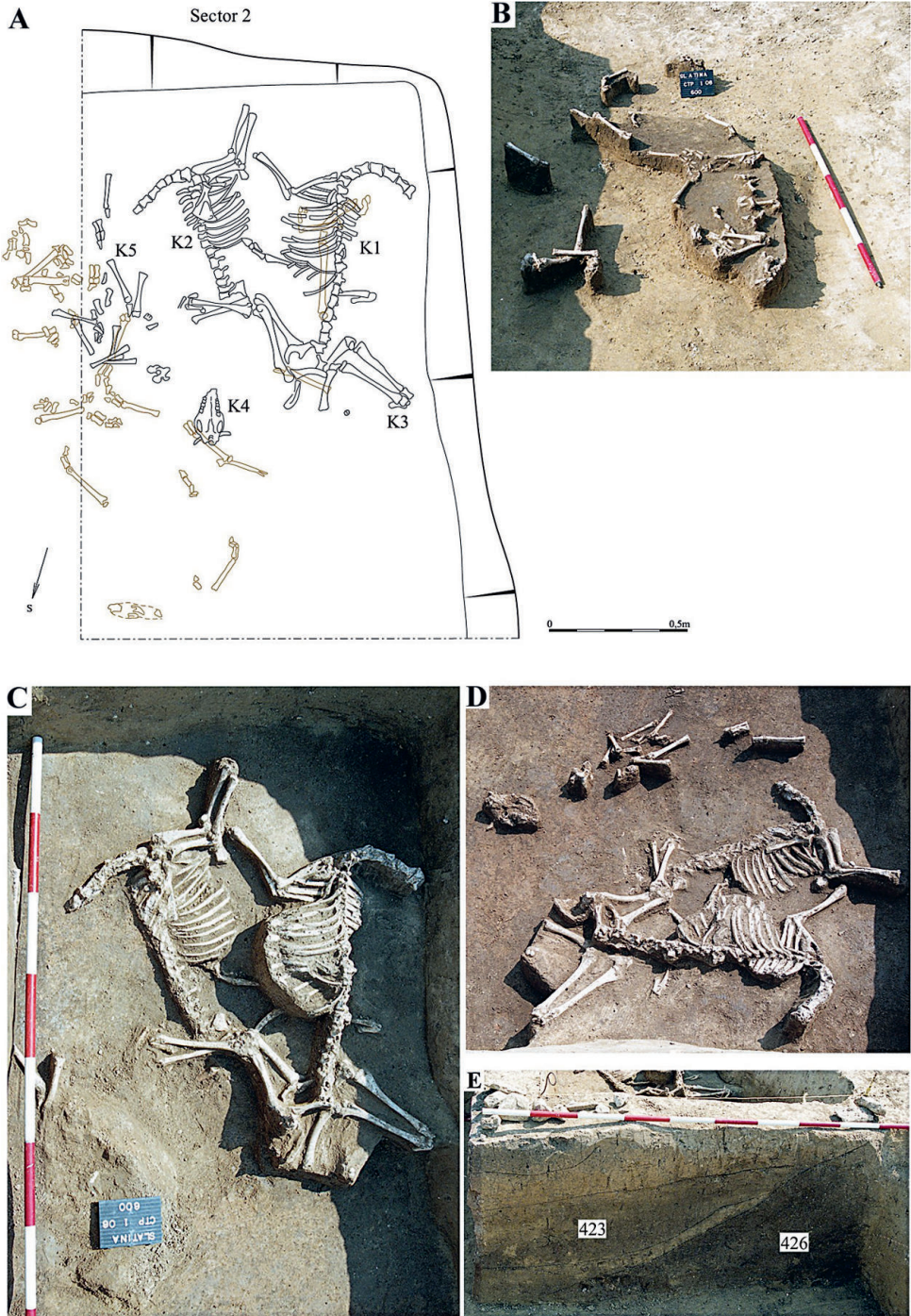
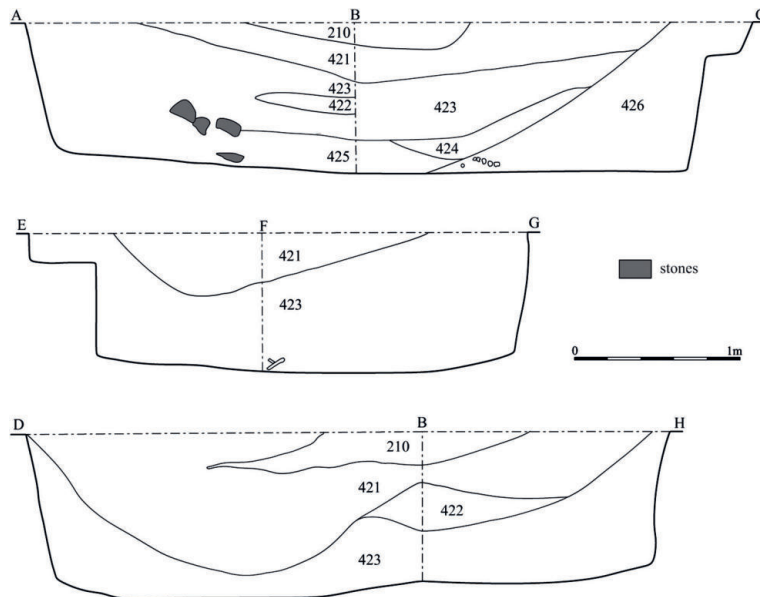


Fig. 5. Brno-Slatina. Feature 600, detail of sector 2. A – Ground plans of levels 0.4 m (black) and 0.5 m (brown); B to D – Gradual excavation of skeletons K1 to K5; E – Profile B-C in sector 3.

Fig. 6. Brno-Slatina. Feature 600, profiles.



an even older fill (context 426) preceded the dark layer (context 423). Nevertheless, no deposits or burial contexts were found in this earlier fill.

Considering the grave's position in a La Tène settlement area characterised by artefact-rich surface layers, it is therefore possible that context 423 itself represents the fill of an earlier grave re-opening. Regardless, the regular rectangular shape of the feature indicates a single initial formation event, while the subsequent filling reflects at least three distinct episodes. None of these involved the placement of deposits or burials directly on the grave bottom. Radiocarbon dating is relevant for the second event (context 423), while the absence of finds in the latest fill (context 421) suggests it may predate the La Tène period.

Analyses

Anthropological analysis

A basic anthropological analysis was carried out on skeleton 800 – the relatively well-preserved, incomplete, and largely fragmented skeletal remains of a child. The surface erosion of the bones is mild to moderate, and the fragments are generally light beige in colour. The skull is severely damaged to the extent that it cannot be reconstructed, but it is essentially complete, with larger portions of all bones preserved. Morphological traits have not yet been reliably assessed. In both jaws, a combination of deciduous and permanent teeth is clearly visible; only the first molars in both the upper and lower jaws had erupted.

Numerous smaller fragments of ribs and some vertebrae are preserved from the axial skeleton. Fractured diaphyses of long bones and smaller fragments of limb girdles are identified in both the upper and lower limbs. The skeleton of the hands and feet has not survived, except for a few fragments of metacarpal bones.

Species/bone type	Capra aegagrus hircus K1	Capra aegagrus hircus K2	Capra aegagrus hircus K3	Capra aegagrus hircus K4	Capra aegagrus hircus K5	Capra aegagrus hircus	Ovis aries	Bos taurus	Equus ferus caballus
Skull	4f/1	7f/1	2f/1	12f/1					
Horn cores				2/1					
Upper jaw				2f/1					
Lower jaw				3f/1					
Teeth	6/1	7/1	3/1	11/1	2/1				
Atlas	1/1	1/1							
Axis (C2 vertebra)	1/1	1/1		1/1					
Vertebrae	6/1	6/1	4/1	5/1					1/1
Sacral bone	1/1	1/1		1f/1					
Ribs	32f/1	28f/1	11f/1	7f/1					1f/1
Scapulae	2/1	3f/1	1f/1						
Humerus	2/1	2/1	1f/1						
Proximal part of humerus					1/1				
Distal part of humerus				1/1			1/1		
Ulna	2/1	2/1	1/1						
Radius	2/1	2/1	2/1	1/1					
Proximal part of radius					1/1				
Carpal bones	6/1	4/1	5/1	2/1					
Metacarpal bones	2/1	2/1	2/1	1/1	2/1	14/7	4/3		
Phalanges	20/1	17/1	5/1	2/1	5/1	152/7	21/3		
Pelvis	1/1	1/1	1f/1					1f/1	
Femur	2/1	2/1							
Proximal part of femur			1/1						
Distal part of femur				2/1	1/1				
Tibia	2/1	2/1	1/1						
Proximal part of tibia				2/1	1/1				
Tarsal bones	4/1	8/1	2/1						
Metatarsal bones	2/1	2/1				13/7	3/3		
Proximal part of metatarsal bones									
Distal part of metatarsal bones			2/1	1/1					
Patella	1/1	2/1							

Tab. 1. Brno-Slatina. Frequency of finds of individual parts of the skeleton in individual species/number of individuals. F – Fragment.

The skeletal remains belong to a child approximately six years old based on the degree of tooth development and mineralisation (*Ubelaker 1978; Vlček 1994*). This age is roughly consistent with the recorded lengths of the humerus and femur (148 and 206 mm; *Stloukal – Hanáková 1978*). The sex of the child cannot be reliably determined using morphological methods.

Zooarchaeological analysis

The archaeozoological material was identified using commonly used anatomical atlases and handbooks (*Schmid 1972; Červený et al. 1999; Komárek et al. 2001*). To distinguish between sheep and goats, the works of *Payne (1973)*, *Prummel and Frisch (1986)*, *Halstead and Collins (1995; 2002)*, along with *Adams and Crabtree (2008)*, were used.

For determining the age of animals, contemporary methods based on epiphyseal development (*Reitz – Wing 2008*), tooth eruption, and wear (*Payne 1973; Grant 1982*) were used. The quality of meat based on the discovered bones was assessed according to the works of *Steinhauser (2000)* and *Kuswati et al. (2014)*. The basic quantification methods follow standard methodologies as outlined in the works of *Kyselý (2004)* and *Reitz and Wing (2008)*. Taphonomic interventions were analysed using the methods of *Lyman (2008)*, and insect traces were examined using the works of *Anderson and Van Laerhoven (1996)*, *Anton et al. (2011)*, and *Genard (2007)*.

In feature 600, the following animal species were found: domestic horse (*Equus caballus f. caballus*), domestic cattle (*Bos taurus*), domestic sheep (*Ovis ammon f. aries*), and domestic goat (*Capra aegagrus f. hircus*). From wild fauna, only molluscs were present, specifically the shells of the hedge snail (*Cepaea hortensis*).

Notably, two nearly complete skeletons of domestic goats (*Capra aegagrus f. hircus*) were preserved in feature 600, specifically skeletons K1 and K2, as well as three incomplete skeletons—K3, K4, and K5. In addition to these individuals, zooarchaeological material comprised remains of seven other domestic goats and three domestic sheep, which were found beneath skeletons K1 to K5 (*Tab. 1*). The most complete skeletons, K1 and K2, were laid with their abdomens facing each other. Both were uncovered without skulls, but skull fragments, including teeth, were identified during the zooarchaeological analysis. These were young individuals; based on the unfused epiphyses and the preserved teeth, these animals were less than 15 months old (*Schmid 1972; Červený et al. 1999; Komárek et al. 2001*). For such young individuals, the skull is thin-walled and porous, which is why it disintegrates easily and is also the first to be consumed by osteophagous organisms. Individual K1 was lying on top of individual K2, primarily with its hind limbs. Beneath K2 lay the incomplete individual K3, represented by skull fragments, teeth, vertebrae, ribs, bones of the forelimb, and part of the hind limbs. Individual K4 was preserved in the form of a skull with teeth and early horn buds, along with fragments of vertebrae, ribs, and long bones of both the forelimbs and hind limbs, including phalanges. Similarly, remains of individual K5 included teeth, long bones of the forelimbs and hind limbs, and phalanges. Among other domestic goat and sheep individuals, mainly metacarpal and metatarsal bones, phalanges, and, in sheep, the distal part of the humerus were identified. This composition is more typical of kitchen waste, as these skeletal parts contain little meat.

The horse was represented by a fragment of the distal humerus, a vertebra, and the head of a rib. In the case of domestic cattle, a fragment of the pelvis with the acetabulum

(the hip joint socket) was recorded—also categorized as waste. However, the thoracic and pelvic regions contain the highest-quality type A meat, while most of the diaphysis and the distal part of the humerus consist of lower-quality type AB meat. Since these were young goats and sheep, it was not possible to measure relevant osteometric dimensions or calculate the withers height of the animals.

All examined bones showed distinct traces of gnawing by molluscs and insects. This indicates that the carcasses of these animals were accessible and not buried or only covered by a thin layer of porous sediment (e.g., branches, leaves, fine humus). The fact that skeletons K1 and K2 were otherwise in an anatomical position suggests that these two carcasses decomposed during a warm and dry climate, which led to rapid mummification. Consequently, the carcasses were predominantly consumed by osteophagous organisms. The tunnels and pits on the bones were created by members of the families *Phoridae* (hump-backed flies, *Diptera*) and *Dermestidae* (skin beetles), and there are visible gnaw marks from snails, likely from the species *Cepaea hortensis* (white-lipped snail), which supplemented its calcium intake in this manner (Genard 2007). Shells of this snail were found among the domestic goat carcasses. No other traces, such as carnivore gnaw marks, were detected on the studied bones.

Radiocarbon dating

To determine the chronology of feature 600, two bone samples were analysed at the Czech Radiocarbon Laboratory (CRL). The first sample (CRL 23_0836) was taken from the proximal part of the right femur of the buried child, while the second sample (CRL 23_0837) originated from goat individual K2 (Tab. 2). The purified samples were crushed, and the fraction was repeatedly leached in solutions of diluted HCl, water, diluted NaOH, water, and highly diluted HCl. The collagen isolated from the samples was gelatinised at a temperature of 75°C and filtered using a glass fibre filter. The dissolved fraction was processed by ultrafiltration, and the retentate was dried to a constant weight at a temperature of 60°C. The measurement of the graphitised samples was carried out using the AMS system MILEA at the CRL facility.

lab number	C14 age	σ	sample	Collagen (%)	Calibrated values (95,4%)
CRL 23_0836	4 135	19	human bone	2,74	2870 – 2623 BC
CRL 23_0837	4 090	20	animal bone (<i>Capra hircus</i>)	1,41	2849 – 2502 BC

Tab. 2. Brno-Slatina. Radiocarbon dates.

Both calibrated dates correspond to the Late Eneolithic period. Assuming that both sampled individuals were deposited in the grave simultaneously, the calibrated values can be combined using the ‘Combine’ function implemented in the OxCal 4.4 software (Bronk Ramsey 2009). Calibration was made with the IntCal 2020 calibration curve (Reimer et al. 2020). The result ($A_{\text{comb}}=80.5$) does not, however, significantly reduce the wide span of probability distribution estimating the death of the buried child and goat. In the result, the sequences come out approximately as 2850–2810, 2750–2730, and 2700–2580 cal BC (95.4% probability) (Fig. 7). It can only be stated that the remains date to the Late Eneolithic

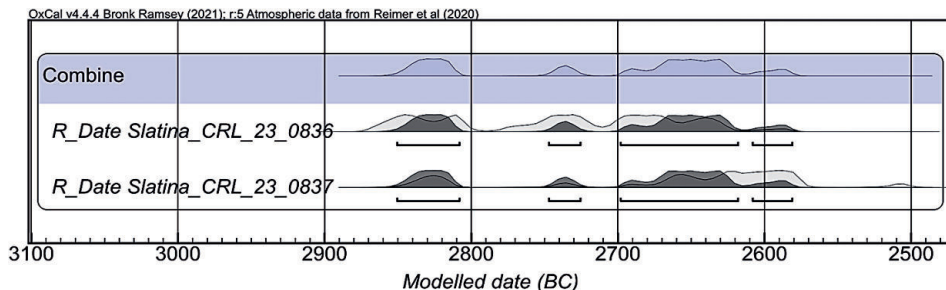


Fig. 7. The Combine model of two radiocarbon dates.

because obtained radiocarbon dates are largely defined by the flattening of the calibration curve. In the first half of the 3rd millennium (more precisely in the years 2880–2580 cal BC and 2620–2480 cal BC) there is a large plateau on the curve, which makes it difficult to precisely place the dates in the absolute time scale (e.g. *Furholt 2003*, 15, Abb. 1).

Discussion

Outside the contemporary settlement component and in the immediate vicinity of a prominent landscape feature – a crag – a large, regularly rectangular pit was dug during the Late Eneolithic. Following partial backfilling, an uncremated child's body was deposited inside, along with numerous whole skeletons of young animals or their parts during several subsequent events. Some of the goat skeletons were demonstrably arranged and left exposed for some time, accessible to molluscs and insects but not carnivores. The feature was later disturbed by a substantial re-opening, suggesting it remained visible on the surface or marked for an extended period. The relatively complex and deliberate deposition clearly indicates a grave, which can be further supported by the absence of any contemporary activities in the surrounding area.

This situation is unusual not only in terms of deposited objects but also its taphonomy having no analogies at currently known Late Eneolithic funerary sites. The bodies of the buried and grave goods are typically found at the bottom, and in cases of secondary disturbance, the original grave arrangement is either absent, the remains dislocated, or deposited within the shaft backfill. Here, the situation is reversed: in the lower layers, mainly isolated animal bones or disarticulated animal body parts were discovered. The human body was found approximately halfway down the backfill, undisturbed, with no other finds beneath. Its position relative to the large grave pit is atypical, as it lies at the very edge, outside the context of other grave goods.

A possible explanation might be that the Brno-Slatina context accommodates at least a two-phase burial sequence. In the first phase, the originally buried body was completely removed from the grave in connection with a re-opening, leaving a cluster of animal bones as the original grave goods. In the second phase, the child was interred along with at least two goats. However, this explanation does not adequately account for the presence of the dark layer above the bottom, which contained no objects and remained undisturbed by re-opening the grave.

To understand the significance of this situation, it is necessary to contextualise it within the funerary practices and the spatial framework of Late Eneolithic populations. Determining the chronological contemporaneity of the observed phenomena using radiocarbon dating is problematic, as the period is characterised by an extended plateau on the calibration curve roughly between 2880 and 2580 BC. Therefore, we turned to relative chronology as a means to gather evidence of contemporary mortuary practices. Nevertheless, we attribute the grave to a specific pottery group only if an artefact unequivocally associated with that group was found within it. Cenotaphs are excluded from the list of graves, as their interpretation remains speculative.

Only three urn cremation graves can be confidently attributed to the Jevišovice pottery style: two from Brno-Štýřice, Polní Street (*Peška – Polcerová 2017*), and one from Popůvky – Pod Šípem (*Geislerová – Parma 2018*, 287). Another known cremation grave was discovered at the Jevišovice settlement in Mokrý u Brna, Dlouhé kopaniny site (*Kos 2019*); however, the associated potsherds lack specific forms or decoration. Among other contemporary cremation burials, two cremation graves of the Bošáca group near a Corded Ware tumulus in Hlinsko u Lipníka are worth mentioning (*Peška et al. 2020*). Beyond Moravia, urn cremation graves associated with the Jevišovice culture can be noted in Lower Austria, specifically at Thunau am Kamp, the Obere Holzweise site, where two urn cremation graves were uncovered in stone boxes (*Ruttkay 1992*).

Contemporary inhumation graves have been discovered at several sites, including Kroměříž-Miňůvky (*Jarošová et al. 2006*; *Peška – Tajer 2006*), Dambořice at the Spálený site (three inhumation graves; *Šmíd et al. 2021*, 18), and Hohenau an der March (*Mitschamärheim 1958*). The grave of a child from Kroměříž-Miňůvky was found near a Jevišovice settlement; however, its grave goods include a bovine molar, a bowl of the ‘Laibacher Moor’ style, and a jug that corresponds to the Coțofeni pottery style originating from western Romania, eastern Serbia, and northwest Bulgaria. This assemblage is contemporaneous with the early stage of Jevišovice pottery production based on modelled radiocarbon dates (*Ciugudean et al. 2022*). The individual from Kroměříž-Miňůvky could not be radiocarbon-dated, and only two animal bones from a nearby settlement were dated to the Jevišovice period. While a contemporaneous age is likely, the grave cannot be directly associated with Jevišovice pottery, as bowls of the ‘Laibacher Moor’ style are a widespread phenomenon, and the jug points to an entirely different region.

A similar situation applies to the grave from Hohenau an der March in Lower Austria, where the skeleton of a child was discovered in a crouched position. The grave goods in this case consist of two miniature vessels and the metatarsus of a young bovine. In the same vein, these items cannot be categorically linked to Jevišovice pottery but can only be generally attributed to the Late Eneolithic.

The remains of contemporary inhumation burials, which exhibit considerable heterogeneity, are known in very small numbers. Therefore, it is not surprising that no direct analogies to the burial from Brno-Slatina have been found in Moravia or Lower Austria. However, certain shared features can be observed: the inhumation graves always involve children or young individuals, and all cases include animal skeletons in the grave, albeit in significantly smaller quantities. Human graves containing animals are a prominent phenomenon of the period and are particularly associated with the Globular Amphora. While no such graves have been identified in Moravia, numerous examples of human-animal burials, as well as sacrificial pits containing only animal remains and spatially related to

human graves, have been documented in eastern Germany, Poland, and western Ukraine. However, the species of animals interred in these contexts differ significantly from the finds at Brno-Slatina, with cattle being the most commonly preferred, followed by pigs, while goats and sheep are only occasionally present (e.g., *Szczodrowski 2015; Witkowska et al. 2020; Pasterkiewicz 2021*). In Kujawy (Poland), *Szmyt (2006, 7)* pointed out the significantly low proportion of sheep and goats in human graves and sacrificial pits compared to the ratio of their bones found in regular settlement waste. Grave goods are also commonly found in these human burial contexts, making it highly questionable to associate the Brno discovery with Globular Amphora culture contexts.

It can be hypothesised that Moravia exhibited a less distinctive burial rite that, in certain respects, could be likened to Corded Ware culture burial practices. This would align chronologically with the situation in Bohemia, where graves containing the earliest Corded Ware pottery are evidenced not only by radiocarbon dating but also by the unmistakable identification of pottery and other artefacts (*Dobeš et al. 2021*). In our case, only burial practices can be compared. The grave from Brno-Slatina shares much of the shape with Corded Ware burials, and its dimensions are a metre longer than the largest Corded Ware grave so far identified in Moravia, which also contained the burial of a child (*Kolář 2018, fig. 51*). Re-openings are also typical for Corded Ware graves, as is the deposition of entire animal bodies, which occurs rarely, while parts of animal bodies are relatively common. The most frequently represented species is also sheep/goat, with occasional finds of horse limb bones (*Kolář 2018, table 65*).

Another significant aspect for understanding the social complexity of the period is the placement of graves in the landscape. Jevišovice and Bošáca cremation graves are always located on sites with pronounced topography, particularly in the context of hills and highlands, which are typically core areas of Jevišovice or Bošáca settlement. In contrast, inhumation graves that cannot be definitively associated with a specific material culture group are located in flat, open landscapes or at the boundary between plains and hilly terrains. The distribution of inhumation graves in the later Eneolithic also coincides with the known distribution of Corded Ware graves, and they are absent west of the Svitava and Svatka rivers, where Corded Ware graves are only rarely found (*Kolář 2018, fig. 32*). However, a quantitative comparison of these two assemblages may be problematic.

When considering the spatial distribution of inhumation graves in relation to population density, and disregarding settlement affiliations with various pottery production types, it is evident that inhumation graves are located in areas with a notably low distribution of settlements, thus reflecting low population density. The grave in Brno-Slatina, for example, is situated between a densely settled area to its north and a virtually unoccupied zone to its south (*Fig. 8*).

A cursory assessment of inhumation and cremation burial practices in a long-term perspective, from the beginning of the Eneolithic period, reveals that inhumation graves are significantly less prone to contain grave goods, particularly pottery vessels. During the Baalberge period, groups of graves with individuals in extended positions rarely included artefacts, and later only isolated barrows or box graves with grave goods were added (*Šmíd et al. 2018; 2021; Trampota et al. 2021*). In contrast, Boleráz cremation graves, typically barrows, are characterised by numerous grave goods, including pottery vessels (e.g., *Šmíd 2003*). A small number of inhumation graves without pottery are known from the classical and late Baden periods (e.g. Hlinsko u Lipníka, not dated by the radiocarbon

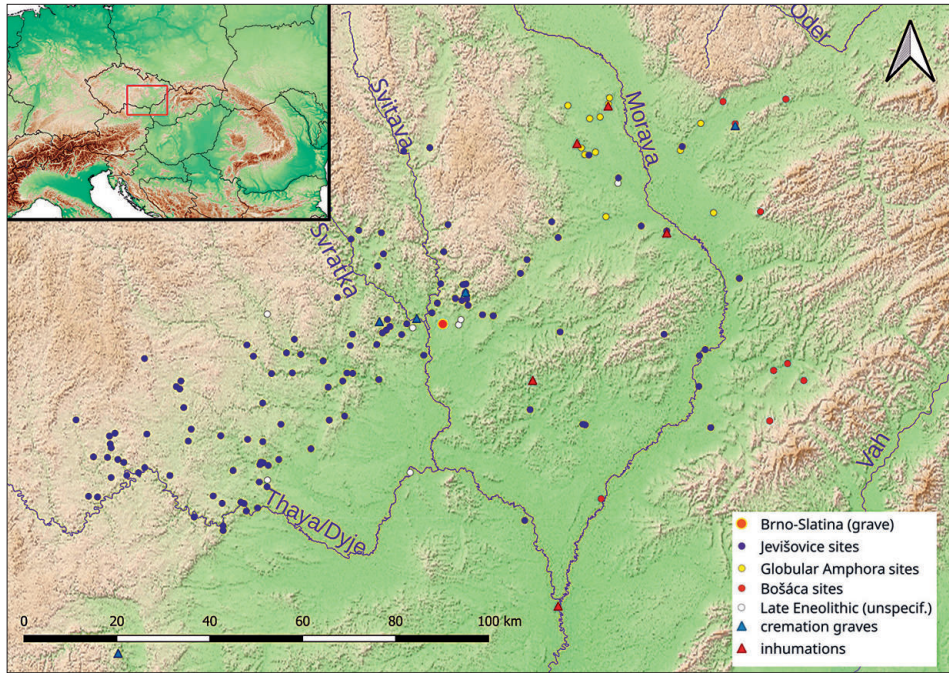


Fig. 8. Settlements and burials in the Late Eneolithic in the Morava River basin.

method, Pavelčík 1990; Brno-Trnitá, Trampota et al. 2021, 324), as well as two cremation graves from Šakvice (*Dočkalová – Šebela 2002*) and Sudoměřice (*Parma – Šmíd 2007*), both of which were deposited in pottery vessels. In the Late Eneolithic, both burial types seemed to coexist, with inhumation burials later being associated with a range of pottery grave goods.

From a general perspective, western Moravia represents a homogeneous region dominated by Jevišovice pottery production. In contrast, central and eastern Moravia are characterised by a mix of Globular Amphora, Bošáca, and Jevišovice pottery, graves linked to the Corded Ware burial practices, and occasional references to Coțofeni pottery. Some inhumation graves in these areas may share a common origin with steppe populations, a hypothesis supported by the low settlement density observed in the flatter regions of Moravia.

Attributes of steppe populations in Moravia have been noted as early as the transition from the Boleráz to classical Baden phases, exemplified by the grave from Olomouc-Nemilany (*Peška – Tajer 2006*). The authors link this grave to the Corded Ware culture, despite four radiocarbon dates showing a much earlier chronology than the assumed range of this culture. *Kolář (2018, 40)* associates this grave with steppe areas, although formally it cannot be associated with the Yamnaya burial practices.

The picture of Moravia before the formation of the Corded Ware culture broadly aligns with description of the gradual hybridisation of two distinct populations—steppe and late Neolithic (in a genetic sense) – proposed by *Kristiansen et al. (2017)*. While the archaeological record in eastern Moravia exhibits more steppe characteristics, including inhumation

tion burial rites with secondary mortuary practices, in the west, evidence points to a society with unique settlement preferences, chronologically unparalleled until that time.

Hybridisation is an appropriate term for characterising the grave from Brno-Slatina. It exhibits contemporary phenomena, such as human burials with animals, but at the same time, it cannot be equated with the standardised burial practices associated with the Globular Amphora or the Yamnaya. The burial shares some features with Corded Ware graves, though it is chronologically too early. This suggests that it reflects the social transformation of populations with a steppe way of life, who likely inhabited lowland areas of Moravia in small numbers, from which the Corded Ware phenomenon later emerged.

It can be expected that more insight into the social complexity of the Late Eneolithic and the profound changes associated with this period will emerge from the complete publication of other burial assemblages, of which only fragmentary information is currently available, as well as analyses of stable isotopes and paleogenetics. The grave from Brno-Slatina should play an indispensable role in advancing our knowledge of the process of complex societal transformation.

Conclusion

A large and unusual grave found in Brno-Slatina contained the inhumation burial of a child and seventeen animals in a complete or partial state. The grave was clearly reopened and significantly disturbed. No grave goods were found, but thanks to radiocarbon dating, the burial can be dated to the Late Eneolithic, specifically to the period between 2850 and 2580 cal BC. The grave was located in a flat landscape with a prominent natural limestone monument and represented a solitary situation.

In comparison with other contemporary finds, it cannot be definitively identified as analogous to any other burial discovery. Contemporary burial practices include both cremation, which can be associated with the Jevišovice pottery production, and inhumations, which cannot be clearly attributed to any specific pottery group. The practice of inhumation during the Late Eneolithic, possibly even earlier, is likely indicative of populations with a steppe lifestyle, whose hybridisation with local Late Eneolithic populations led to the emergence of a society characterised by specific burial practices associated with the Corded Ware.

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References

- Adams, B. J. – Crabtree, P. J. 2008: Comparative Skeletal Anatomy. A Photographic Atlas for Medical Examiners, Coroners, Forensic Anthropologists, and Archaeologists. Totowa: Humana Press.
- Anderson, S. – Van Laerhoven, S. L. 1996: Initial Studies on Insect Succession on Carrion in Southwestern British Columbia. *Journal of Forensic Sciences* 41, 617–625.
- Anton, E. – Niederegger, S. – Beutel, R. G. 2011: Beetles and flies collected on pig carrion in an experimental setting in Thuringia and their forensic implications. *Medical and Veterinary Entomology* 25, 353–364. <https://doi.org/10.1111/j.1365-2915.2011.00975.x>

- Bronk Ramsey, C. 2009: Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337–360. <https://doi.org/10.1017/S0033822200033865>
- Červený, Č. – Komárek, V. – Štěrba, O. 1999: Koldův atlas veterinární anatomie. Praha: Grada Publishing – Avicenum.
- Ciugudean, H. – Quinn, C. P. – Uhnér, C. 2022: Considerații privind evoluția culturii Coțofeni în lumina noilor date radiocarbon. *Acta Musei Apulensis* 59, 9–39.
- Čížmář, I. 2019: Brno (k. ú. Židenice, okr. Brno-město). *Přehled výzkumů* 60, 193.
- Dobeš, M. – Pecinová, M. – Ernée, M. 2021: On the earliest Corded Ware in Bohemia. In: V. Heyd – G. Kulcsár – B. Preda-Bălănică (eds.), *Yamnaya Interactions. Proceedings of the International Workshop held in Helsinki, 25–26 April 2019*. Budapest: *Archaeolingua*, 487–511.
- Dobeš, M. – Šumberová, R. – Kyselý, R. 2013: Bošácká keramika z Kolína. *Doklad kontaktu postbadenských kultur v závěru středního eneolitu. Archeologické rozhledy* 65, 382–400.
- Dočkalová, M. – Šebela, L. 2002: Žárový hrob badenské kultury ze Šakvic. In: S. Stuchlík (ed.), *Oblast vodního díla Nové Mlýny od pravěku do středověku. Spisy Archeologického ústavu AV ČR Brno 20*. Brno: Archeologický ústav Akademie věd České republiky Brno, 481–485.
- Furholt, M. 2003: Die absolutchronologische Datierung der Schnurkeramik in Mitteleuropa und Südsandinavien. *Universitätsforschungen zur prähistorischen Archäologie* 101. Bonn: Dr. Rudolf Habelt.
- Geislerová, K. – Parma, D. (eds.) 2013: Výzkumy – Ausgrabungen 2005–2010. Brno: Ústav archeologické památkové péče.
- Geislerová, K. – Parma, D. (eds.) 2018: Výzkumy – Ausgrabungen 2011–2016. Brno: Ústav archeologické památkové péče.
- Genard, D. 2007: *Forensic Entomology: An Introduction*. Chisteter: John Wiley and Son.
- Grant, A. 1982: The use of tooth wear as a guide to the age of domestic ungulates. In: B. Wilson – C. Grigson – S. Payne (eds.), *Ageing and sexing animal bones from archaeological sites*. Oxford: B. A. R., 91–108.
- Halstead, P. – Collins, P. 1995: *Sheffield Animal Bone Tutorial: Taxonomic Identification of the Principal Limb Bones of Common European Farmyard Animals and Deer: A Multimedia Tutorial*. Glasgow: Archaeology Consortium, TL TP, University of Glasgow.
- Halstead, P. – Collins, P. 2002: Sorting the sheep from goats: Morphological distinctions between the mandibles and mandibular teeth of adult *Ovis* and *Capra*. *Journal of Archaeological Science* 29, 545–553. <https://doi.org/10.1006/jasc.2001.0777>
- Horváth, T. 2022: The Baden complex in Austria and Hungary – A comparative study. *Ziridava, Studia Archaeologica* 36, 41–83.
- Hrala, J. 1959: Několik nálezů z Kolínska. *Archeologické rozhledy* 11, 21–25.
- Jarošová, I. – Králík, M. – Nováček, J. – Peška, J. – Tajer, A. 2006: Antropologické hodnocení tělesných pozůstatků jedince jevišovické kultury (?) z lokality Kroměříž 3 – Miňůvky, Křivky. *Archeologické centrum Olomouc – Ročenka* 2019, 53–71.
- Kalferst, J. – Prostředník, J. 1998: Nové nálezy bošácké skupiny ve východních Čechách. *Archeologické rozhledy* 50, 586–599.
- Kolář, J. 2018: *Archaeology of Local Interactions. Social and Spatial Aspects of the Corded Ware Communities in Moravia. Studien zur Archäologie Europas* 31. Bonn: Dr. Rudolf Habelt.
- Komárek, V. – Štěrba, O. – Fejfar, O. 2001: *Anatomie a embryologie volně žijících přežvýkavců*. Praha: Grada.
- Kos, P. 2005: Document M-TX-201602240. AMCR Digital Archive. <https://digiarchiv.aiscr.cz/id/M-9102350A>
- Kos, P. 2006a: Document M-TX-201602133-D001. AMCR Digital Archive. <https://digiarchiv.aiscr.cz/id/M-TX-201602133>
- Kos, P. 2006b: Brno (k.ú. Slatina, okr. Brno-město). *Přehled výzkumů* 47, 122.
- Kos, P. 2019: Mokrá-Horákov (k. ú. Mokrý, okr. Brno-venkov). *Přehled výzkumů* 60, 196.
- Kristiansen, K. – Allentoft, M. E. – Frei, K. M. – Iversen, R. – Johannsen, N. N. – Kroonen, G. – Pospieszny, L. – Price, T. D. – Rasmussen, S. – Sjögren, K.-G. – Sikora, M. – Willerslev, E. 2017: Re-theorising mobility and the formation of culture and language among the Corded Ware Culture in Europe. *Antiquity* 91, 334–347. <https://doi.org/10.15184/ayq.2017.17>
- Kuswati, K. – Kusmartono, K. – Susilawati, T. – Rosyidi, T. – Agus, A. 2014: Carcass Characteristics of Brahman Crossbred Cattle in Indonesian Feedlot. *Journal of Agriculture and Veterinary Science* 7(4), 19–24. <https://doi.org/10.9790/2380-07431924>
- Kyselý, R. 2004: Kvantifikační metody v archeozoologii. *Archeologické rozhledy* 56, 279–296.

- Lyman, R. L. 2008: Vertebrate Taphonomy. Cambridge Manuals in Archaeology. Cambridge: Cambridge University Press.
- Mellnerová Šuteková, J. 2015: Western Slovakia during the period of Post-Baden cultural development. In: M. Nowak – A. Zastawny (eds.), The Baden culture around the Western Carpathians. Kraków: Krakowski Zespół do Badań Autostrad, 501–511.
- Mitscha-Märheim, H. 1958: Die Grabung 1953/54 am „Föhrenhügel“ in Hohenau a. d. March. Unsere Heimat 29, 50–56.
- Neustupný, E. – Dobeš, M. – Turek, J. – Zápotocký, M. 2013: Prehistory of Bohemia 3. The Neolithic. Praha: Archeologický ústav AV ČR, Praha.
- Oppenheimer, J. 1907: Der Malm der Schwedenschanze bei Brünn. Beiträge zur Paläontologie und Geologie Österreich-Ungarns 20, 221–271.
- Parma, D. – Šmíd, M. 2007: Ossarnský hrnc z Sudoměřic, okr. Hodonín. In: R. Tichý (ed.), Otázky neolitu a eneolitu našich zemí 2006, Hradec Králové: Univerzita Hradec Králové, 131–146.
- Pasterkiewicz, W. 2021: Sepulchral complexes of human burials and animal deposits, site 23, Sadowie, Opátów district. Study of selected examples. Baltic-Pontic Studies 25, 79–116. <https://doi.org/10.14746/bps.2021.25.3>
- Pavelčík, J. 1990: Rituální hrob ženy na výšinné eneolitické osadě lidu s kanelovanou keramikou v Hlinsku u Lipníka nad Bečvou (okr. Přešov). Archeologické rozhledy 42, 501–508.
- Payne, S. 1973: Kill-off patterns in sheep and goats: the mandibles from Aşvan Kale. Anatolian Studies 23, 281–303.
- Peška, J. 2023: Following the traces of the earliest Corded Ware in Moravia and steppe elements in its content. Sprawozdania Archeologiczne 75, 141–174. <https://doi.org/10.23858/SA/75.2023.1.3506>
- Peška, J. – Hadrava, V. – Mlejnek, O. 2020: Objev prvních žárových hrobů bošácké kultury na mohylníku kultury se šňůrovou keramikou v Hlinsku-Podhůře, trať Kouty (okr. Přešov). Archeologické centrum Olomouc – Ročenka 2019, 107–135.
- Peška, J. – Polcerová, L. 2017: První pohřebiště jevišovické kultury na Moravě. Archeologické rozhledy 69, 531–554. <https://doi.org/10.35686/AR.2017.30>
- Peška, J. – Tajer, A. 2006: První kostrový hrob jevišovické kultury na Moravě? Archeologické centrum Olomouc – Ročenka 2005, 35–52.
- Přichystal, A. 2013: Lithic Raw Materials in Prehistoric Times of Eastern Central Europe. Brno: Masaryk University.
- Prummel, W. – Frisch, H. J. 1986: A guide for the distinction of species, sex and body side in bones of sheep and goat. Journal of Archaeological Science 13, 567–577. [https://doi.org/10.1016/0305-4403\(86\)90041-5](https://doi.org/10.1016/0305-4403(86)90041-5)
- Régészeti adadabázis. Magyar Nemzeti Múzeum. Available at: <https://archeodatabase.hnm.hu/en/node/21570> [accessed 13-04-2024].
- Reimer, P. – Austin, W. – Bard, E. – Bayliss, A. – Blackwell, P. et al. 2020: The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62, 725–757. <https://doi.org/10.1017/RDC.2020.41>
- Reitz, E. – Wing, E. 2008: Zooarchaeology. Cambridge: Cambridge University Press.
- Ruttkay, E. 1992: Zwei endneolithische Brandgräber aus Gars am Kamp, Thunau, VB Horn, Niederösterreich. Beitrag zur Gräberkunde des Endneolithikums. Balcanica 23, 281–297.
- Schmid, E. 1972: Atlas of Animal Bones. For Prehistorians, Archaeologists and Quaternary Geologists. Amsterdam – London – New York: Elsevier.
- Šmíd, M. 1999: Nové poznatky o vývoji střední Moravy v období středního a mladého eneolitu. In: I. Kuzma (ed.) Otázky neolitu a eneolitu našich krajín. – 1998: zborník referátov zo 17. pracovného stretnutia bádateľov pre výskum neolitu a eneolitu Čiech, Moravy a Slovenska Nitra: Archeologický ústav Slovenskej akadémie vied, 241–252.
- Šmíd, M. 2003: Mohylová pohřebiště kultury nálevkovitých pohárů na Moravě. Pravěk – Supplementum 11. Brno: Ústav archeologické památkové péče.
- Šmíd, M. – Lečbych, M. – Šmerda, J. – Kala, J. – Limburský, P. 2021: Sídliště a pohřebiště kultury nálevkovitých pohárů v Dambořicích, okr. Hodonín. Příspěvek k poznání pohřebišť s pohřby v natažené poloze. Archeologické rozhledy 73, 3–47. <https://doi.org/10.35686/AR.2021.1>
- Šmíd, M. – Tvrdlý, Z. – Parma, D. – Kos, P. 2018: Pohřebiště kultury nálevkovitých pohárů s pohřby v natažené poloze z Modřic, okr. Brno-venkov. Acta Musei Moraviae, Scientiae sociales 103, 101–140.

- Steinhauser, L. 2000: *Produkce masa*. Tišnov: Last.
- Stloukal, M. – Hanáková, H. 1978: Die Länge der Längsknochen altslawischer Bevölkerungen unter besonderer Berücksichtigung von Wachstumsfragen. *Homo* 29, 53–69.
- Szczodrowski, R. 2015: Spatial aspects of Globular Amphora Culture funeral rites with animal deposits in Poland. In: A. Pluskowski (ed.), *The Ritual Killing and Burial of Animals. European Perspectives*. Oxford: Oxbow Books. 51–60. <https://doi.org/10.2307/j.ctv13pk7nt.8>
- Szmyt, M. 2006: Dead animals and living society. *Journal of Neolithic Archaeology* 8, 1–10. <https://doi.org/10.12766/jna.2006.19>
- Trampota, F. – Bíšková, J. – Čerevková, A. – Čížmář, I. – Drozdová, E. – Kala, J. – Kos, P. – Květina, P. – Parma, D. – Přichystal, M. – Světlík, I. – Štůl, L. – Tvrdý, Z. – Vrána, J. 2021: Eneolitický kostrový pohřební ritus na Moravě ve světle radiokarbonového datování. *Archeologické rozhledy* 73, 315–358. <https://doi.org/10.35686/AR.2021.11>
- Ubelaker, D. H. 1978: *Human Skeletal Remains: Excavation, Analysis, Interpretation*. Chicago: Aldine Publishing Company.
- Vlček, E. 1994: Metodika určování zubního věku podle stupně mineralizace chrupu v historické antropologii a paleoantropologii. *Stomatologické zprávy* 35, 30–39.
- Witkowska, B. – Czebreszuk, J. – Gmińska-Nowak, B. – Goslar, T. – Szmyt, M. – Ważny, T. 2020: The cemetery of the Globular Amphora Culture community at the Złota-Gajowizna site in the light of radiocarbon analysis and dendrochronology. *Sprawozdania archeologiczne* 72, 61–86. <https://doi.org/10.23858/SA/72.2020.2.2116>

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RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

Social networks around the Orońsko flint mining area (Central-Southern Poland) during the Late Palaeolithic: The first results of the SEM-EDS analysis of flints and pigments

Sociální sítě v okolí těžebního areálu Orońsko (středojižní Polsko) v pozdním paleolitu: První výsledky SEM-EDS analýzy silicitů a pigmentů

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Dominik Gurba – Mateusz Słoniewski

Orońsko site 2 is a Palaeolithic shaft mine located in the area of chocolate flint deposits in Central-Southern Poland. This raw material was highly valued by Stone Age communities and widely distributed during the Late Palaeolithic. The mine is associated with the Arch-Backed Pieces (Federmesser) and Tanged Point Technocomplexes. This article aims to explore the connections between artefacts made of chocolate flint found at various Late Palaeolithic sites located outside the chocolate flint deposits (Całowanie and ochre quarry at Rydno) with the Orońsko mine and to investigate a possible connection between the ochre found in the Orońsko mining shaft with the Rydno quarry. Macroscopic and SEM-EDS analyses were conducted on selected samples of these raw materials and artefacts from the Orońsko mine, the Orońsko workshop, Rydno, and Całowanie, all of which can be chronologically linked to one another. The results suggest that some of the flint may have been transported from the Orońsko mining area to Rydno or Całowanie. However, the reverse transport of ochre from Rydno to Orońsko remains unclear and requires further research, including a broader range of analytical methods.

chocolate flint – pigment – ochre – mine – Palaeolithic – Orońsko – SEM-EDS

Orońsko 2 je paleolitický šachtový důl, který se nachází v oblasti nalezišť čokoládového silicitu ve středojižním Polsku. Tato surovina byla komunitami doby kamenné vysoce ceněna a v pozdním paleolitu široce rozšířena. Dolování je spojeno s technokomplexy s obloukovitě retušovanými hroty (Federmesser) a řapovými hroty. Cílem tohoto článku je prozkoumat souvislosti mezi artefakty vyrobenými z čokoládového silicitu nalezenými na různých pozdně paleolitických lokalitách mimo naleziště čokoládového křemene (Całowanie a okrový lom u Rydna) s dolem v Orońsku a prozkoumat možnou souvislost mezi okrem nalezeným v Orońské těžební šachtě s lomem v Rydně. Byly provedeny makroskopické a SEM-EDS analýzy vybraných vzorků těchto surovin a artefaktů z dolu Orońsko, Orońské dílny, Rydna a Całowanie, které spolu mohou chronologicky souviset. Výsledky naznačují, že část křemene mohla být transportována z oblasti dolu Orońsko do Rydna nebo Całowanie. Reverzní transport okru z Rydna do Orońska však zůstává nejasný a vyžaduje další výzkum, včetně širšího spektra analytických metod.

čokoládový silicit – pigment – okr – důl – paleolit – Orońsko – SEM-DES

Introduction

The detailed characterisation and diversification of siliceous rocks, as well as other materials such as pigments, are key issues for understanding the economy, mobility, and interactions of Stone Age communities. To effectively link the origins of the artefacts or pigments to

their extraction points, particular macroscopic and microscopic observations along with chemical analyses are essential. By utilising these advanced techniques, we can create a strong framework connecting distinct settlement areas, enhancing our understanding of Palaeolithic social networks and cultural exchanges. This, in turn, provides insight into the complexities of prehistoric human interactions. In recent years, efforts have been made to characterise some types of flint, including chocolate flint and pigments like ochre. These studies have yielded interesting and valuable results (see *Weinstein-Evron – Ilani 1994; Hughes et al. 2010; Hughes et al. 2011; Högberg et al. 2012; Přichystal 2013; Roldan et al. 2015; Werra et al. 2015; Brandl et al. 2016; Sobkowiak-Tabaka et al. 2016; Fiers et al. 2019; Velliky et al. 2021; Werra – Siuda 2022; Mandra et al. 2024*).

The term ‘flint’ is a commonly used name in Polish archaeology for describing siliceous rocks, such as cherts/silicites, including chocolate flint, Świeciechów flint, striped flint, and others (see, for instance, *Přichystal 2013; Matyszkiewicz-Kochman 2020*). As previously noted in the literature, chocolate flint was a highly significant raw material during the Palaeolithic, particularly for Late Palaeolithic communities. It was distributed over distances of several hundred kilometres during this period (*Sulgostowska 2005; 2008*). Its deposits were first described in the 1920s by S. Krukowski and J. Samsonowicz (*Krukowski 1922; Samsonowicz 1923*). The term ‘chocolate flint’ was originally referred to as ‘waxy-chocolate’ by S. Krukowski (*1922; 1923*), due to its brownish colour and waxy lustre. The first attempt to characterise and classify varieties of chocolate flint was made by R. Schild, based on samples collected during surface surveys focused on mining sites (*Schild 1971; 1976*). Schild categorised the raw material into 11 groups, each with further subgroups, based on macroscopic characteristics supplemented by features observable under an optical microscope. In recent years, D. H. Werra and her team have continued this research. They analysed samples of chocolate flint obtained from mining fields and natural exposures, employing various specialised methods in addition to macroscopic characteristics. Studies have included descriptions of micropaleontology through organic compound analysis (*Grafka et al. 2015*) and geochemical techniques such as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) (*Brandl et al. 2016*), X-ray fluorescence spectrometry (EDXRF) (*Hughes et al. 2016*), reflectance spectroscopy (VNIR – Visible Near Infrared), and Fourier Transform Infrared spectroscopy (FTIR) (*Parish – Werra 2018*). New research is also being conducted in the Krakow-Częstochowa Upland, where exploitation of chocolate flint has been confirmed, along with initial analyses of flint samples (*Mandra et al. 2024*). These findings have significantly advanced the methods for characterising flints and have enhanced our understanding of the distribution of chocolate flint.

The ochre mine located in Rydno was discovered by S. Krukowski and later excavated by various research teams, primarily under the direction of R. Schild. The name ‘Rydno’ was also given by S. Krukowski for the complex of Late Palaeolithic and Mesolithic sites located in the Kamienna River valley, clustered around the ochre outcrops. Rydno is located near the belt of chocolate flint deposits, about 25 km south of Orońsko (*Fig. 1*).

While the ochre quarry has not yet been the focus of extensive research, some analyses have already been conducted on this material (e.g. *Schild et al. 2011*). The previous research showed that the material in question is composed mostly of iron (30.73–70.12 wt%), which is also responsible for its shade. Moreover, further elements were noted, such as silica (8.00–27.00 wt%) and aluminium (1.70–4.40 wt%), followed by magnesium, titanium and calcium with levels below 2.00 wt% (*Schild et al. 1981; Hensel 2011, 406*). It was assessed

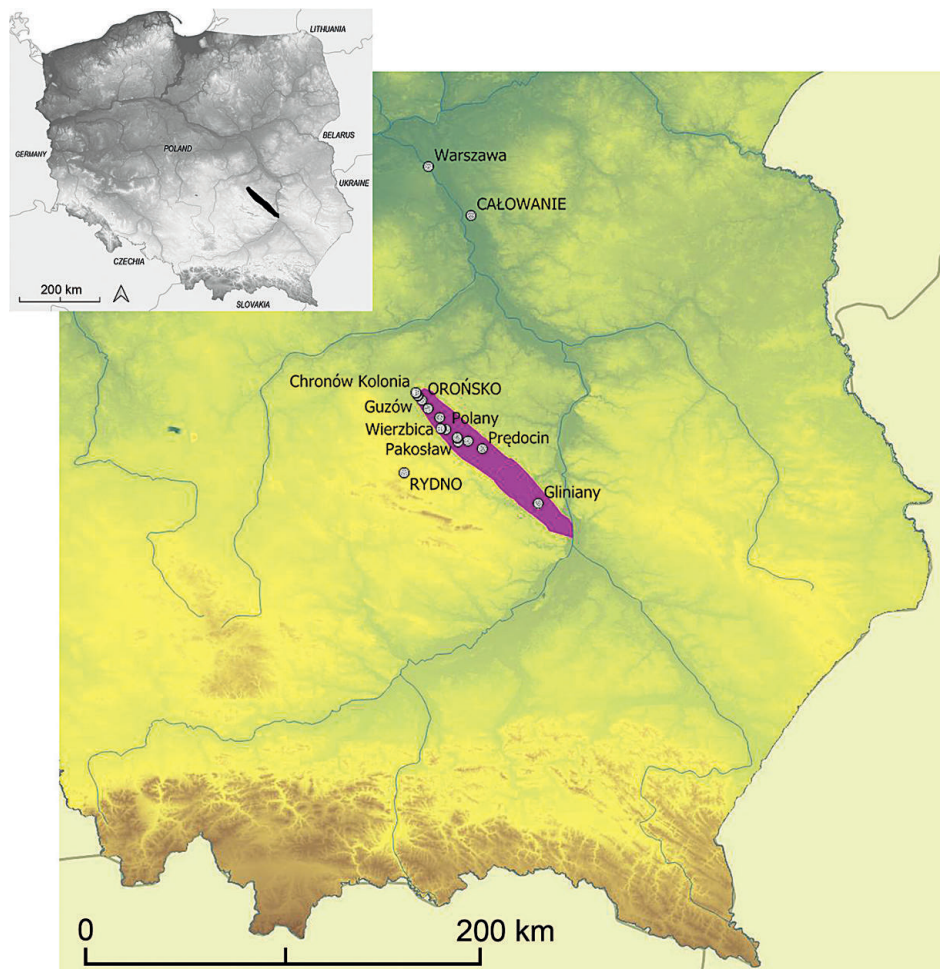


Fig. 1. Location of Orońsko site complex and the chocolate flint outcrops with the main exploitation points and the sites mentioned in the text (by K. Kerneder-Gubała, S. Buławka, and N. Buławka).

that the iron-bearing materials were mostly hematite, occurring in the form of gravels, and hematite-bearing conglomerates, such as sands and clays (Schild *et al.* 2011, 54–58).

Additional research has been performed on ochre samples from Orońsko mining shaft no. 2 (see Osipowicz *et al.* 2019). Given the proximity of both sites and the prominence of the Rydno complex, a hypothesis has been formed regarding the possible transportation of ochre to Orońsko. This article aims to present the preliminary results of comparative analyses of chocolate flint from the mine alongside artefacts from distant workshops, all dated to the same period. The second objective is to analyse and compare pigments from Orońsko with local clay variants and samples derived from Rydno. The research includes both macroscopic and laboratory analyses, specifically using SEM-EDS. Through meticulous work, this study aims to address the reconstruction of social networks during the Palaeolithic in the microregion around Orońsko, explore the possibilities and limitations

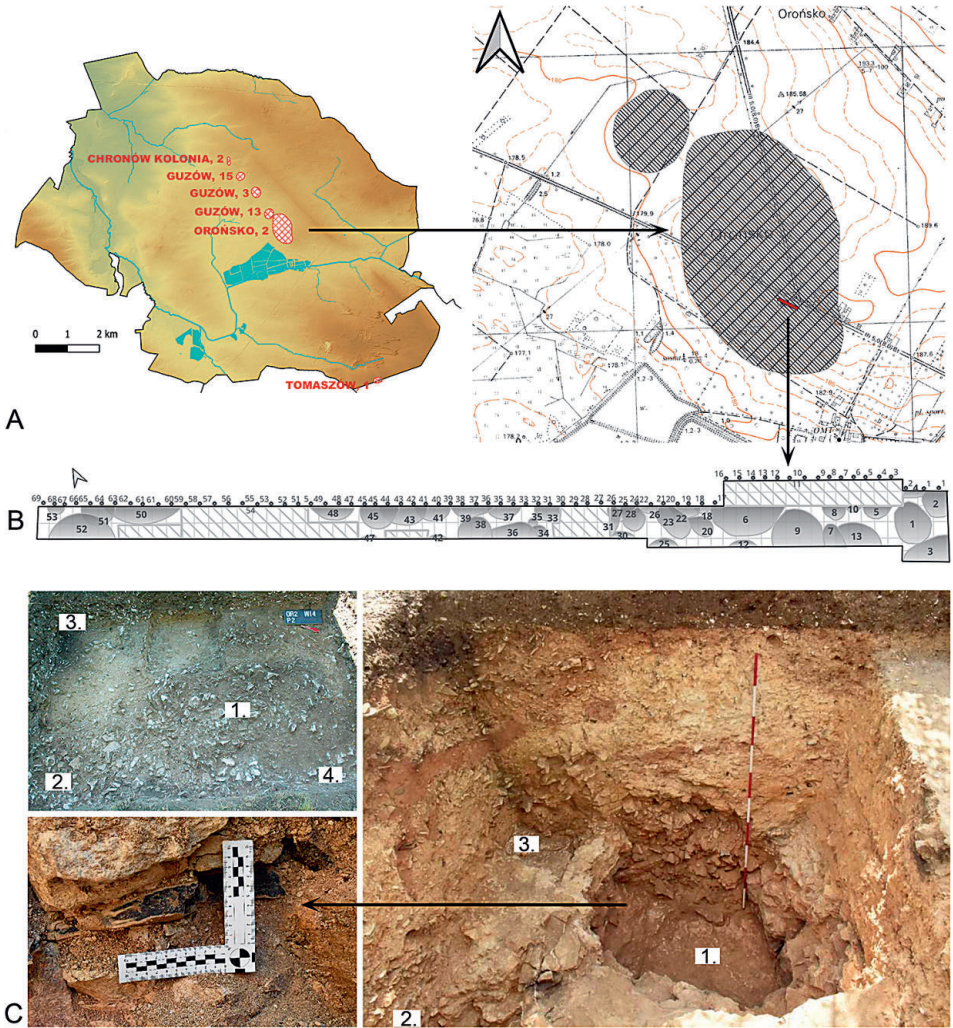


Fig. 2. Location of the trench I4/2016–2024 at site 2 in Orońsko (A, B) and the mining shafts with flint-bearing layers (C; by K. Kerneder-Gubała, S. Buławka, and N. Buławka).

of using SEM-EDS for analysing flint and pigment samples, and propose future directions for research.

Materials and methods

Orońsko is located in the northwestern part of the chocolate flint outcrops, in the Oronka River valley. Chocolate flint deposits are situated along the Upper Jurassic belt, which separates the Kielce-Sandomierz Upland from the Masovian Lowland at the northern edge of the Holy Cross Mountains (Fig. 1; Schild 1971, 19–38; Schild et al. 1977; 1985, 13–16;

Budziszewski 2008). S. Krukowski and J. Samsonowicz identified most of the known chocolate flint outcrops. Research in this area began in the 1920s with a surface survey around the Orońsko 2 site and the adjacent area (*Krukowski 1922; 1923; 1939–1948*). In 1935, as a result of excavations, S. Krukowski discovered the remains of mining shafts sunk into flint-bearing layers of residual clays at the Orońsko 2 site (*Krukowski 1939–48; Kozłowski 2008*). Further research in the region was conducted by Romuald Schild and his team (*Schild 1971*), who performed extensive surface surveys and excavations at neighbouring Neolithic and Bronze Age mining sites such as Tomaszów and Polany Kolonie (*Schild 1995a; 1995b; Schild et al. 1977; 1985*). During this time, multiple samples of flint from sites near Orońsko (*Schild 1971*) were also collected and subjected to an initial study. Extensive excavations were conducted at other sites located in the chocolate flint outcrops, such as Wierzbica Zele and Polany II, both of which were located in the mining fields (*Lech – Lech 1984; Chmielewska 1988; Herbich – Lech 1995; Lech – Werra 2019*). The entire area was later investigated by Janusz Budziszewski and other researchers, though mainly through surface surveys (*Budziszewski 2008*).

Pigments have been identified in archaeological layers at Orońsko particularly in the form of loose powders found in the sediments, on bone tools, and on flint artefacts excavated in the fills of mining shafts. Notably, these pigments were primarily reddish to pinkish in hue. In the immediate vicinity of the site, accumulations of ferruginous clays with yellowish to dark orange hues were observed. Additionally, ochre mining pits and artefacts covered with ochre were noted in the Rydno complex (see *Schild et al. 2011*). For the research presented here, samples of loose-pigmented materials were collected and analysed for comparison.

The Orońsko chocolate flint mine, trench I4/2016–2024

The latest excavation campaign at the Orońsko 2 site conducted since 2016 has led to the discovery of new mining shafts (*Kerneder-Gubata 2019; Osipowicz et al. 2019; Werra – Kerneder-Gubata 2021*). Dozens of new mining shafts were uncovered in trench I4. These shafts were found in a layer of weathered rock as well as at the level of the limestone bedrock, where flint-bearing layers were identified (*Fig. 2*). Both the archaeological artefacts and radiocarbon dating confirmed that the shafts were used in the Late Palaeolithic period, specifically the late Allerød and Younger Dryas periods (GI-1a-GS1, *Kerneder-Gubata 2019; Osipowicz et al. 2019; Werra – Kerneder-Gubata 2021*). Flint artefacts from the mining shafts discovered by S. Krukowski were also assigned to the same period. These artefacts exhibit features characteristic of the Arch-Backed Pieces and Tanged Point Technocomplexes (comp. *Krukowski 1939–48; Schild 1971; Kerneder-Gubata 2019*).

Late Palaeolithic workshops outside the chocolate flint outcrop

In our study of exchange networks, we also focused on sites that are distant from Orońsko. We analysed flint samples from Calowanie, located approximately 80 km to the north, and flint and ochre samples from the Rydno site complex, situated about 25 km to the south of Orońsko (see *Fig. 1*). Rydno is a complex of Late Palaeolithic and Mesolithic sites that served as flint workshops, camps, and an ochre mine (*Schild et al. 2011*). In contrast, Calowanie is a multicultural site with layers dated from the Late Pleistocene to the Early

CHOCOLATE FLINT SAMPLES												
No	Site	Site function	Trench	Chronology	Colour (Munsell scale)	Lustre	Transparency (1-3)	Smudges/streaks	Stains	Cortex – colour	Cortex – form	Romuald Schild's classification number
FLINT 1	Orońsko 2	flint mine	I4/shaft no. 1	Late Palaeolithic / OTP	10 YR 3/2 very dark greyish brown	waxy, matt	2	+	-	10YR 8/2-8/1 white	irregular, rough, very thick	Vlb
FLINT 2	Orońsko 2	flint mine	I4/shaft no. 1	Late Palaeolithic / OTP	5YR very dark grey	waxy	1	-	+	10YR 8/2-8/1 white	irregular, rough, thick	IX / VI
FLINT 3	Orońsko 2	flint mine	surface	Late Palaeolithic	10 YR 3/2 very dark greyish brown	waxy	1	+	+	10YR 6/4 light yellowish brown	little irregular	Vlla
FLINT 4	Orońsko 2	flint mine	I4/shaft no. 1	Late Palaeolithic / OTP	5YR very dark grey, 2/1 dark reddish brown	waxy	1	-	+	10YR 8/2-8/1 white	irregular, rough, thick	IX / VI
FLINT 5	Orońsko 2	flint mine	I4/shaft no. 1	Late Palaeolithic / OTP	5YR very dark grey, 2/1 dark reddish brown	waxy	1	-	+	10YR 8/2-8/1 white	irregular, rough, thick	IX / VI
FLINT 6	Orońsko 1	workshop	Surface	Late Palaeolithic	dark grey to light grey – 4/1 to 6/1	waxy	1	+	-	5YR 7/6 reddish yellow	irregular, rough, thick	Vlld
FLINT 7	Catowanie	workshop, camp	trench IX, level IVb	Late Palaeolithic, ABP	5YR 4/4 REDDISH BROWN	waxy	1	+	-	10 YR 8/2 – 8/1 white	smooth, thick, irregular	VI
FLINT 8	Rydno	workshop, camp	trench X/1959	Late Palaeolithic, ABP	dark grey to light grey – 4/1 to 6/1	waxy	1	+	+		little irregular	Vlld
FLINT 9	Rydno	workshop, camp	trench IV/1960	Late Palaeolithic, OTP	dark grey to light grey – 4/1 to 6/1	waxy	1	+	+	5YR 7/6 reddish yellow	smooth, thick, irregular	Vlld
FLINT 10	Rydno	workshop, camp	trench IX/1959	Late Palaeolithic, OTP	dark grey to light grey – 4/1 to 6/1	waxy	1	+	+		little irregular	Vlld

A

OCHRE SAMPLES				
No	Site	Trench	Object	Sample description
OCHRE 1	Orońsko 2	I4	6	sediment
OCHRE 2	Rydno	RK-77	-	sediment – sand
OCHRE 3	Rydno	RK-77	-	sediment – gravel
OCHRE 4	Orońsko 2	I4	1	flint flake
OCHRE 5	Orońsko 2	I4	1	bone tool
OCHRE 6	Orońsko 2	I4	6	limestone
OCHRE 7	Orońsko 2	I4	1	sediment
OCHRE 8	Orońsko 2	I4	6	sediment
OCHRE 9	Rydno	RK-77	-	sediment – gravel

B

Tab. 1. List of samples: A – flint sample macroscopic characteristic, B – list of ochre samples.

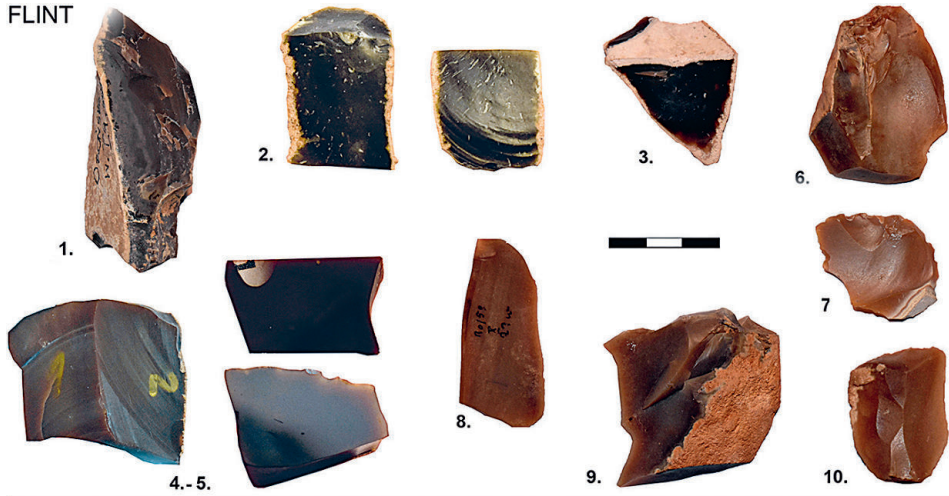
Holocene, situated a few dozen kilometres from the chocolate flint outcrop (*Schild 2014*). Some Late Palaeolithic assemblages from this site were crafted from mined chocolate flint. Based on macroscopic features, it was suggested that some of these artefacts could have originated from the chocolate flint found in Orońsko or, more broadly, from the western group of chocolate flint outcrops (*Tomaszewski et al. 2008; Schild 2014*). Also, the initial results of the comparative chemical analysis of ochre from the Całowanie site and Rydno showed some similarities (*Hensel 2011, 407*).

All analysed flakes were excavated at Late Palaeolithic sites associated with the Older Tanged Point Technocomplex (OTP/Bromme culture) at Rydno X/1959 (sample FLINT 8), Rydno IV/1960 (sample FLINT 9) and the Arch-Backed Pieces Technocomplex (ABP) at Całowanie (trench IX, level IVb, sample FLINT 7) and Rydno X/1959 (sample FLINT 10). These sites correspond chronologically to the period in which the mine in Orońsko was in operation.

Methods and samples

Ten samples of chocolate flint and nine pigment samples were selected for microstructural and compositional analysis using a scanning electron microscope (SEM) with an energy-dispersive X-ray spectrometer (EDS) (see *Fig. 3; Tab. 1*). The chocolate flint group consists of both artefacts and natural nodules collected from flint-bearing levels of the mine and from the surface of the Orońsko area (samples FLINT 1–FLINT 6). Additionally, four samples (FLINT 7–FLINT 10) were obtained from flint workshops located outside the known regions of chocolate flint occurrence, specifically from Całowanie and the Rydno complex. Qualitative EDS analysis of the chocolate flint samples (FLINT 1–FLINT 10) was conducted using a Hitachi electron microscope (PGI-NRI, Warsaw). The analysis was performed on the rough surfaces of each sample under variable vacuum conditions. However, the FLINT 4 and FLINT 5 samples were cut, polished, and carbon-coated to obtain high-resolution SEM images and semiquantitative EDS analysis, which were performed using a ZEISS microscope combined with an Oxford EDS ISIS 300 detector (PGI-NRI, Warsaw). For comparative purposes, the samples were also described in detail through petrographic analysis. The SEM images and semiquantitative EDS analysis of the pigment samples (OCHRE 1–OCHRE 6) were collected using a TESCAN VEGA GMS scanning electron microscope, coupled with an Aztec Live Advanced UltimMAX 40 series EDS detector (PAS, Warsaw). The OCHRE 1 sample was collected from the sediment of shaft no. 6 in Orońsko, while OCHRE 2 and OCHRE 3 were sampled from sand and gravel in the Rydno area, respectively. These three samples were ground, homogenised, and compressed into tablet form. The OCHRE 4–OCHRE 6 group includes samples of distinctive red traces on the surfaces of various objects: a flint flake (OCHRE 4), a bone tool (OCHRE 5), and a piece of natural limestone slab from shaft no. 6 in Orońsko (OCHRE 6). The chemical composition of three additional samples (OCHRE 7–OCHRE 9) was analysed using a Tescan VEGA XM scanning electron microscope with an energy-dispersive X-ray spectrometer (JU, Cracow). The selected samples varied as follows: OCHRE 7 was obtained from feature 1 at the Orońsko 2 site and was orange in hue; OCHRE 8 was collected from feature 6 and was dark orange; OCHRE 9 was sampled from the Rydno complex, with storage number R-K/77, and was red in colour. These samples underwent pulverisation with carbon dust in a turbomolecular duster and were stabilised with carbon glue.

FLINT



OCHRE



Fig. 3. Flint and ochre samples. FLINT: 1, 2, 4, 5 – Orońsko, site 2, shaft no. 1, flint sample; 3 – Orońsko, site 2, surface, artefact; 6 – Orońsko, site 1, workshop, artefact; 7 – Całowanie, tr. IX, level IVb, artefact; 8 – Rydno, tr. X/59, artefact; 9 – Rydno, tr. IV/1960, artefact; Rydno, tr. IX/1959. OCHRE: 1 – Orońsko, site 2, shaft no. 6, sediment; 2 – Rydno ochre mine, R-K/77, sand; Rydno ochre mine, R-K/77, gravel; 4 – Orońsko, site 2, shaft 1, flint artefact; 5 – Orońsko, site 2, shaft 1, bone tool, 6 – Orońsko, site 2, shaft 6, piece of limestone; 7 – Orońsko, site 2, shaft 1, sediment; 8 – Orońsko, shaft 6, sediment; 9 – Rydno, ochre mine, R-K/77, sediment (photo by authors).

Results

Characteristics of the flint deposits from Orońsko

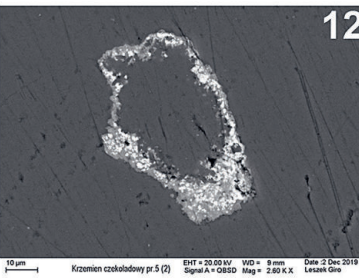
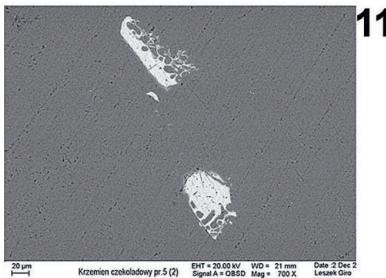
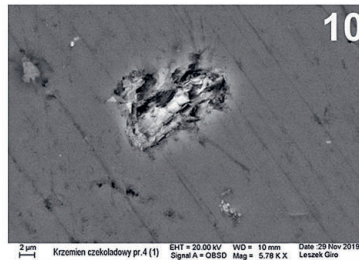
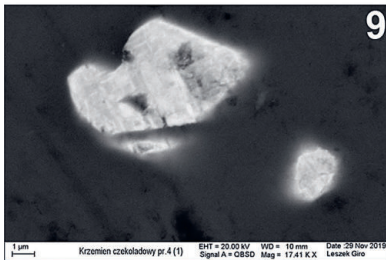
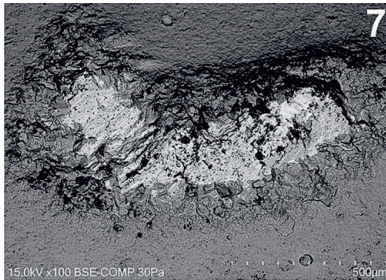
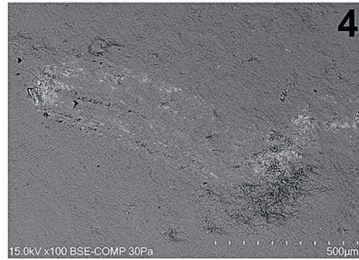
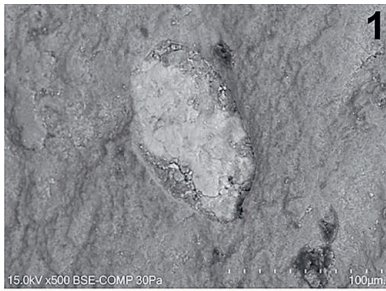
Chocolate flint primarily occurs in layers or nodules found in limestone or marly rocks from the Upper Oxfordian and Lower Kimmeridgian stages of the Upper Jurassic Belt, specifically in the Northern Margin of the Holy Cross Mountains (*Schild 1971; Gutowski 1998; Budziszewski 2008*) and in the Kraków-Częstochowa Upland (*Krajcarz et al. 2012; Sudół-Procyk et al. 2018; Sudół-Procyk 2022; Mandera et al. 2024*). These formations consist of flat, plate-like layers containing flint nodules. In the Orońsko area, flint can be found in layers of residual clays, and the use of mining shafts and pits has been confirmed thanks to the excavations conducted by S. Krukowski. These shafts were up to 3.4 metres deep but did not reach the limestone bedrock and thus the primary layers (*Krukowski 1939–1948; Schild 1971*). Recent studies indicate that chocolate flint was also obtained from primary deposits and a flint-bearing layer found in limestone in the Orońsko area. The differences between raw materials derived from primary and secondary deposits can be attributed to various weathering geological processes. These processes result in the degeneration of the cortex and a smoothing effect observed on the natural surfaces.

Petrography of chocolate flint

The variety of chocolate flint is extensive. The types of this sedimentary rock primarily composed of polycrystalline quartz have been classified into 11 categories, with subcategories based on macroscopic features. The light brown to grey-brown flint from Orońsko 2 corresponds to groups VIb, VIIa, VIIc, and VIId (*Schild 1971, 7–17*). A light beige layer beneath the cortex, along with delicate spots and streaks, has been observed (see macroscopic features of the flint samples presented in *Tab. 1; Fig. 3*). The samples from Orońsko 1 (located about 1.5 kilometres from the flint outcrop in Orońsko 2) and Rydno (samples FLINT 8 and 9) are noteworthy. According to *Schild (1971)*, these refer to group VIId. The artefact from Rydno has a slightly more brownish hue (group VII). The samples from Orońsko and Rydno exhibit a range of greyish hues with varying degrees of saturation. Artefact FLINT 7 (group VIb) from the Całowanie site is associated with the raw material obtained from Orońsko and also shows a slightly reddish hue (5YR 4/4), likely interpreted as a result of soil acid interaction. Similar flint has been noted on the surface of the northern part of the mining field in Orońsko (R. Schild's and K. Kerner-Gubała's observations). Based on macroscopic features, several preliminary conclusions can be drawn, partially confirming previous assumptions regarding the import of chocolate flint from the Orońsko region.

Observation of chocolate flint using a scanning electron microscope (SEM) and analysis of EDS spectra

The flint samples were imaged using scanning electron microscopy (SEM) and analysed for mineral composition (see *Fig. 4*). Several mineral phases were identified in the Orońsko flint. Barite was found in samples FLINT 1 and FLINT 6, while clusters of clay minerals were also present in these samples. Sample FLINT 2 contained calcite. Rutile



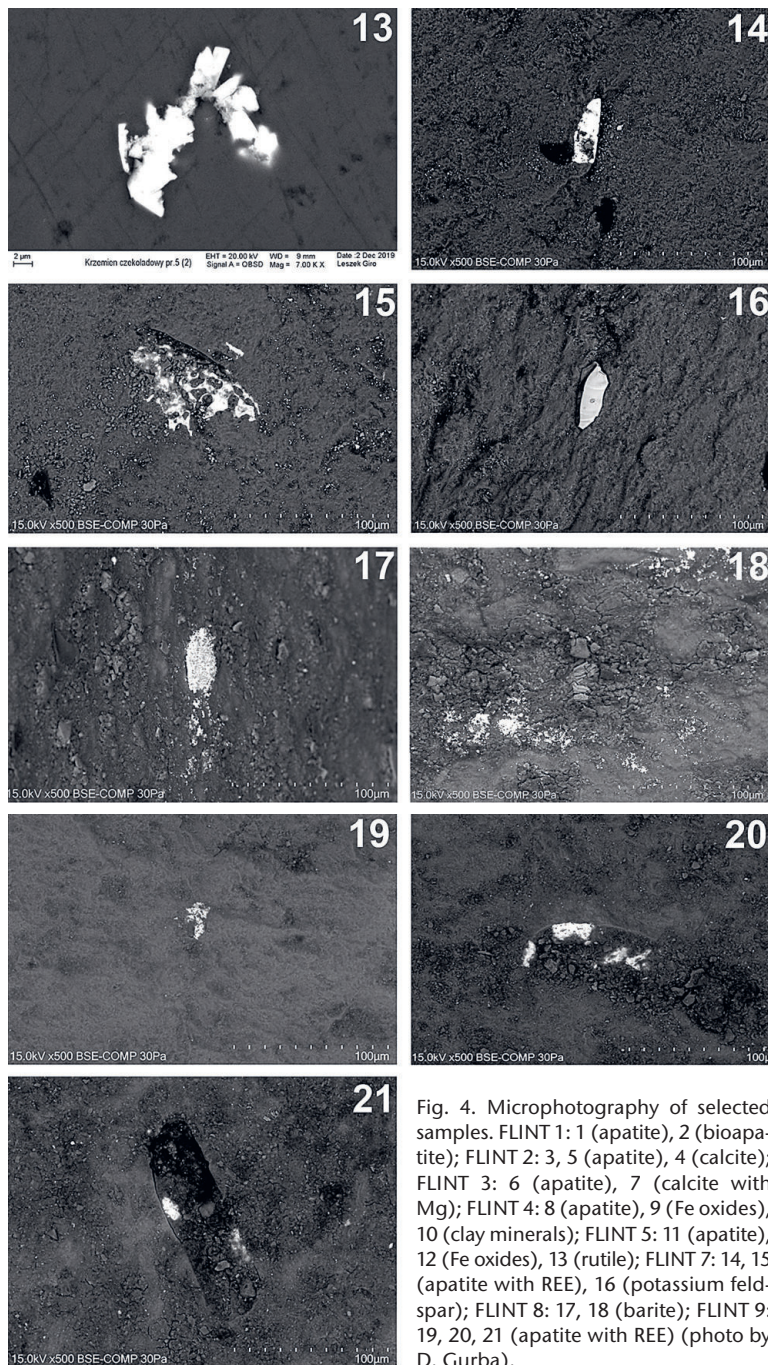


Fig. 4. Microphotography of selected samples. FLINT 1: 1 (apatite), 2 (bioapatite); FLINT 2: 3, 5 (apatite), 4 (calcite); FLINT 3: 6 (apatite), 7 (calcite with Mg); FLINT 4: 8 (apatite), 9 (Fe oxides), 10 (clay minerals); FLINT 5: 11 (apatite), 12 (Fe oxides), 13 (rutile); FLINT 7: 14, 15 (apatite with REE), 16 (potassium feldspar); FLINT 8: 17, 18 (barite); FLINT 9: 19, 20, 21 (apatite with REE) (photo by D. Gurba).

was identified in samples FLINT 3, FLINT 4, and FLINT 5; iron oxides were found in samples FLINT 2, FLINT 4, FLINT 5, and FLINT 6. Additionally, bioapatite was detected as tiny inclusions in all samples from the mine (primary layer).

The polished samples, FLINT 4 and FLINT 5, were examined in different orientations: FLINT 4 was cut parallel to the microlayer and is partially foliated, showing inclusions of clay minerals, iron oxides (in aggregates), rutile, and apatite. The Back Scattered Electron (BSE) image of sample FLINT 5 revealed silica microveins, indicative of quartz recrystallisation. This sample also contained bioapatite, very fine iron oxides or iron hydroxides, rutile, and aggregates of iron and rutile oxides. The samples from the OTP workshop in the Rydno complex (FLINT 8 and FLINT 9) exhibited inclusions of aluminosilicates, iron oxides, and clay minerals. In the sample from the ABP workshop (Rydno X / 1959, No. FLINT 10), rutile and barite were documented. Feldspar was identified in sample FLINT 7 from the Całowanie site (ABP).

Characteristics of pigments from Orońsko and Rydno

The deposits of Rydno quarry

At Rydno the pigment was obtained from natural layers in the form of gravels, sand, or larger plastic elements such as clays. They are composed of hematite and lepidocrocite, as primary works have shown (comp. *Hensel 2011*, 407). The samples chosen for analysis were taken from the well-dated mining pits in trench I/77. The colour of the selected samples is red, with most of them being dark red in hue (*Fig. 3*). The samples were taken from a conglomerate bed consisting of gravel, including quartz, pebbles, hematite, chert, and sandstone in clay. This conglomerate lies on the slope between variegated sandstone of the Upper Raethian of the Triassic period. The conglomerate is formed from eroded deposits of older sediments (*Schild et al. 2011*, 55).

Orońsko mining shafts and clays from the immediate vicinity

Pigments from Orońsko consist of two distinct varieties. One was found in the shafts near the charcoals, suggesting the presence of fire. This material was likely composed of natural clay sediments with a significant iron content. Through fire treatment and dehydration, it changed to darker tones, resulting in a hue that can be described as light red to orange (*Fig. 3*). The second variety present in Orońsko is a natural clay component that exhibits a darker orange colour. This variant is also found in natural clay deposits.

Macroscopic description of ochre

The samples chosen for the SEM-EDS research displayed a variety of characteristics. The sample from Orońsko shaft 1 (OCHRE 7) was a pale orange colour and had a lump form that could easily be crumbled in the hand. In contrast, the samples from Orońsko shaft 6 (OCHRE 1, OCHRE 8) were of a dark orange hue, also in lump form, but these contained visible grains that could be observed macroscopically. The sample from the Rydno complex (OCHRE 2, OCHRE 3, and OCHRE 9) was dark red and came in stable lumps, also with discernible grains.

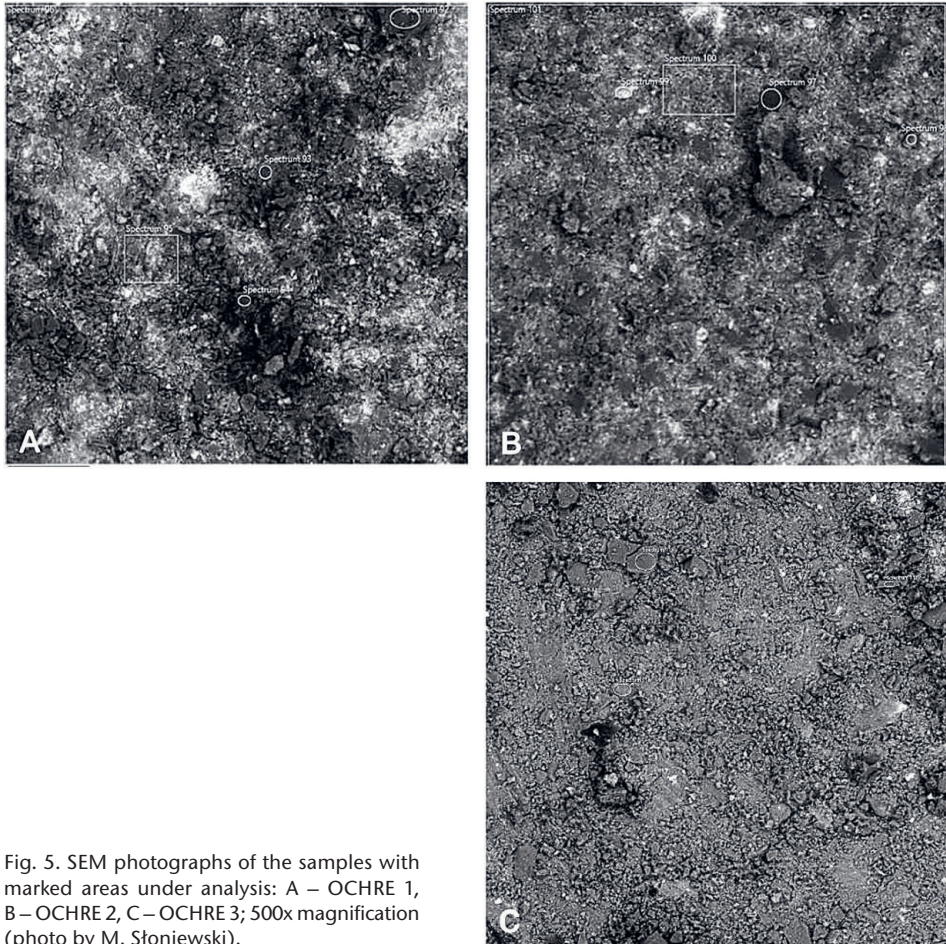


Fig. 5. SEM photographs of the samples with marked areas under analysis: A – OCHRE 1, B – OCHRE 2, C – OCHRE 3; 500x magnification (photo by M. Stoniewski).

SEM-EDS analyses of red material samples

The results obtained for samples OCHRE 1–OCHRE 3 were notably distinct (*Tab. 2; Fig. 5*). Each sample exhibited a relatively high mass percentage of silica oxide, with the highest recorded for the OCHRE 1 sample at 81.2 wt%. A significant distinguishing factor was the iron oxide content: OCHRE 1 ranged from 3.65 wt% to 4.08 wt%, OCHRE 2 from 27.42 wt% to 28.42 wt%, and OCHRE 3 from 38.16 wt% to 39.58 wt%. Additionally, the calcium oxide content was higher in OCHRE 1 (4.33–4.36 wt%) compared to the other two samples. The flint artefact displaying visible red staining (OCHRE 4, *Tab. 3*) showed typical elements found in cherts. A slight discrepancy was noted in the Fe_2O_3 levels between sections with macroscopically observable staining (OCHRE 4-1 and OCHRE 4-2) and those devoid of a red coating (OCHRE 4-3 and OCHRE 4-4). It appears that the red coating was not thick enough to be analysed using the selected method, especially without an additional conductive coating. Upon closer examination of areas with a greater accumulation of red material at higher magnifications, elevated levels of iron oxides were present

No		Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	SO ₃	K ₂ O	CaO	TiO ₂	Fe ₂ O ₃	Cr ₂ O ₃	NiO	MnO
OCHRE 1	Oxide %	0.45	0.49	7.11	80.44	0.34	1.61	4.33	0.52	4.08	x	0.47	0.16
	Oxide % Sigma	0.03	0.03	0.06	0.16	0.04	0.03	0.05	0.04	0.07	x	0.05	0.04
OCHRE 1	Oxide %	0.45	0.51	7.25	81.29	0.3	1.62	4.36	0.46	3.65	x	x	0.11
	Oxide % Sigma	0.03	0.03	0.05	0.14	0.04	0.03	0.04	0.04	0.06	x	x	0.03
OCHRE 2	Oxide %	0.17	0.32	13.7	56.24	0.3	0.95	0.42	0.47	27.42	x	x	x
	Oxide % Sigma	0.05	0.05	0.11	0.2	0.06	0.04	0.04	0.05	0.17	x	x	x
OCHRE 2	Oxide %	0.17	0.3	12.53	56.17	0.27	0.89	0.43	0.47	28.42	0.14	0.21	x
	Oxide % Sigma	0.03	0.03	0.07	0.14	0.04	0.02	0.03	0.04	0.12	0.03	0.05	x
OCHRE 3	Oxide %	x	0.21	4.84	54.6	x	0.46	x	0.32	39.58	x	x	x
	Oxide % Sigma	x	0.04	0.07	0.18	x	0.03	x	0.05	0.16	x	x	x
OCHRE 3	Oxide %	x	x	4.95	55.92	0.15	0.45	0.11	0.26	38.16	x	x	x
	Oxide % Sigma	x	x	0.06	0.16	0.04	0.02	0.03	0.04	0.14	x	x	x

Tab. 2. The outcomes of the EDS analyses of samples OCHRE1 to 3. These samples were grounded and pressed and analysed without coating of conductive layers.

OCHRE4	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	NiO
Ochre4-1	-	-	4.80	93.39	-	-	-	0.56	-	-	1.25	-
Ochre4-2	-	0.26	4.94	92.95	-	-	-	0.57	-	-	1.28	-
Ochre4-3	-	-	3.26	95.68	-	-	-	0.32	-	-	0.74	-
Ochre4-4	-	-	3.28	95.79	-	-	-	0.27	-	-	0.66	-
Ochre4-5	-	0.39	6.71	67.67	0.19	0.59	0.72	16.23	0.56	0.20	6.56	0.19
Ochre4-6	0.21	1.07	13.8	63.31	0.34	0.39	2.07	3.63	1.19	0.11	13.87	-
Ochre4-7	0.21	1.09	13.77	58.90	0.39	0.39	2.13	4.09	1.56	0.12	17.36	-

Tab. 3. Results of EDS analyses of the OCHRE 4 sample. Ochre 4-1 and Ochre 4-2 were taken on parts of the artefact with visible red traces, Ochre 4-3 and Ochre 4-4 were taken on the surface without visible red staining, Ochre 4-5 to Ochre 4-7 were taken on restricted areas with observed macroscopically accumulations of red material.

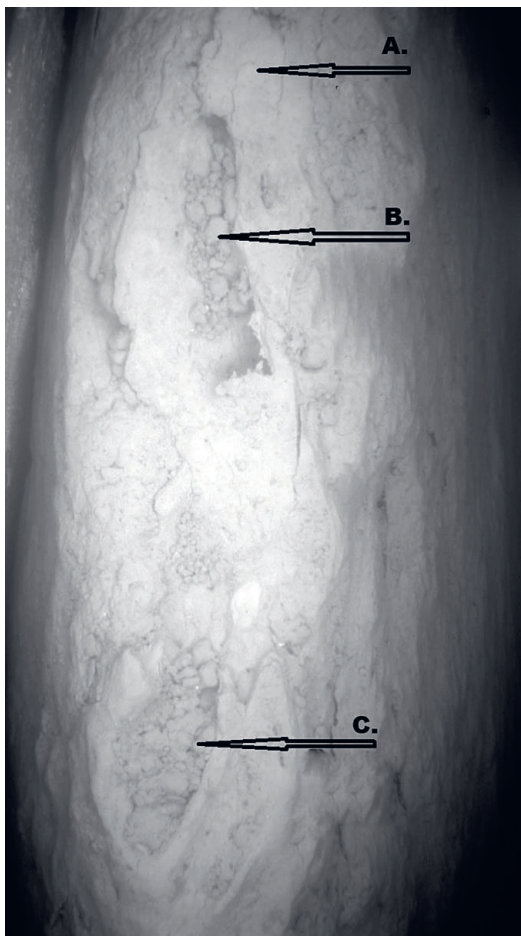
OCHRE 5	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	K ₂ O	CaO	TiO ₂	Fe ₂ O ₃
Ochre5-1	0.31	0.78	7.87	42.67	6.44	1.02	35.31	1.00	4.61
Ochre5-2	-	1.59	6.25	48.42	4.35	0.81	34.59	0.50	3.48
Ochre5-3	-	1.19	5.26	14.60	20.41	0.52	54.91	0.55	2.55
Ochre5-4	0.39	1.17	6.21	15.54	21.72	0.62	51.81	-	2.54
Ochre5-5	0.34	1.15	7.15	17.90	18.85	0.74	51.35	-	2.51

Tab. 4. The EDS results taken on the bone tool OCHRE 5. Ochre 5-1 and Ochre 5-2 were taken on the surface visibly stained with red pigments, Ochre 5-3 was taken on flat surface without distinctive staining, Ochre 5-4 and Ochre 5-5 were taken on the distal end of the tool without visible red staining.

OCHRE 6	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	K ₂ O	CaO	TiO ₂	Fe ₂ O ₃
Ochre6-1	1.02	10.57	37.64	0.46	1.30	42.90	0.60	5.50
Ochre6-2	0.99	9.43	36.29	0.45	1.22	45.88	0.66	5.09
Ochre6-3	1.06	9.02	32.77	-	1.21	50.22	0.67	5.06

Tab. 5. The EDS results taken on the OCHRE 6 sample, which was a piece of limestone with red stains. The analyses were done on the spots with clearly observable red traces.

Fig. 6. Occurrence of iron on the surface of analysed the OCHRE 4 sample with macroscopically observable red coating: A – point without red pigment, B – pit 1, C – pit 2 (photo by M. Słoniewski).



(OCHRE 4-5 to OCHRE 4-7, *Tab. 3*). Sample OCHRE 4 was additionally analysed a second time after pulverisation with a carbon layer, allowing for the creation of elemental distribution maps on the surface of the artefact (*Fig. 6*). The red staining appeared to be of a discontinuous nature, with larger accumulations observed in the material's bends. Further analyses were conducted on a bone tool identified as sample OCHRE 5 (*Fig. 7; Tab. 4*). Notably, the results for OCHRE 5-3 to OCHRE 5-5 showed significantly elevated levels of calcium oxide and phosphorus oxide, alongside reduced silica oxide levels. These findings should be interpreted as representative of the bone material. Conversely, the results for OCHRE 5-1 and OCHRE 5-2 exhibited notably higher levels of SiO_2 and Fe_2O_3 , attributed to the red staining on the surface. However, due to the persistence of notable P_2O_5 and CaO levels, these results should be understood as representative of both the staining and the background material. The OCHRE 6 limestone fragment was also visibly coated with a rusty-red layer. The outcomes indicated iron oxides at levels exceeding 5.00 wt%, likely linked to the observed surface hue (*Tab. 5*). Samples OCHRE 7 to OCHRE 9 were analysed meticulously, with an examination of the various portions of the sample surfaces.

Analysis no	Si	Ti	Al	Fe	Mg	Ca	K
Oro1-1 (24)	44.05	0.00	8.71	5.91	1.04	37.95	2.34
Oro1-2 (25)	17.86	0.00	3.78	2.63	1.01	74.71	0.00
Oro1-3 (26)	9.88	0.00	4.22	2.66	0.67	82.57	0.00
Oro1-4 (27)	86.37	0.00	2.48	1.33	0.00	9.82	0.00
Oro1-5 (28)	34.35	0.00	7.45	4.26	1.06	51.30	1.58
Oro1-6 (29)	55.83	0.56	14.16	7.04	1.76	17.20	3.45
Oro1-7 (30)	85.15	0.00	7.03	2.99	0.95	2.62	1.28
Oro1-8 (31)	58.53	0.00	7.40	3.75	1.23	27.63	1.45
Oro1-9 (32)	27.84	0.00	9.20	14.15	1.47	45.47	1.86
Oro1-10 (35)	8.73	0.00	4.08	2.55	1.41	83.22	0.00
Oro1-11 (36)	9.56	0.00	4.14	2.98	0.85	82.47	0.00
Oro1-12 (37)	10.23	0.00	3.81	4.32	0.68	79.98	0.98

Tab. 6. EDS results of the OCHRE 7 sample with excluded carbon (due to the pulverisation with carbon dust) and oxygen (due to insufficient sensitivity of the equipment). Presented in wt%.

Analysis no	Si	Ti	Al	Fe	Mg	Ca	K	Na	S
Oro2-1 (38)	29.21	0.67	11.61	9.05	1.23	45.49	2.28	0.00	0.45
Oro2-2 (39)	54.21	0.97	22.57	13.05	2.24	2.83	4.14	0.00	0.00
Oro2-3 (40)	55.98	0.97	19.32	14.27	1.89	3.84	3.73	0.00	0.00
Oro2-4 (41)	63.28	0.76	16.69	10.62	1.73	2.78	3.28	0.56	0.31
Oro2-5 (42)	36.62	1.33	15.99	37.76	1.93	2.90	3.47	0.00	0.00
Oro2-6 (43)	69.27	0.59	15.43	8.94	1.62	1.60	2.53	0.00	0.00
Oro2-7 (44)	58.83	0.75	20.10	10.97	2.04	3.79	3.23	0.00	0.29
Oro2-8 (45)	71.40	0.46	15.07	7.91	1.59	1.49	2.07	0.00	0.00
Oro2-9 (46)	9.49	0.00	4.48	2.84	0.55	82.63	0.00	0.00	0.00
Oro2-10 (47)	99.27	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00
Oro2-11 (48)	93.18	0.00	3.62	1.96	0.51	0.25	0.48	0.00	0.00
Oro2-12 (49)	15.49	0.00	5.81	3.92	0.71	72.76	0.97	0.00	0.34
Oro2-13 (50)	63.94	1.12	19.02	8.99	2.33	1.68	2.92	0.00	0.00
Oro2-14 (51)	42.49	1.85	16.09	29.04	1.57	3.40	5.32	0.00	0.25
Oro2-15 (52)	49.49	0.94	25.08	14.41	2.12	4.59	3.37	0.00	0.00

Tab. 7. EDS results of the OCHRE 8 sample with excluded carbon (due to the pulverisation with carbon dust) and oxygen (due to insufficient sensitivity of the equipment). Presented in wt%.

Analysis no	Si	Ti	Al	Fe	Mg	Ca	K	Na
Ryd1-1 (53)	36.17	0.52	13.38	48.18	0.00	0.30	1.44	0.00
Ryd1-2 (54)	34.81	0.72	15.24	47.16	0.00	0.42	1.64	0.00
Ryd1-3 (55)	35.71	0.62	15.76	45.95	0.00	0.47	1.48	0.00
Ryd1-4 (56)	32.48	0.62	16.28	47.82	0.70	0.88	1.22	0.00
Ryd1-5 (57)	29.18	0.94	14.43	52.77	0.50	0.00	1.72	0.46
Ryd1-6 (58)	74.45	0.00	4.38	20.50	0.00	0.00	0.66	0.00
Ryd1-7 (59)	69.00	0.00	5.30	25.09	0.00	0.00	0.61	0.00
Ryd1-8 (60)	38.40	0.50	17.25	41.58	0.40	0.83	1.05	0.00
Ryd1-9 (61)	27.28	0.55	17.41	52.85	0.00	0.57	1.33	0.00
Ryd1-10 (62)	31.77	0.58	17.52	48.83	0.00	0.00	1.30	0.00
Ryd1-11 (63)	90.89	0.00	1.43	7.45	0.00	0.00	0.23	0.00
Ryd1-12 (64)	34.88	0.48	19.59	44.29	0.00	0.00	0.77	0.00

Tab. 8. EDS results of the OCHRE 9 sample with excluded carbon (due to the pulverisation with carbon dust) and oxygen (due to insufficient sensitivity of the equipment). That sample presents a notably lower amount of calcium, followed by relatively high outcomes for iron. Presented in wt%.

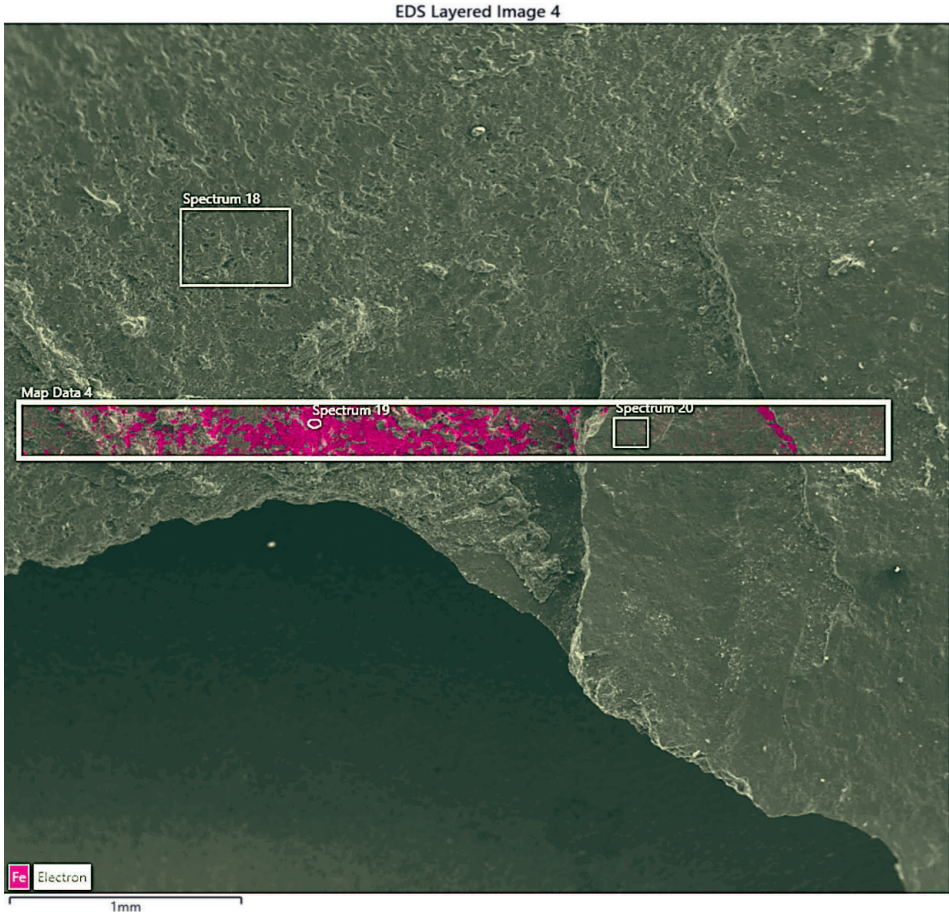


Fig. 7. Photography of the bone tool, named OCHRE 5, with traces of red pigments. Arrows point to spots of conducting EDS analyses (photo by M. Słoniewski).

The OCHRE 7 and OCHRE 9 specimens each received 12 individual EDS analyses, while OCHRE 8 received 15 analyses. The results were presented as weight percentages for each element. For the OCHRE 7 sample, the iron content was relatively low, with an average value of 4.55 wt%. The most abundant elements were calcium, averaging 49.58 wt%, followed by silica at 37.36 wt% and aluminium at 6.37wt%. The remaining components – magnesium, potassium, and titanium – averaged around 1.00 wt% or below that level (*Tab. 6; Fig. 8*). The OCHRE 8 sample showed a higher iron content, averaging 11.58 wt%. In addition, silica (54.14 wt% on average), calcium (15.34 wt% on average), and aluminium (14.11 wt% on average) were the major components. Other elements, including titanium, potassium, sulphur, magnesium, and sodium, were noted at average levels below 3.00 wt% (*Tab. 7; Fig. 8*). The last sample, OCHRE 9, was significantly enriched with iron, showing an average outcome of 40.20 wt%. Silica, at an average level of 44.59 wt%, and aluminium, at 13.16 wt%, were also abundant, while the remaining recognised elements presented mean values below 1.20 wt% (*Tab. 8; Fig. 10*).

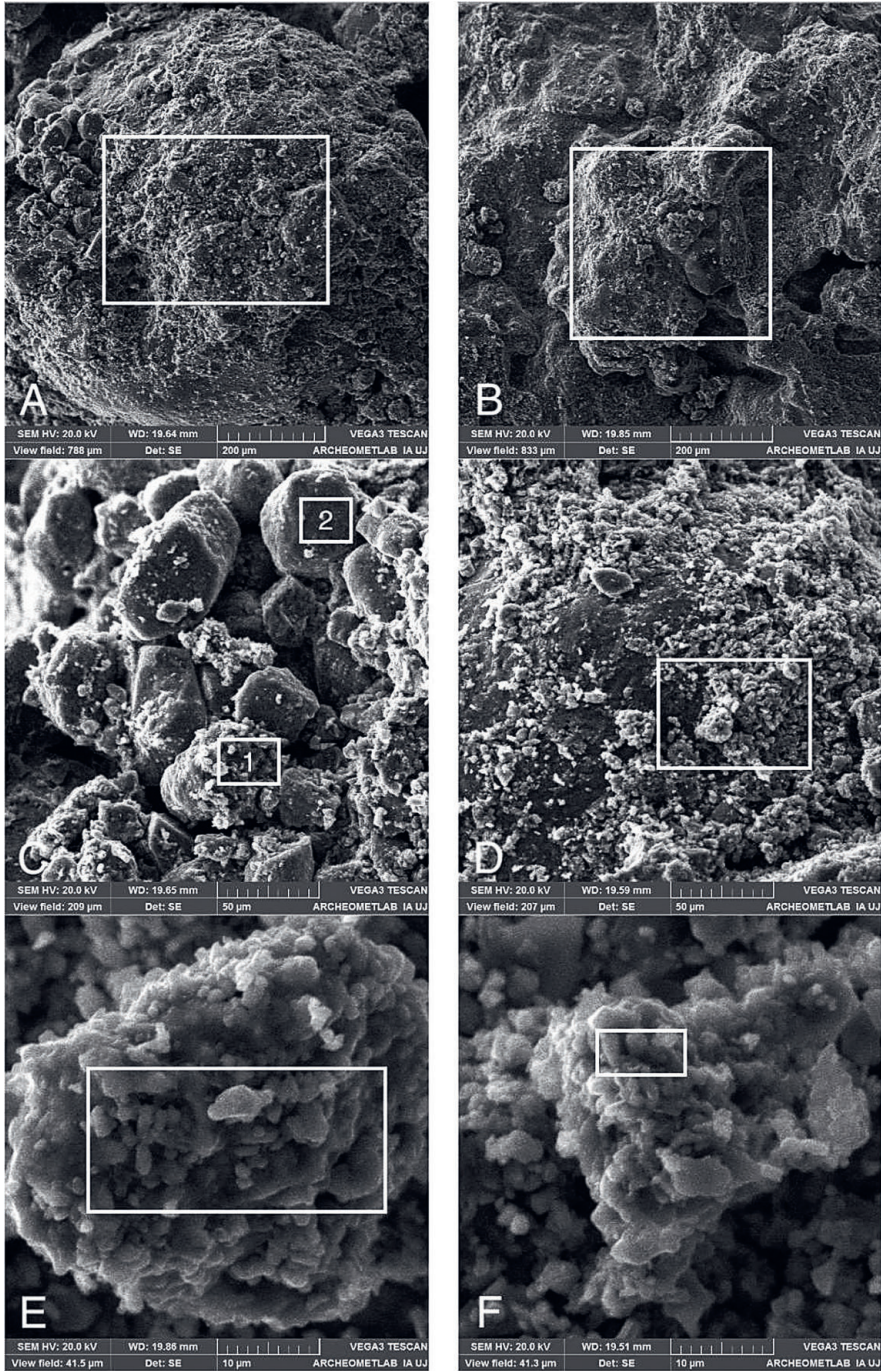


Fig. 8. The SEM microphotographs of the OCHRE 7 sample with marked spots of analyses. A – analysis Oro1-1; B – analysis Oro1-2; C – analysis Oro1-6 (point 1) and Oro1-7 (point 2); D – analysis Oro1-5; E – analysis Oro1-12; F – analysis Oro1-10 (photo by J. Kościuk-Zatupka).

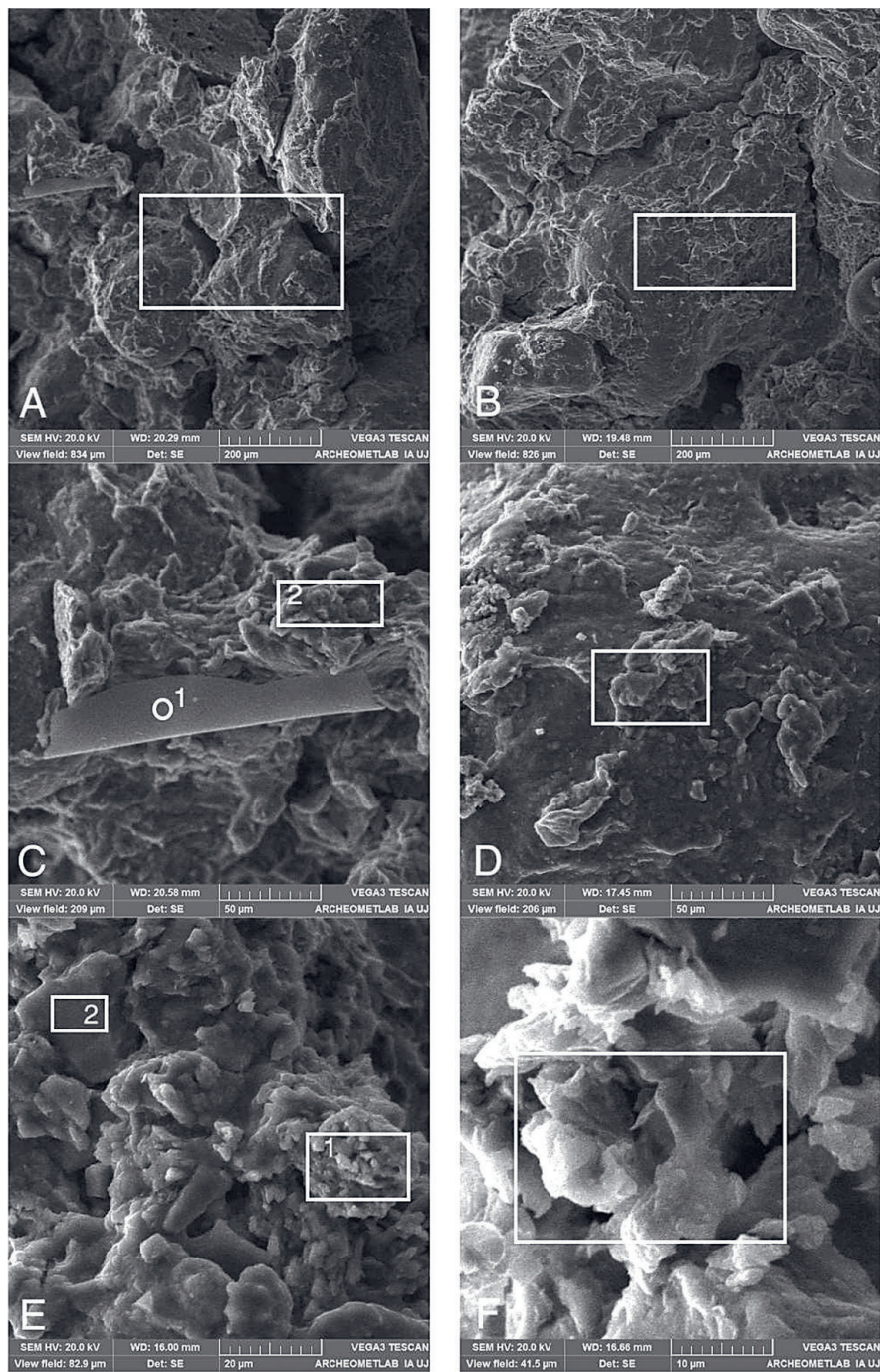


Fig. 9. The SEM microphotographs of the OCHRE 8 sample. with marked spots of analyses. A – analysis Oro2-3; B – analysis Oro2-2; C – analysis Oro2-5 (point 1) and Oro2-6 (point 2); D – analysis Oro2-7; E – analysis Oro2-9 (point 1) and Oro2-10 (point 2); F – analysis Oro2-14 (photo by J. Kościuk-Załużka).

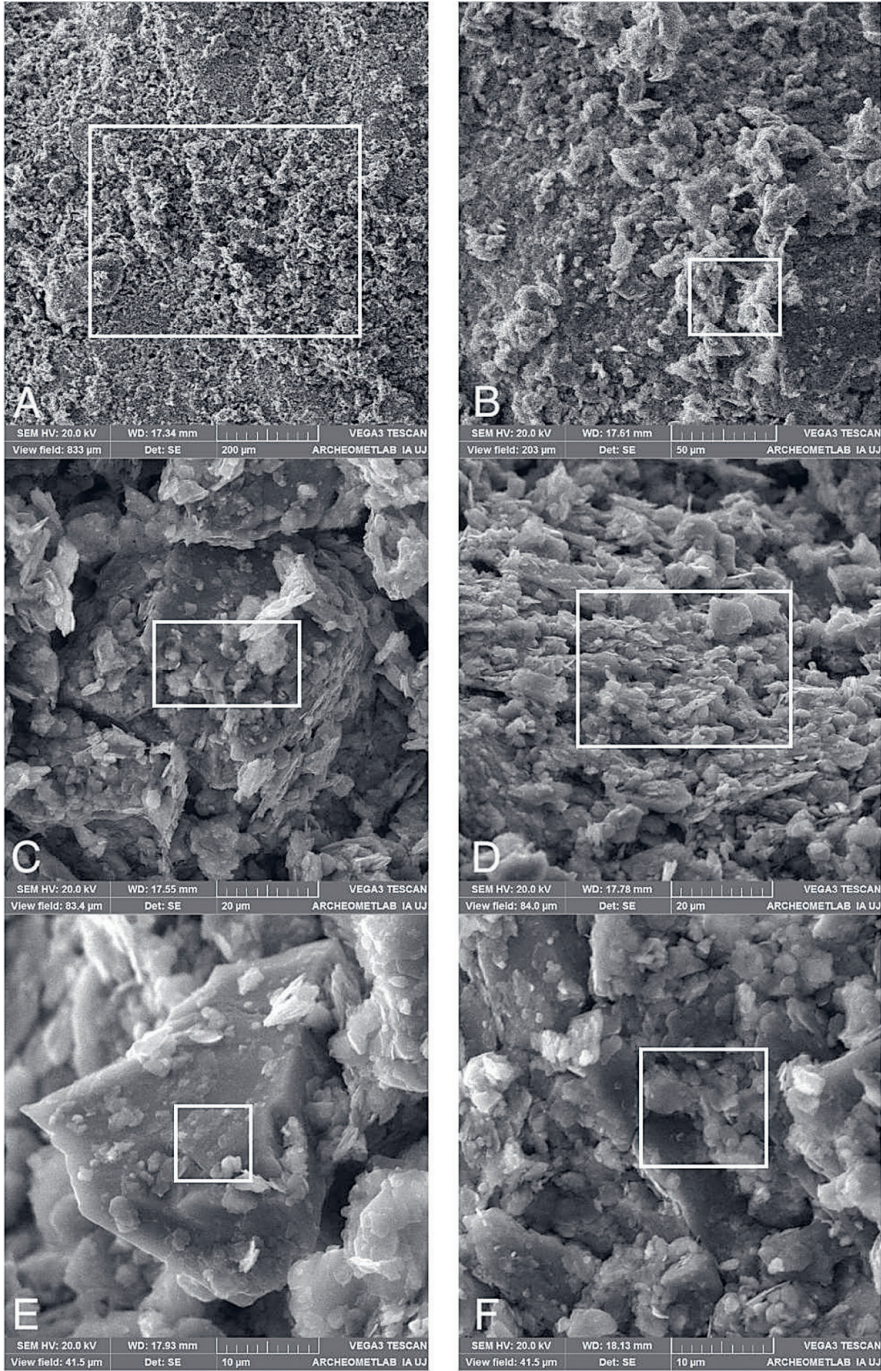


Fig. 10. The SEM microphotographs of the OCHRE 9 sample, with marked spots of analyses. A – analysis Ryd1-2; B – analysis Ryd1-4; C – analysis Ryd1-7; D – analysis Ryd1-9; E – analysis Ryd1-11; F – analysis Ryd1-12 (photo by J. Kościuk-Zatupka).

Discussion

Chocolate flint

We made an initial attempt to characterise the flint from the northernmost part of the chocolate flint deposits and to compare it with the earlier published results on this subject (see *Hensel 2011; Werra – Siuda 2015; Brandl et al. 2016; Hughes et al. 2016; Sobkowiak-Tabaka et al. 2016*). The material was initially identified by its light hue, which included a range of grey and light brown shades featuring characteristic streaking, delicate lighter streaks, or smaller, more expressive spots of varying sizes and intensities. Most specimens were concentrated in the Orońsko area, and they were primarily classified into groups V, VI, VII, and IX. Additionally, darker specimens were identified, lacking additional characteristic grey stripes and displaying hues of brown, dark brown, and dark brown-grey. However, macroscopic characteristics alone cannot definitively identify the source of specific raw materials. Therefore, an effort was made to compare the specimens – especially those from Orońsko – with samples from more distant sites based on their elemental and mineral constituents using SEM-EDS equipment. The results showed the presence of apatite in each analysed sample, which was noteworthy. Furthermore, the samples contained rutile, barite, iron oxides, and clusters of clay minerals. The analysis of the chemical composition of chocolate flint in the micro-area has revealed the presence of hematite, pyrite, gypsum, barite, calcite, rutile, ilmenite, zircon, monazite, churchite, and apatite. According to previously published data, hematite, barite, and pyrite were the most common minerals, with apatite now considered a probable determinant of chocolate flint (see *Werra – Siuda 2015*), as observed in the samples described in this article. It is important to note that the elements responsible for the colour (Cr, Mn, Fe, Ni) may not be useful for distinguishing the sources of the raw material (*Brandl et al. 2016, 130*). Conversely, the results of the EDXRF analysis of chocolate flint from the modern quarry in Wierzbica (published elsewhere, e.g. *Hughes et al. 2016*) revealed discrepancies in these component proportions when compared to specimens from mining shafts at varying stratigraphic positions. The presence of pyrite also indicated this differentiation (*Hughes et al. 2016, 109*). In other previous studies on chocolate flint (*Brandl et al. 2016*), the combination of various components revealed that the calcium content among samples in Orońsko and Tomaszów was low, while the aluminium content was high (*Brandl et al. 2016, 144*). Analyses conducted on samples of other varieties of flints, including erratic flint, indicated differentiation among the samples based on the calcium versus iron elements (*Sobkowiak-Tabaka et al. 2016*). This approach appears to be a promising method for future research, including the analysis of the distribution of chocolate flint from the Orońsko mine during the Palaeolithic.

Red materials

In the analysis of ochre, several key points should be emphasised. The first issue concerns the comparison of the samples. Initial assessments indicate that the samples from the Rydno site (OCHRE 2, OCHRE 3, and OCHRE 9) show increased levels of iron and iron oxides, particularly when compared to the specimens collected at Orońsko. In contrast, the samples from the shafts in Orońsko (OCHRE 1, OCHRE 7, and OCHRE 8) exhibit higher calcium and calcium oxide levels. These differences may serve as distinctive features that allow for preliminary differentiation between the sets of samples from these two

locations. Additionally, three items with visible ochre stains were analysed: a flint flake (OCHRE 4), a bone tool (OCHRE 5), and a limestone fragment (OCHRE 6). In these cases, the results for the underlying background material influenced the outcomes (e.g., elevated P_2O_5 in OCHRE 5), complicating the analysis of the red material. Nonetheless, the red stains showed elevated levels of iron and iron oxides compared to the background materials, validating their identification as ochre traces. Another noteworthy observation is that despite using various analytical modes and presenting outcomes as elemental or oxide compositions, the initially observed trends remained consistent. This consistency allows for the comparison of results derived from different laboratories and presented in various formats, which is particularly useful for pigment analysis and provenance studies. These observations suggest a preliminary hypothesis that the pigments were not transported from Rydno to Orońsko, at least not during the Late Palaeolithic period of occupation in the Orońsko mine area. More samples must be analysed with various techniques and better resolution to compare minor and trace elements. This would facilitate a more detailed characterisation, potentially revealing additional distinguishing features.

Conclusion

The ongoing research into the provenance of raw materials is yielding results by comparing various siliceous raw materials using a combination of macro- and microscopic techniques. Preliminary conclusions can be drawn based on the macroscopic features of the chocolate flint samples from the analysed sites, partially confirming earlier assumptions about the export of chocolate flint from the Orońsko region. Further studies will continue using a broader range of analytical methods and a larger number of samples from the chocolate flint mine in Orońsko and other sites dated to the same period but located away from the chocolate flint deposits in the northern slope of the Świętokrzyskie Mountains, as well as the Cracow-Częstochowa Upland (Krajcarz *et al.* 2012; Sudot-Procyk 2022; Mandera *et al.* 2024). Regarding flint, it has been suggested that some of it could have been transported to Rydno or Całowanie from mining areas in or near Orońsko. Also, some of the results of red pigment analysis from Całowanie has shown some similarities with the Rydno quarry (Hensel 2011, 407), indicating a close relationship between these communities. In contrast, the reverse transport of ochre from Rydno to Orońsko remains unclear. The SEM-EDS analysis of red pigments showed no similarity to the samples of ochre taken from the Rydno mine, which was proposed initially as the original source. It is possible that communities in the Orońsko mining area used local red pigments during the Palaeolithic, despite direct contact with societies inhabiting the Rydno and Całowanie sites, which may be inferred from the similarity of the flints. Further research with the use of particular chemical and geological methods will certainly help to confirm or refute this hypothesis.

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References

- Brandl, M. – Hauzenberger, C. – Martinez, M. M. – Filzmoser, P. – Werra, D. H. 2016: The Application of the Multi-Layered Chert Sourcing Approach (MLA) for the Characterisation and Differentiation of 'Chocolate Silicites' from the Holy Cross Mountains, South-Central Poland. *Archaeologia Austriaca* 100, 119–150. <https://doi.org/10.1553/archaeologia100s119>
- Budziszewski, J. 2008: Stan badań nad występowaniem i prądziejową eksploatacją krzemieni czekoladowych. In: W. Borkowski – J. Libera – B. Sałacińska – S. Sałaciński (eds.), *Krzemień czekoladowy w prądziejach. Materiały z konferencji w Orońsku, 08–10.10.2003. Studia nad gospodarką surowcami krzemiennymi w prądziejach 7*. Warszawa–Lublin: Państwowe Muzeum Archeologiczne, 33–106.
- Chmielewska, M. 1988: The early Bronze age flint mine at site II, Polany, Radom district. *Przegląd Archeologiczny* 35, 139–181.
- Fiers, G. – Halbrucker, E. – Kock De, T. – Laforce, B. – Vandendriessche, H. – Messiaen, L. – Vincze, L. – Crombe, P. – Cnudde, V. 2019: Preliminary characterization of flint raw material used on prehistoric sites in NW Belgium. *Geoarchaeology* 34, 400–412. <https://doi.org/10.1002/gea.21719>
- Grafka, O. – Werra, D. H. – Siuda, R. 2015: Analysis of Organic Compounds: Applications in Archaeology and Earth Science. *Litikum* 3, 26–37. <https://doi.org/10.23898/litikuma0010>
- Gutowski, J. 1998: Oxfordian and Kimmeridgian of the northeastern margin of the Holy Cross Mountains, Central Poland. *Geological Quarterly* 42, 59–72.
- Hensel, Z. 2011: Physical and chemical examination of hematite gravel from Rydno quarry. In: R. Schild – H. Królik – A. J. Tomaszewski – E. Ciepiewska (eds.), *Rydno, a Stone Age red ochre quarry and socio-economic center. A century of research*. Warszawa: Instytut Archeologii i Etnologii Polskiej Akademii Nauk, 405–408.
- Herbich, T. – Lech, J. 1995: PL 5 Polany II, Radom Province. *Archaeologia Polona* 33, 488–506.
- Högberg, A. – Olausson, D. – Hughes, R. 2012: Many Different Types of Scandinavian Flint: Visual Classification and Energy Dispersive X-ray Fluorescence. *Fornvännen* 107, 225–240.
- Hughes, R. E. – Baltrūnas, V. – Kulbickas, D. 2011: Comparison of two analytical methods for the chemical characterization of flint from Lithuania and Belarus. *Geologija* 53, 69–74. <https://doi.org/10.6001/geologija.v53i2.1850>
- Hughes, R. E. – Högberg, A. – Olausson, D. 2010: Sourcing flint from Sweden and Denmark. A pilot study employing non-destructive energy dispersive X-ray fluorescence spectrometry. *Journal of Nordic Archaeological Science* 17, 15–25.
- Hughes, R. – Werra, D. H. – Siuda, R. 2016: On the Chemical Composition of 'Chocolate' Flint from Central Poland. *Archaeologia Polona* 54, 99–114.
- Keneder-Gubata, K. 2019: In search of the chocolate flint mine in Orońsko (PL1, Southern Poland): New data for analysis of exploitation and use of flint in north-western part of its outcrops. *Anthropologica et Præhistorica* 128, 199–208.
- Kozłowski, S. K. 2008: Legenda Orońska. In: W. Borkowski – J. Libera – B. Sałacińska – S. Sałaciński (eds.), *Krzemień czekoladowy w prądziejach. Materiały z konferencji w Orońsku, 08–10.10.2003. Studia nad gospodarką surowcami krzemiennymi w prądziejach 7*. Warszawa – Lublin: Państwowe Muzeum Archeologiczne, 25–32.
- Krajcarz, M. T. – Krajcarz, M. – Sudol, M. – Cyrek, K. 2012: From far of from near? Sources of Kraków-Częstochowa banded and chocolate silicate raw material used during the stone age in Biśnik Cave (Southern Poland). *Anthropologie* 50, 411–425.
- Krukowski, S. 1922: Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski, cz. II. *Wiadomości Archeologiczne* 7, 34–57.
- Krukowski, S. 1923: Sprawozdania z działalności Państwowego Konserwatora Zabytków Prahistorycznych na okręg kielecki na rok 1922. *Wiadomości Archeologiczne* 8, 69–70.
- Krukowski, S. 1939–1948: Paleolit. In: *Encyklopedia polska PAU. Prehistoria ziem polskich 4*. Kraków: Polska Akademia Umiejętności, 1–117.
- Lech, H. – Lech, J. 1984: The prehistoric flint mine at Wierzbica 'Zełe': a case study from Poland. *World Archaeology* 16, 190–208.
- Lech, J. – Werra, D. H. 2019: The flint mine site Wierzbica 'Zełe' (Poland) and Bronze Age workshop materials after forty years of new research (1979–2018). *Anthropologica et Præhistorica* 128, 85–100.

- Mandera, S. – Sudoł-Procyk, M. – Malak, M. – Skrzatek, M. – Krajcarz, M. T. 2024: New deposit of chocolate flint in Załęże gully (Kraków-Częstochowa Upland, Poland) – Raw material characterization and its availability for prehistoric communities. *Journal of Archaeological Science: Reports* 53, 104328. <https://doi.org/10.1016/j.jasrep.2023.104328>
- Matyszkiewicz, J. – Kochman, A. 2020: The provenance of siliceous rocks from the Kraków-Częstochowa Upland (Poland) used as raw-materials in the manufacture of siliceous artefacts from Central-Eastern Europe; An old problem in new light. *Journal of Archaeological Science: Reports* 34, 102600. <https://doi.org/10.1016/j.jasrep.2020.102600>
- Osipowicz, G. – Kernereder-Gubała, K. – Bosiak, M. – Makowiecki, D. – Orłowska, J. 2019: The oldest osseous mining tools in Europe? New discoveries from the chocolate flint mine in Orońsko, site 2 (southern Poland). *Quaternary International* 512, 82–98. <https://doi.org/10.1016/j.quaint.2019.02.005>
- Parish, R. M. – Werra, D. H. 2018: Characterizing “Chocolate” Flint Using Reflectance Spectroscopy. *Archaeologia Polona* 56, 89–101. <https://doi.org/10.23858/APa56.2018.007>
- Příchystal, A. 2013: *Lithic Raw Materials in Prehistoric Times of Eastern Central Europe*. Brno: Masaryk University Press.
- Roldan, C. – Carballo, J. – Murcia, S. – Eixea, A. – Villaverde, V. – Zilhao, J. 2015: Identification of local and allochthonous flint artefacts from the Middle Palaeolithic site ‘Abrigo de la Quebrada’ (Cherva, Valencia, Spain) by macroscopic and physicochemical methods. *X-Ray Spectrom* 44, 209–216. <https://doi.org/10.1002/xrs.2602>
- Samsonowicz, J. 1923: O złożach krzemieni w utworach jurajskich północno-wschodniego zbocza Gór Świętokrzyskich. *Wiadomości Archeologiczne* 8, 17–24.
- Schild, R. 1971: Lokalizacja prahistorycznych punktów eksploatacji krzemienia czekoladowego na północno-wschodnim obrzeżeniu Gór Świętokrzyskich. *Folia Quaternaria* 39, 1–61.
- Schild, R. 1976: Flint mining and trade in Polish prehistory as seen from the perspective of the chocolate flint of central Poland. A second approach. *Acta Archaeologica Carpathica* 16, 147–177.
- Schild, R. 1995a: PL 2 Tomaszów I, Radom Province. *Archaeologia Polona* 33, 455–465.
- Schild, R. 1995b: PL 4 Polany Kolonie II, Radom Province. *Archaeologia Polona* 33, 480–488.
- Schild, R. (ed.) 2014: *Całowanie*. A Final Paleolithic and Early Mesolithic Site on an Island in the ancient Vistula channel. Warszawa: Instytut Archeologii i Etnologii Polskiej Akademii Nauk.
- Schild, R. – Królik, H. – Marczak, M. 1985: Kopalnia krzemienia czekoladowego w Tomaszowie. Wrocław – Warszawa – Kraków: Zakład Narodowy im. Ossolińskich.
- Schild, R. – Królik, H. – Marczak, M. – Mościbrodzka, J. – Hensel, W. 1981: Rydno: a final Paleolithic ochre mining complex. *Przegląd Archeologiczny* 29, 53–100.
- Schild, R. – Królik, H. – Mościbrodzka, J. 1977: Kopalnia krzemienia czekoladowego z przełomu neolitu i epoki brązu w Polanach Koloniach. Wrocław – Warszawa – Kraków: Zakład Narodowy im. Ossolińskich.
- Schild, R. – Królik, H. – Tomaszewski, A. J. – Ciepielewska, E. 2011: Rydno. A Stone Age red ochre quarry and socioeconomic center. A century of research. Warsaw: Instytut Archeologii i Etnologii Polskiej Akademii Nauk.
- Sobkowiak-Tabaka, I. – Werra, D. H. – Hughes, R. E. – Siuda, R. 2016: Erratic Flint from Poland: Preliminary results of petrographic and geochemical analyses. *Archaeologia Polona* 54, 67–82.
- Sudoł-Procyk, M. 2022: One century of studies on chocolate flint. And what do we really know about it ...? *Sprawozdania Archeologiczne* 74, 49–65. <https://doi.org/10.23858/SA/74.2022.1.3012>
- Sudoł-Procyk, M. – Budziszewski, J. – Krajcarz, M. – Jakubczak, M. – Szubski, M. 2018: The Chocolate Flint Mines in the Udorka Valley (Częstochowa Upland) – a Preliminary Report on the Field and Lidar Surveys. In: D. H. Werra – M. Woźny (eds.), *Between History and Archaeology: Papers in honour of Jacek Lech*. Oxford: Archaeopress, 89–102.
- Sulgostowska, Z. 2005: Kontakty społeczności późnopaleolitycznych i mezolitycznych między Odrą, Dźwiną i Górnym Dniestrem. Warszawa: Instytut Archeologii i Etnologii Polskiej Akademii Nauk.
- Sulgostowska, Z. 2008: Szczególna pozycja krzemienia czekoladowego wśród społeczności między Odrą, Dźwiną i Dniestrem u schyłku paleolitu i w późnym mezolocie. In: W. Borkowski – J. Libera – B. Sałacińska – S. Sałaciński (eds.), *Krzemień czekoladowy w pradziejach*. Materiały z konferencji w Orońsku, 08–10.10.2003. *Studia nad gospodarką surowcami krzemieniowymi w pradziejach* 7. Warszawa – Lublin: Państwowe Muzeum Archeologiczne, 151–170.

- Tomaszewski, A. J. – Królik, H. – Ciepielewska, E. – Mańka, D. 2008: Kto inny, kiedy indziej, na drugim brzegu... Różnice w wykorzystywaniu krzemienia czekoladowego w niektórych zespołach późnopalaeolitycznych na Rydnie, In: W. Borkowski – J. Libera – B. Sałacińska – S. Sałaciński (eds.), *Krzemień czekoladowy w pradziejach. Materiały z konferencji w Orońsku, 08–10.10.2003. Studia nad gospodarką surowcami krzemiennymi w pradziejach 7*. Warszawa – Lublin, 379–397.
- Velliky, E. C. – MacDonald, B. L. M. – Porr, M. – Conard, N. J. 2021: First large-scale provenance study of pigments reveals new complex behavioural patterns during the Upper Palaeolithic of south-west Germany. *Archaeometry* 63, 173–193. <https://doi.org/10.1111/arc.12611>
- Weinstein-Evron, M. – Ilani, S. 1994: Provenance of ochre in the Natufian layers of el-Wad cave, Mount Carmel, Israel. *Journal of Archaeological Sciences* 2, 461–467. <https://doi.org/10.1006/jasc.1994.1045>
- Werra, D. H. – Kerneder-Gubala, K. 2021: 'Chocolate' flint mining from Final Palaeolithic up to Early Iron Age – a review. In: F. Bostyn – F. Giligny – P. Topping (eds), *From Mine to User: Production and Procurement Systems of Siliceous Rocks in the European Neolithic and Bronze Age. Proceedings of the XVIII UISPP World Congress (4–9 June 2018, Paris, France). Volume 10. Session XXXIII-1&2*. Oxford: Archaeopress Archaeology, 42–56. <https://doi.org/10.2307/jj.15136049.9>
- Werra, D. H. – Siuda, R. 2015: The mineral composition of 'chocolate' flint compared to other varieties of chert from Central and Southern Poland used by prehistoric communities. In: X. Mangado – O. Crandell – M. Sánchez – M. Cubero (eds), *International Symposium on Knappable Materials 'On the Rocks'*. Barcelona 7–11 September 2015. Abstracts 128. Barcelona: University of Barcelona.
- Werra, D. H. – Siuda, R. 2022: The use of phosphate minerals for determination of the provenance of flint used by prehistoric communities in East-Central Europe. *Quaternary International* 615, 5–17. <https://doi.org/10.1016/j.quaint.2021.04.028>
- Werra, D. H. – Siuda, R. – Grajka, O. – Segit, T. 2015: Pierwsze próby charakterystyki geochemicznej i palinologicznej krzemienia „czekoladowego” z kopalni Wierzbitca „ZeZe”, pow. Radom. *Acta Universitatis Nicolai Copernici, Archaeologia* 34, 249–270.

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RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

Typological and production-technological study of selected finds decorated with the mosaic enamel technique in the 2nd–3rd century AD

Typologická a výrobně-technologická studie vybraných nálezů zdobených technikou mozaikového smaltu ve 2.–3. století n. l.

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The article focuses on a specific group of Roman Period finds from Bohemia with mosaic or millefiori enamel decorations. The study examines various artefacts, including disc fibulae, balteus fittings, glass beads, and a seal box, all identified as Roman-provincial imports. Disc fibulae adorned with millefiori enamel have been discovered throughout the Barbaricum, with notable concentrations in the Tisza and Elbe river regions. Although Roman-provincial circular balteus fittings are less common, recent discoveries in Bohemia have expanded their known distribution. Both fibulae and balteus fittings predominantly date to the period surrounding the Marcomannic Wars and the first half of the 3rd century AD. Glass beads are typical grave goods in women's burials from the Late Roman Period. Mosaic glass beads, though less common, are primarily found in rich female graves dating to the 3rd century AD. A central aim of this study is to investigate and compare the production technologies employed in creating millefiori enamels. To achieve this, analytical methods such as micro-XRF, SEM/EDS, and LA-ICP-MS were utilised to determine the composition of the glass and metal substrates. Additionally, the design of selected glass beads was examined using computed micro-tomography (micro-CT) scanning.

Roman period – millefiori decoration – enamel decoration – fibulae – beads – archaeometric analyses

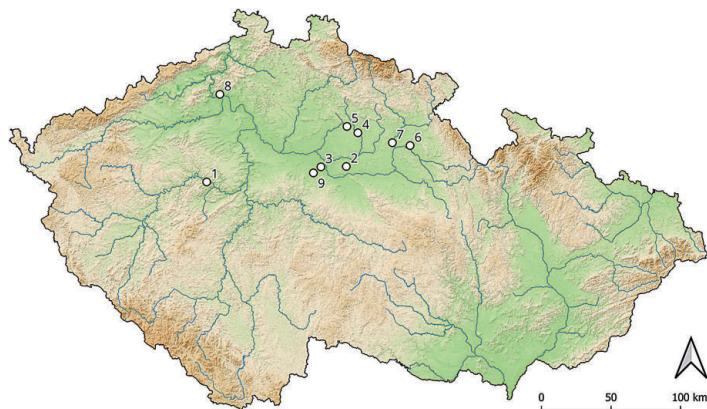
Tento text se zabývá specifickou skupinou nálezů z Čech s výzdobou mozaikového/millefiori emailu nebo skla, které pocházejí z doby římské. Pro účely našeho výzkumu byla vybrána skupina nálezů sestávající z destičkovitých spon, kování římského opasku (balteu), skleněných korálků a jedné pečeti schránky. Všechny patří do široké skupiny římsko-provinciálního importu. Destičkovité spony zdobené millefiori emaillem se sice objevují v celé oblasti barbarika, nicméně koncentrují se v Polabí a Potisí. Kruhová kování balteu jsou podstatně vzácnějším artefaktem, přesto v Čechách evidujeme několik nových nálezů. Jak tyto spony, tak i kování balteu se objevují především v období tzv. markomanských válek a v 1. polovině 3. století. Skleněné korálky pak představují typické nálezy v ženských hrobech mladší doby římské. Mozaikové korálky však patří k méně početné skupině skleněných korálků a objevují se obvykle v bohatých ženských hrobech 3. století. Jeden z hlavních cílů této studie je průzkum technologií použitých při výrobě millefiori emailu. Analytické metody micro-XRF, SEM/EDS a LA-ICP-MS byly použity pro stanovení složení skla a kovového podkladu. Konstrukce vybraných skleněných korálků byla prozkoumána počítačovou mikrotomografií (micro-CT).

doba římská – výzdoba millefiori – emailová výzdoba – spony – korálky – archeometrické analýzy

Introduction

Thanks to surface prospecting with the use of metal detectors, there has been a significant increase in recent years in metal finds, which were considered quite exceptional in previous

Fig. 1. Map of selected artefacts presented in the article 1 – Stradonice; 2 – Lipeč; 3 – Sokoleč; 4 – Chotělice; 5 – Češov; 6 – Jeníkovice; 7 – Plotiště nad Labem; 8 – Litoměřice; 9–11 – Plaňany.



decades. A typical example are artefacts imported from the Roman Empire. In this article, we focus on a specific group of finds with mosaic and millefiori enamel decoration. The term ‘enamel’ refers to frit, i.e. crushed glass powder coloured with the appropriate metal oxides, which is firmly fused to a metal substrate under high temperatures (Urbanová 2015, 21–23). In the case of artefacts with millefiori/mosaic enamel, this is a pit enamel technique, where small blocks of glass were placed on a metal base (often supplemented with a fine coloured frit with a lower melting point); the enamel fused to the substrate under high temperatures (750–800°C). The surface was then levelled and polished. The earliest finds produced by the glass mosaic technique appear already in ancient Egypt, from the second half of the 2nd millennium BC; however, the real heyday of the mosaic technique came in the Hellenistic period. The most important workshops were to have been located in Ptolemaic Egypt (Price 2002, 112). For simpler patterns of mosaic glass, various combinations of coloured segments were used, either for the creation of glass vessels or for polychrome decoration on a metal base. For the more complex millefiori technique, several pre-prepared glass rods had to be joined together. This bundle of rods was then carefully heated and pulled to reach lengths of up to several metres. The coloured rod could then be cut into smaller segments that looked like a stylised flower or spiral in section (Antonaras 2012, 19).

Finds of mosaic glass are uncommon in the territory of the Barbaricum. Fragments of mosaic and millefiori vessels from the Stradonice and Staré Hradisko oppida can be dated from the 2nd century to the beginning of the 1st century BC and are associated with the Canosa and Antikythera-Delos groups (Venclová et al. 2015, 223). In the 1st century BC, mosaic glasses were widespread in Italy, where workshops for their production were also to have been located (Price 2002, 114). In the Roman Period, we also come across small finds made with this technique, including a set of game pieces from rich inhumation grave no. 1 at Emersleben (Becker et al. 2006, 49, Taf. 128: 3). Another peculiar application of the millefiori enamel technique is found on metal pyxides from Roman-provincial territory, especially in the western provinces (Gaul and the Rhineland), where their production can also be assumed. The mosaic enamel technique is used mainly on small functional objects such as fibulae and the fittings of belts and a horse harness dated to the 2nd–3rd century AD (Thierry 1962, 67). However, mosaic/millefiori glass was also widely used in the production of beads.

For the purposes of this study, diverse groups of artefacts were selected primarily for investigating and comparing the employed production technologies (*Fig. 1; Fig. 2; Online Supplementary Material 1*). To this end, the micro-XRF, SEM/EDS and LA-ICP-MS analytical methods were utilised to help determine the composition of the glass and metal substrate and to characterise the millefiori technique in greater detail. The design of the selected glass beads was investigated using computed micro-tomography scanning (micro-CT); for more details of analytical methods, see *Online Supplementary Material 2*.

Materials

Seal box

The ‘Stradonice’ collection at the National Museum in Prague includes a lid from a seal box (no. 1). Relatively simple U-shaped boxes are typical for the Republican Period, whereas square boxes are less common. The majority of cases involve bone boxes, while a small number of bronze boxes are also known (these occur in greater numbers in the Augustan Age). These finds could be Roman-provincial imports from the 1st century BC, but local imitations are another possibility (*Kysela 2020, 183*).

Based on finds from Augusta Raurica, the first seal boxes with enamel decoration can be dated to the end of the 1st century AD, with the greatest boom in the 2nd century AD. The production and use of Roman enamel boxes ends roughly at the end of the 3rd century AD (*Bateson 1981, 50; Derks – Roymans 2002, 92; Furger et al. 2009, 49*). Finds of seal boxes come from civilian settlements, but urban sites predominate greatly over rural settlements. Perhaps the largest concentration of seal box finds comes from the area of the Limes (*Derks – Roymans 2002, 93*).

The find of the seal box lid from Stradonice (*Fig. 2: 1*) can be identified as a ‘Blattförmige Siegelkapseln 2b’ type after *Furger et al. 2009*, or as Group 1 after *Bateson (1981)*, which is one of the most widespread types in the provincial environment. Boxes of this type have an elongated pear shape, the edge of the lid is slightly convex and the shorter edge has one eyelet for the hinge used to fasten the lid to the box itself. The closest parallels to the find from Stradonice are three seal boxes from Augst (*Furger et al. 2009, Abb. 29: 4–5, Taf. 4: 28–30*). Boxes of the ‘Blattförmige Siegelkapseln 2b’ type are most widespread in the Danube and Rhineland regions and also appear in Britain and parts of Gaul (see *Furger et al. 2009, Abb. 33*). Our lid is characterised not only by richer polychromy, but also by a gilded surface (see *Fig. 8*). This type of artefact represents an exceptional decorative technique to which there are no parallels in the large assemblage of seal boxes from Augst. However, we can mention the golden lid of a seal box from Carnuntum (*Humer 2009, 170*).

While the find of the seal box from Stradonice is certainly a remarkable representative of Roman-provincial products, it is necessary to take into account the unclear circumstances of its discovery. The first illustration of this artefact dates back to the early 20th century (*Piř 1903, 48–49, Tab. XIII: 33*). The assemblage of artefacts from Stradonice comes from several private collections, the creation of which was quite chaotic, and the assemblage contains evidence of both fakes and artefacts originally acquired outside the territory of Bohemia. Finally, *J. L. Piř* himself (*1903, 48*) states that the find of the ‘enamel plate’



Fig. 2. 1 – Seal box, Stradonice, Beroun district; 2 – Exner III 30 disc fibula, Lipeč; 3 – Exner III 30 disc fibula, Sokoleč, Kolín district; 4 – Exner III 22 disc fibula, Chotělice, Hradec Králové district; 5 – Exner III 48/51 circular fibula, Češov, Jičín district; 6 – Balteus fitting, Jenikovice, Hradec Králové district; 7 – Balteus fitting, Plotíště nad Labem, Hradec Králové district; 8 – Balteus fitting, Litoměřice, Litoměřice district.

comes from the old collection of the National Museum, where it was labelled as the Podmokly find. He also states that the find comes from the private collection of Professor Wydra, which was to have contained artefacts from the Stradonice hillfort (i.e. it also contained artefacts from other sites!). Given these circumstances and the uncertain provenance of some finds, it is advisable to view the collection from Stradonice with a dose of caution, and we can assume a completely different origin for selected artefacts. All of this also applies in the case of the seal box presented here. For the time being, finds of other Roman seal boxes are missing from the territory of Bohemia; moreover, in the area of the Stradonice oppidum, finds from the Roman Period form only a small and poorly identified group.

Exner III 30 disc fibulae

The first variant of Roman-provincial fibulae with millefiori decoration discussed here consists of a circular plate, the face of which is not structured in any way and is only framed by a low perimeter border. The entire decorative surface is filled with millefiori glass set in a chequerboard pattern. Although the fastening mechanism can be either hinged or with a coil spring, most of the imported artefacts in the Barbaricum are documented with a spring. For the first time, we present two examples of fibulae from Lipec (no. 2) and Sokoleč (no. 3) (*Fig. 2: 2* and *Fig. 2: 3*). These rank alongside five previously published finds of this type in Bohemia, which were summarised not long ago by *E. Droberjar* (2016, 503, 506). While the fibula from Lužice near Chomutov probably also comes from a settlement context, the circumstances of the find from Plzeň-Valcha, which has not yet been described in the literature, are still unknown. The fibulae from Lipec and Sokoleč can be classified among unstratified finds from topsoil in the area of multicultural settlements, just like the fibula from Nová Ves I near Kolín. That is why – especially in the context of other evidence of these fibulae abroad – the find from children’s grave 207 in Opočno near Louny, where a pair of these fibulae was found, is valuable (*Pleinerová* 1995, 29, 86, Taf. 37: 1–2, 73).

These fibulae can be classified as the Exner III 30 type (*Exner* 1941, 107–108, Taf. 14: 6), or also the Thomas ‘c’ (*Thomas* 1966, 132–134), Böhme 41z (*Böhme* 1972, 38, Taf. 26: 1007–1015), Ettlínger 45.5 (*Ettlínger* 1973, 123), Jobst 27c (*Jobst* 1975, 109, Taf. 45: 307), Riha 7.14.4 (*Riha* 1979, 189–191, Taf. 61–62; *Riha* 1994, 161–162, Taf. 42), or as the Grumeza IA (*Grumeza* 2015, 192) or Vaday III/1/1/3 (*Vaday* 2003, 326, Fig. 5). The rich citation apparatus documents the wide spread of this type of fibula, which is found practically throughout the Rhineland and the Danube Region, usually also on the Limes, and is therefore not exceptional even in the Barbaricum. A number of researchers believe they were produced in Gaul (summarised by *Vaday* 2003, 326). Compared to other enamelled fibulae, these fibulae are assigned a relatively later date, usually as late as the first half of the 3rd century (*Exner* 1941, 107–108; *Böhme* 1972, 37; *Ettlínger* 1973, 123; *Jobst* 1975, 109; *Vaday* 2003, 326; *Mačzyńska – Urbaniak* 2006, 133–134).

An inventory of Exner III 30-type fibulae was carried out in the Barbaricum in the 1960s by Sigrid Thomas; at that time, it consisted of 13 finds concentrated in the Elbe river region. While it is certainly understandable that after nearly 60 years we can expand this list somewhat (see *Online Supplementary material 3; Fig. 3*), it seems that the trend of concentration of these fibulae in the Elbe river region remains unchanged. However, we cannot ignore the fact that 10 of these fibulae are recorded in the Tisza river region occupied by the Sarmatians (*Vaday* 2003, 326, Fig. 5), which is another reason their minimal representation in the Middle Danube Region, i.e. in Lower Austria, Moravia and Slovakia, is striking. Poland is also represented by only a single grave find from Kowalewko in Greater Poland.

A more detailed analysis of the sources reveals one remarkable connection. Although well-documented grave finds involving Exner III 30-type fibulae are scarce in the Barbaricum, they point to one recurring phenomenon. In several cases of grave finds, these fibulae were found in pairs: grave 157 from Očkov (which, however, was not fully published; see *Kolník* 1965, 187, Fig. 3: 8, 4: 3), grave 230 from Kowalewko in Greater Poland (*Skorupka* 2001, 67, Tabl. 70: 230/1–2) and grave 207 from Opočno near Louny (*Pleine-*

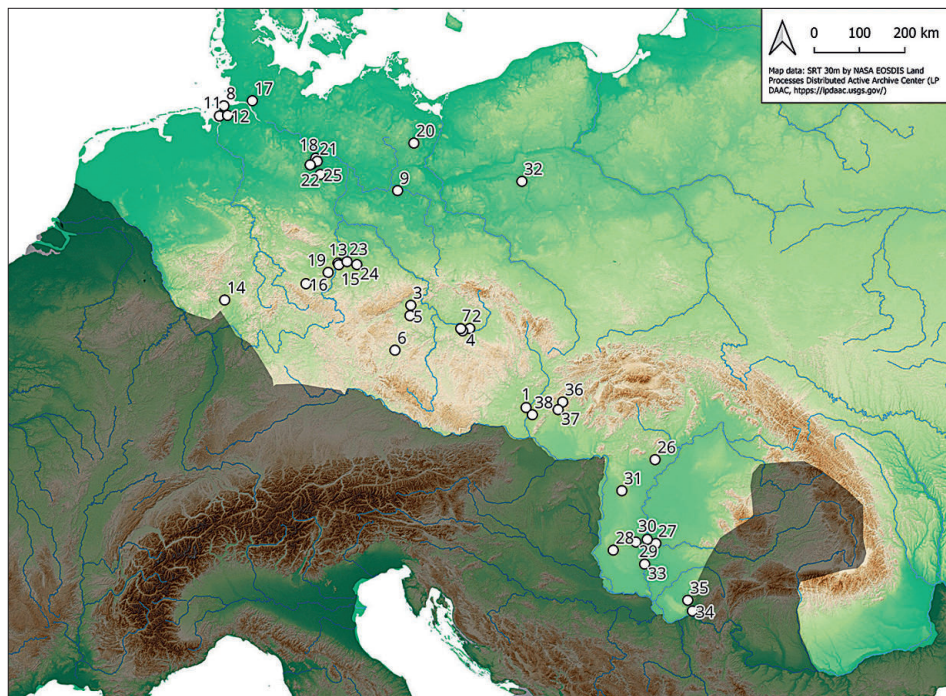


Fig. 3. Map of Exner III 30 disc fibulae in the Central European Barbaricum. 1 – Bernhardstahl; 2 – Lipeč; 3 – Lužice; 4 – Nová Ves I; 5 – Opočno; 6 – Plzeň-Valcha; 7 – Sokoleč; 8 – Altenwalde; 9 – Berlin-Mariendorf; 10 – Cheine; 11 – Feddersen Wierde; 12 – Flögeln; 13 – Freyburg; 14 – Gießen; 15 – Großjena; 16 – Haaren; 17 – Hodorf; 18 – Lüchow; 19 – Mattstedt; 20 – Potzlow; 21 – Rebenstorf; 22 – Rockenthin; 23 – Schkortleben; 24 – Wiederau; 25 – Zethlingen; 26 – Füzesabony; 27 – Kiszombor; 28 – Madaras; 29 – Mórahalom; 30 – Szeged-Tápe; 31 – Pusztavacs; 32 – Kowalewko; 33 – Ada; 34 – Bela Crkva; 35 – Vršac; 36 – Beckov; 37 – Očkov; 38 – Závod.

rová 1995, 29, 86, Taf. 37: 1–2, 73). In the case of older finds from often destroyed cemeteries, multiple fibulae of this type sometimes occur; however, it is no longer possible to say whether they were originally part of the same grave, e.g. Cheine in Saxony-Anhalt (*Becker et al. 2006*, 71, Taf. 98: 6–7, 11). Also noteworthy is the association of a trio of plate fibulae in grave 874 at the Zethlingen site in Saxony-Anhalt, where one of the fibulae is represented by the Exner III 30 type, while the other two are Germanic plate fibulae in the shape of a boar (*Leineweber 2021*, 65, Taf. 108: 1). As such, the context of the same fasteners, or at least fasteners of a similar type, in a single grave is repeated here. It is the popularity of domestic plate fibulae in the Elbe river cultural circle that may explain the popularity of their Roman-provincial counterparts. These fibulae are commonly said to have been worn by women in a provincial environment (*Böhme 1972*, 37; *Vaday 2003*, 326, 375–377), and it is worth noting that barbarian plate fibulae are also typical for female graves (e.g. *Meyer 1969*, 48). In the Central European Barbaricum, a pair of clasps are recorded in two children's graves, the gender of which could not be specified: Opočno near Louny and Kowalewko. Conversely, in grave 425 from the Sarmatian cemetery in Madaras, this fibula was deposited with a young girl (*Vaday 2003*, 398).

Exner III 22 disc fibula

This plate fibula variant is also a circular fastener. However, its face is divided by a partition into a central circular field and an outer orbital field (*Exner 1941*, 102–103, Taf. 13: 2–3). This fibula differs from the Exner III 23 or 26 types by a lower number of concentric circular fields and also by the absence of a central circular projection (button). Not all examples of this variant are filled by the millefiori technique like the find from Chotělice (no. 4) published here (*Fig. 2: 4*). Alternatively, this type can also be designated as the Böhme 41y (*Böhme 1972*, 38, Taf. 26: 998–1004), Ettliger 45.3 (*Ettliger 1973*, 122), Riha 7.13 (*Riha 1979*, 188–189, Taf. 61: 1607; *Riha 1994*, 161, Taf. 42), or Vaday III/1/1/1/1 type (*Vaday 2003*, 324, Fig. 4). It also belongs to the broadly conceived type ‘a’ after Thomas, which includes all circular fibulae with a concentrically articulated face, regardless of whether they have a central button or protrusions along the edge (*Thomas 1966*, 126–130).

The problem of finding more precise analogies to the fibula from Chotělice lies in the generally considerable diversity of circular plate fibulae, where different specimens may contain features of several types, regardless of any typological system. However, it is certain that the artefact from Chotělice did not have a central button, which is widespread in many types of circular Roman-provincial fibulae. Other aspects that complicate a more accurate typological classification of these fibulae are the damage caused by the heat of cremation in the case of finds from cremation graves, or the poorly rendered illustration of these fibulae, as is commonly encountered in older literature. A few finds can be cited that resemble the Chotělice specimen in at least certain features: a fibula from Gießen in Hesse, although it has lost its enamel (*von Uslar 1938*, 197, Taf. 22: 50, 24: 15; *Thomas 1966*, 158); Körner in Thuringia, reputedly from an inhumation grave (*von Uslar 1938*, 210, Taf. 22: 52; *Thomas 1966*, 162); and finally, these could include a disc fibula with a concentrically articulated plate with lost enamel inlays from Hodorf in Schleswig-Holstein (*Thomas 1966*, 161). S. Thomas describes two relatively similar fibulae with millefiori from the Latvian sites of Gailiši and Piltene (*Thomas 1966*, 126, 158, 167). In the Sarmatian territory of the Tisza river region, similar fibulae are recorded from the Tápiószéle and Adács sites, both from female graves. A close parallel from Lower Austria is represented by a surface find from Ringelsdorf (*Adler 1994*, 583, Abb. 884). Plate fibulae of this type are apparently not as widespread in the Danube river region as in the Rhineland (*Exner 1941*, 103; *Feugère 1985*, 368–370; *Riha 1994*, 161), which probably also had an effect on their weaker representation in the territory of Poland (*Mączyńska – Urbaniak 2006*). We can date these fibulae, like other related variants, from the second half of the 2nd century to the first half of the 3rd century (*Thomas 1966*, 127–130; *Feugère 1985*, 371; *Riha 1994*, 161).

Exner III 48/51 open-work circular plate fibula

The fourth example presented here of a plate fibula decorated using the millefiori technique is an incomplete fibula from Češov (no. 5; *Fig. 2: 5*). This artefact combines the features of the Exner III 48 and 51 types; multiple narrow spokes, which originally converged into the central wheel (wheel hub), are characteristic of the Exner III 48 type. The placement of the spokes indicates that there were originally six. As this part of the fibula is unfortunately broken off, the form of the central hub is unknown (i.e. flat or with a button). The Exner III 51 type is suggested by 12 small lobe-like projections on the perimeter (*Exner*

1941, 112–113, Taf. 16: 4, 7).¹ The catch mechanism of the needle of the Češov fibula is a hinge, which is common for other examples of these fibulae presented by K. Exner.

Open-work fibulae are usually called fibulae in the shape of spoked wheels (Radfibeln) and can be classified according to a number of typological systems: Böhme 42e (*Böhme 1972*, 39, Taf. 27: 1040–1041), Ettlenger 40.2 (*Ettlenger 1973*, 112, Taf. 12: 15–16), Jobst 28 (*Jobst 1975*, 112, Taf. 45: 314–316), Feugère 28a (*Feugère 1985*, 372–377, Pl. 156: 1957–1959), Rey-Vodoz 7.26 (*Rey-Vodoz 1986*, 168, Pl. 13: 210), Riha 7.25 (*Riha 1994*, 173, Taf. 46: 2925), or Vaday III/8/3/2 (*Vaday 2003*, 354, Fig. 19). S. Thomas also refers to them as type ‘e’ (*Thomas 1966*, 137–139).

Although an exact analogy to the Czech fibula is difficult to find, a certain analogy from Poland is a fibula from Słopanowo in the Łódź Voivodeship, though it is a four-spoke wheel type (*Maczyńska – Urbaniak 2006*, 153, Ryc. 3: 6). Similarly, it is possible to name three fibulae of the Vaday III/8/3/2 type from the Tisza river region (*Vaday 2003*, Fig. 19). A fibula from Farsleben in Saxony-Anhalt is interesting for a different reason: the plate fibula with millefiori decoration on the surface of the circular frame was found in a 5th-century female inhumation grave. This fibula was secondarily modified by breaking out the middle section with spokes for use as a buckle (*Thomas 1966*, 156). Although it is not a type that would be close to the find from Češov (in addition, it is a representative of relatively large fibulae), it nevertheless proves that these fibulae were so aesthetically interesting even in the following centuries that they could also be used for secondary purposes. These fibulae are traditionally dated to the 2nd or early 3rd century AD (e.g. *Thomas 1966*, 139; *Böhme 1972*, 39).

Balteus fittings

Roman fittings for military belts (baltei) are not very common finds in Bohemia (*Musil 1994*, 5, Abb. 3: 1–2). These can be divided into two basic groups. The first category is composed of circular fittings in a wide range of profiles without enamel, the second of enamelled circular fittings. Far more finds of artefacts from the first group have been made (*Oldenstein 1976*, Taf. 84–86). For many years, the only evidence in Bohemia of fittings of Roman baltei with preserved enamel was the artefact from grave 772 in Plotiště nad Labem (no. 7; Fig. 2: 7) (*Rybová 1979*, 371, Fig. 37: 2; *Rybová 1980*, 147, Fig. 14; *Jílek – Horník 2017*, 67, Fig. 4: 8, 13: 6).

The review of older finds carried out for the purpose of creating this article uncovered another balteus fitting in the collections of the National Museum. It is a fragment of a circular fitting with millefiori glass from Litoměřice (no. 8) (Fig. 2: 8) which had previously been published numerous times as a fibula (*Preidel 1930*, 75, Abb. 82; *Svoboda 1948*, Taf. 7: 3; *Sakař 1970*, 32; *Droberjar 2016*, Abb. 6: 12); however, traces of a catch or a cross-piece for the axis of the winding are missing from the back side. In contrast, there is a fragment of a cast rivet, which, in terms of construction, makes this the same type of fitting as the artefact from Plotiště nad Labem. A more distant parallel is found at the Sz wajcaria

¹ However, lobe-shaped or semicircular protrusions in various numbers on the edge of the fibulae are a feature that also appears on other types of circular plate fibulae, e.g. those without open-work or tutulus-like fibulae (see *Exner 1941*).

cemetery in Poland. This fitting was also initially misinterpreted as a fibula (Thomas 1966, 171, Taf. 9: 1; cf. with Nowakowski 2001, 109, Taf. IV: 5).

In 2022, another artefact from Jeníkovice (no. 6) in east Bohemia was added to these two fittings (Fig. 2: 6). The circular plate from thick sheet metal is divided by partitions into four segments. The first two rings are filled with millefiori glass. Visible on the reverse is a massive rivet running through the middle of the plate. All three fittings have the same construction. The fittings consist of a circular plate with a border and concentric circles filled with millefiori glass. In the middle of the fitting is a hole with a fastening rivet. The fittings differ from each other in the number of concentric circles, the colour of the glass and the smaller decoration placed inside the glass bands. Another common feature is plant and chequerboard motifs. These are common in fittings of a military nature, as is the alternation of two glass colours (Benea 2016, 782, 785, Abb. 6). Fairly close parallels to the Jeníkovice fitting are found in Dacia—specifically in the Tibiscum camp (Benea 2016, Fig. 5: 21), where even the production of bronze objects and enamel is documented from the middle of the 2nd to the 4th century. As such, Dacia can be considered as one of the possible production centres. Exceptionally well-preserved pieces of discoid belt ornaments, the decorative composition of which is very similar to our finds, also come from Mušov-Burgstall – the central location of the Roman army from the period of the Marcomannic Wars (Hložek et al. 2015, 39–41, Fig. 8–11).

Starting in the 1st century, baltei were used exclusively by officers in the Roman army alongside the more common waist belt to carry swords (Przybyła 2010, 93). The broader spread of wide baltei occurred in response to changes in Roman army gear in the second half of the 2nd century, when shorter gladii were gradually replaced by longer spathae. The longer and heavier weapon required a different carrying method (Bemmann – Hahne 1994, 407). Balteus fittings from the Roman fort of Niederbieber prove that they were used in the Roman military environment from the end of the 2nd century and during the 3rd century (Oldenstein 1976, 230). Roman balteus fittings appear in the Elbe-Germanic cultural sphere primarily at the turn of the 3rd century (Oldenstein 1976, 230; Przybyła 2010, 94, 96, note 4, Abb. 2). In the northern and eastern parts of the Barbaricum, these fittings spread later during the 3rd century (Kaczanowski 1992, 179–180).

Beads

For the purpose of research, three mosaic glass beads, part of one of two necklaces, were selected from a rich female inhumation grave of the Late Roman Period from Plaňany (Beneš in Lutovský et al. 2023, 671–673). The selection of beads for research was conditioned by the specific type/pattern in the mosaic glass technique. Bead no. 9 (Fig. 4: A–B) belongs to group XXIII and type 366d (barrel-shaped bead with coloured millefiori forming a chequerboard motif) after Tempelmann-Maczyńska (1985), or to compound glass group XIII/2 after Gopkalo (2008). Beads from this group are spread throughout the entire Barbaricum. Gopkalo (2008, 58) mentions the occurrence of this type in assemblages from the Northern Black Sea Region as early as the 1st–2nd century AD. A similar situation is also observed in the Central European Barbaricum, where they appear in rare instances in assemblages from the Early Roman Period (Tempelmann-Maczyńska 1985, 60). As a certain parallel, we can mention fragments of two barrel-shaped millefiori beads of blue-green translucent glass with a pattern from yellow, bright red opaque glass, which

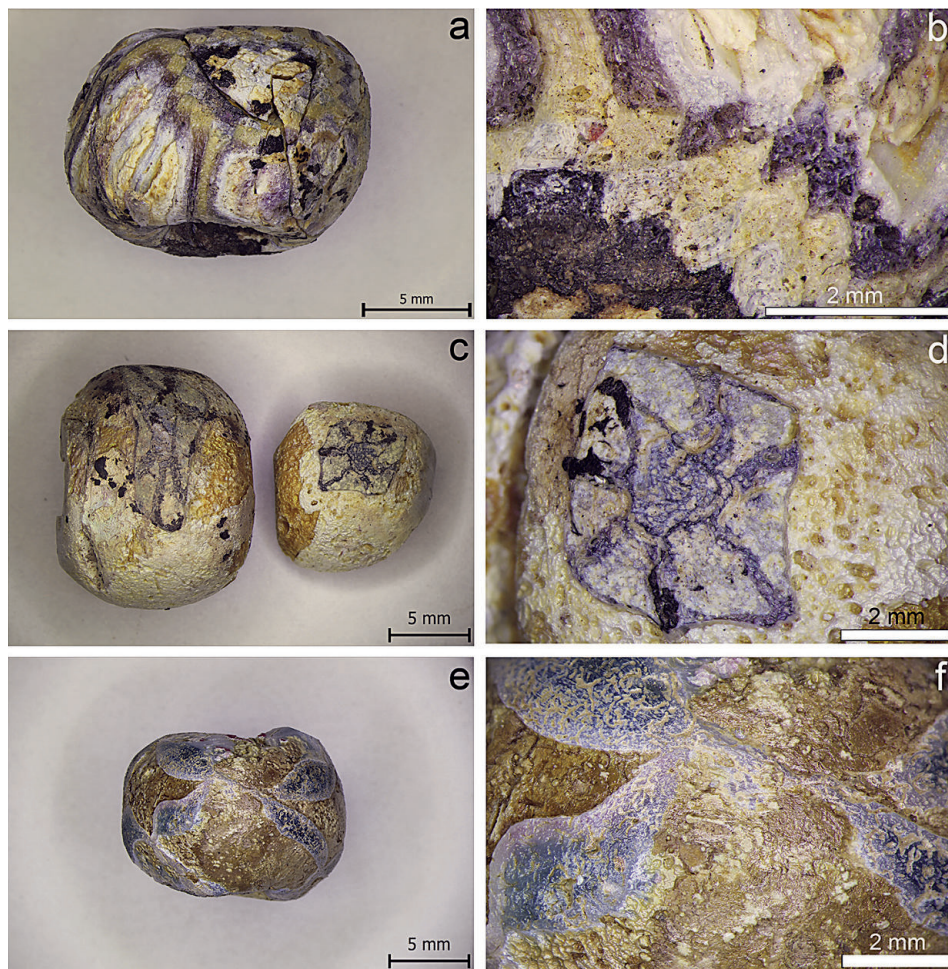


Fig. 4. Glass beads from the rich female grave in Plaňany: a–b – bead with a chequerboard motif, Plaňany no. 9; c–d – bead with simple floral motif, Plaňany no. 10; e–f – bead with floral motif, Plaňany no. 11.

come from disturbed graves in Dobřichov-Třebická. Another three beads of this type come from grave 861 from Třebusice (*Droberjar – Motyková 2023*, Tab. 258: 14–16), which can be dated on the basis of a plate fibula in the shape of a boar to the second half of the 3rd century (*Reszczyńska 2017*, 339). Multicoloured millefiori beads with an irregular chequerboard motif also come from other sites, including cremation grave 4 from Eischleben dated to the 3rd century (*Dušek et al. 2017*, 50, Taf. 91: 1).

Bead no. 10 (*Fig. 4: C–D*) can be classified in group XXIII, type 362a_h (barrel-shaped bead with a simple rosette motif). This is a relatively popular type that is also known from Bohemia. We can list seven beads of this type from the inhumation grave of Prosmky 1 dated to the second half of the 3rd century (*Blažek 1995*, 144–145). Another bead with decoration in the form of a solitary rosette comes from disturbed graves at the Opočno cemetery (*Pleinerová 1995*, Tab. 78: 28). A bead of the same type was found in the assem-

blage from grave 12 at Ichstedt dated to the first half of the 3rd century (*Dušek et al. 2017*, 77, Taf. 89: 2). Based on finds from Central Europe, we can state that beads of type 362 are mainly found in graves dated to the 3rd century and their use continues until the beginning of the 4th century (*Tempelmann-Maczyńska 1985*, 59).

Due to the distinctive floral motif in the form of a four-leaf clover, bead no. 11 (*Fig. 4: E–F*) can be roughly linked to type 356b (barrel-shaped bead with a floral motif). As a parallel from our territory, we can mention the find from grave 63 in Dobřichov-Třebická, a barrel-shaped terracotta-red bead with a motif of blue-white leaves or rosettes (*Píř 1892; Sakař 1970*, 25–29). A bead of a similar type comes from grave 1188 in Plotička nad Labem (*Rybová 1979*, 377–378). Two heat-deformed green glass beads with yellow-white leaf decoration come from grave 930 in the same cemetery (*Rybová 1979*, 373). Type 356 beads are already found in assemblages dated to the 2nd century (*Tempelmann-Maczyńska 1985*, 59), and their use continues in the Late Roman Period. The motif of a simple coloured rosette or leaves also appears on beads from the Migration Period, albeit with more complex ornament (*Koch 2001*, 160–163, Taf. 8).

The beads presented here are part of grave goods from a rich inhumation grave dated to the second half of the 3rd century. It is a necklace made of glass and amber beads that appears in most of the rich female inhumation graves from the Late Roman Period, with the beads even numbering up to several dozen. For example, a necklace from a rich woman's grave in Žiželice was composed of 78 amber and 282 glass beads (*Blažek 1995*, 150–152). In the previous period, these are isolated pieces. However, the occurrence of beads with millefiori/mosaic decoration in the Roman Period in the territory of Central Europe is not completely common. Within a single assemblage, their number is in the single digits.

Chemical and technological analysis

Glass

Most of the glasses we evaluated can be classified as natron glasses with a characteristically low content of MgO and K₂O (up to c. 1.5%) and a certain amount of CaO (up to c. 8%) (*Freestone 2021; Basso et al. 2014*, 238). The exception seems to be red glasses, for which in some cases a higher content of potassium and magnesium oxide was determined (despite 2% in baltei fittings from Litoměřice and Jeníkovice, fibulae from Sokoleč and bead no. 10 from Plaňany, if we consider 'reduced composition') as well as a higher phosphorus content (these differences are discussed in the text regarding red glasses).

The colours of translucent glasses depend on the colouring elements or ions (elements in their ionic form are integrated into the network structure of the glass matrix). The most common colourants found in ancient glass are Fe²⁺, Fe³⁺, Mn³⁺, Cu²⁺ and Co²⁺ ions (*Gedzevičiūtė et al. 2009*, 19–20; *Basso et al. 2014*, 238). Without an intentionally added colourant such as copper or cobalt, the colour of the glass depends largely on the amount and oxidation state of the present iron (commonly added to the glass, e.g. in sand). The Fe²⁺ ion is responsible for the pronounced bluish colour, while the ferrous Fe³⁺ ion is responsible for the much less intense yellow. The majority of glasses contain iron in both oxidation states (Fe²⁺ and Fe³⁺), giving rise to a range of green and bluish shades (*Freestone – Stapleton 2015*, 64). The Fe₂O₃ content is c. 0.4% in Roman glasses (for glasses of the early imperial period according to *Freestone – Stapleton 2015*, 64).

Manganese and antimony oxides (so-called decolourising agents) were intentionally added to some glasses to change the blue-green colour of glass with a predominant Fe^{2+} content to a less pronounced yellowish Fe^{3+} colour. For Roman glasses of the 1st–4th century, two basic groups are distinguished according to decolourising agents: *Roman-Sb* (glass decoloured with antimony; produced in Egypt) and glass produced in the Levant (*Roman-Mn*). We also often encounter a ‘mix’ of these groups, *Roman Sb-Mn*, which is the result of recycling glasses with different compositions, or by different decolourising agents. *Boschetti et al.* (2022, 7) lists thresholds for $\text{Mn} < 250$ ppm and for $\text{Sb} < 30$ ppm, below which both elements can be considered natural impurities of the silica source. *Schibille et al.* (2017, 1226–1231) specifies individual groups as follows:

- (a) The *Roman-Sb* glass group is characterised by high antimony content and an MnO content of less than 0.025 wt%.
- (b) Typical for *Roman-Mn* is a high content of MnO (> 0.025 wt%) and low antimony (or Sb_2O_3); below the detection limit of their analytical technique, c. 0.03 wt%.
- (c) *Roman Sb-Mn* glass is characterised by these contents— $\text{MnO} > 0.025$ wt% and $\text{Sb}_2\text{O}_3 >$ detection limit around 0.03 wt%.

However, for our studied assemblage, this division is rather ‘unusable’, because most of the glasses are opacified by particles with an antimony admixture, so it is not possible to distinguish whether antimony was introduced into the glass as a decolourisation agent or as an opacifier. The possible introduction of antimony or manganese with the colouring raw material also cannot be ruled out. However, for a smaller group of samples, it was possible to use this division as follows: two non-opacified blue glasses have contents of up to 20 ppm Sb (balteus fittings from Litoměřice and Jenkovice, both with millefiori decoration). The *Roman-Mn* group can be assumed for these two samples. Glasses/enamels with a low MnO content (below 250 ppm) were found in the following artefacts (unless otherwise stated, this was white glass): the balteus fitting from Litoměřice (part of the flower motif), the fibula from Češov (again part of the flower), the fibula from Lipeč (part of the millefiori decoration), the balteus fitting from Plotiště nad Labem (slightly higher MnO content of c. 300 ppm), bead no. 9 from Plaňany (white and yellow and green glass), bead no. 11 (white and red glass) and can therefore be classified as to antimony-decoloured glass. Even from this small list, it is evident that Roman-Sb-type glass is part of the millefiori segments and was also the raw material for the production of bead no. 9 and 11.

If coloured or opaque glass is desired (these properties are combined in the resulting colour shade), additional raw materials must be added. *Brems and Degryse* (2014) list the following elements related to the (de)colouring of ancient glass: Mn, Co, Ni, Cu, Zn, As, Ag, Sn, Sb, and Pb. Some of these elements do not influence the colour of the glass, but they occur as impurities in the mineral (de)colourants. Elevated concentrations of these (de)colourant-related elements (over 1,000 ppm) suggest that they were deliberately added to the glass batch to influence the colour of the resulting product. Concentrations between about 100 ppm and 1,000 ppm are typically interpreted as indications of glass recycling. These levels were used in evaluating glasses in this work.

Non-opacified glass

The assemblage contains a smaller amount of glass that can be assessed as non-opacified glass. These are the blue parts in the millefiori decoration of the balteus fittings from

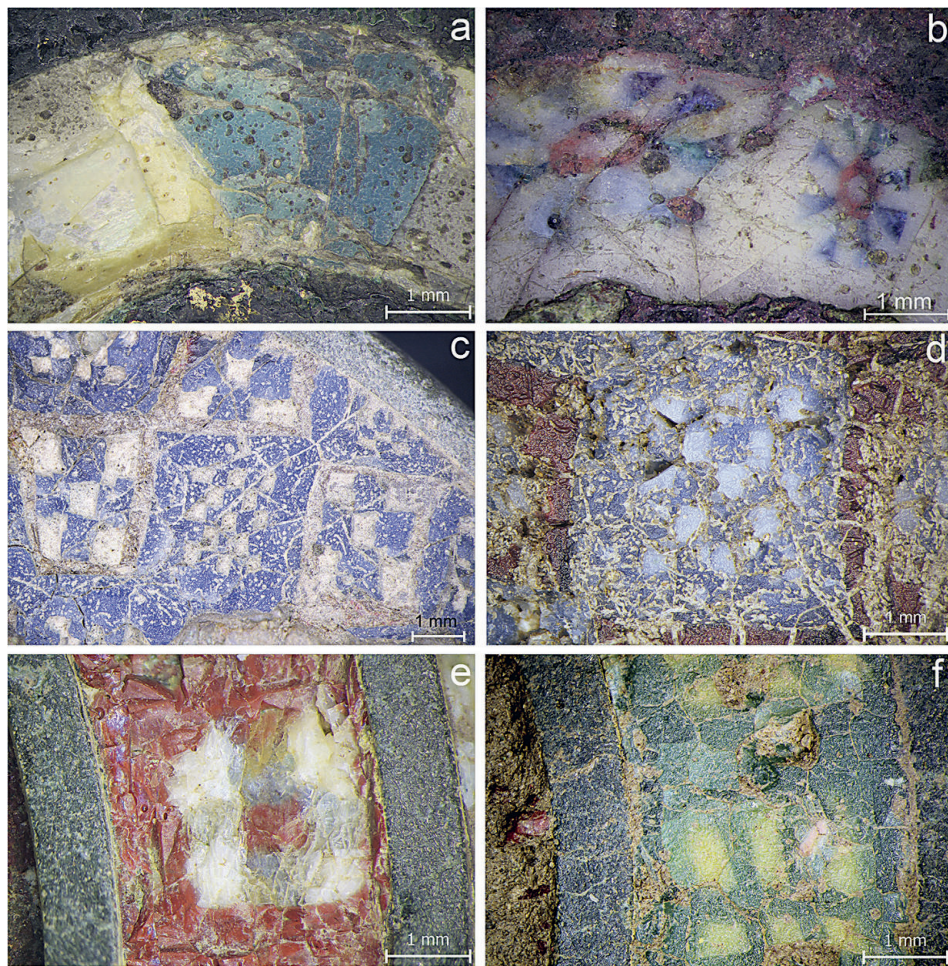


Fig. 5. Examples of the representation of coloured glass: a – detail of enamel on the lid of the seal box; b – balteus fitting from Litoměřice – detail of surface, non-opacified glass was found in the blue segments of the flower and dark discs; c – detail of fibula from Sokoleč, millefiori decoration; d – another type of millefiori decoration, fibula from Lipec; e and f – segments from decoration of balteus fitting from Jenkovice.

Litoměřice and Jenkovice (Fig. 5: B, E), the dark glass in the fitting from Litoměřice, the fibulae from Češov and bead no. 9 from Plaňany (green glass). The chemical composition table shows that the antimony content (a frequent component of opacifiers) is very low in these samples (e.g. only tens of ppm in the glasses of the artefacts from Litoměřice). However, according to the overall composition, the glasses can be classified as coloured. In the case of both of the aforementioned balteus fittings, blue-colouring copper ions (c. 900 ppm Cu) and cobalt (up to 1,398 ppm Co in sample 2) are represented. In the case of dark glass (the fitting from Litoměřice and the fibulae from Češov), the shade is influenced by the high content of Fe_2O_3 in higher percentage units compared to the aforementioned 0.4%. In the case of bead no. 9, the dark glass is influenced by a higher content of manganese (1.4%) and probably also iron.

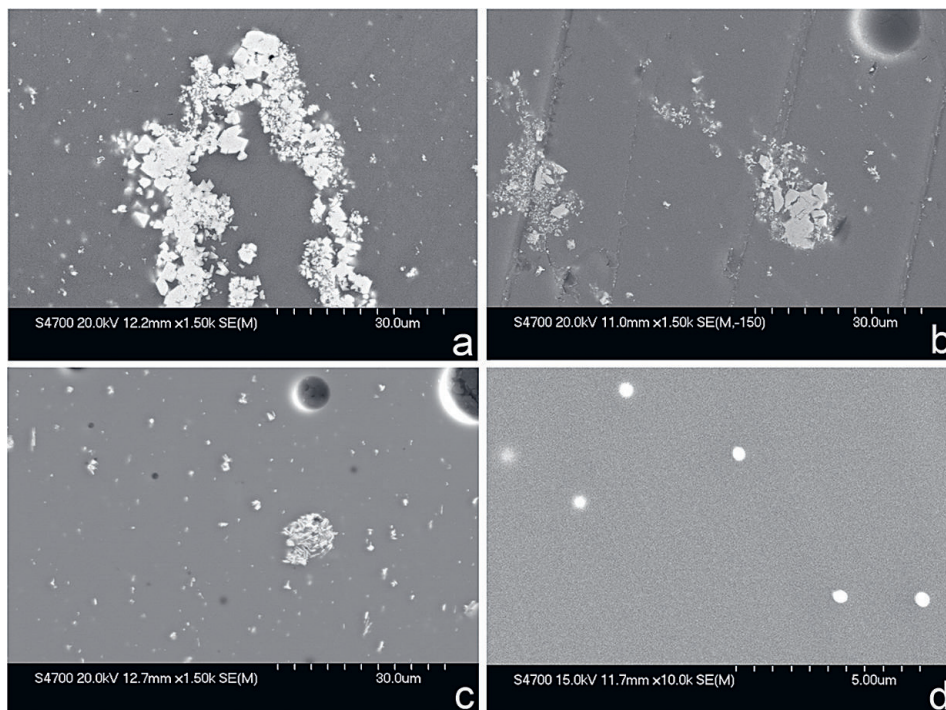


Fig. 6. Scanning electron microscopy images: a – aggregates of microcrystals containing calcium and antimony in white enamel, Lipec fibula; b – microcrystals containing tin in white enamel, seal box lid; c – microcrystals in yellow enamel, balteus fitting from Jenikovice; d – nanoparticles of metallic Cu (probably), Lipec fibula.

Opaque white glass

Three basic groups of white glasses/enamels can be distinguished: (a) white enamel on the lid of the seal box (see Fig. 5: A) is completely different from the other glasses mainly represented by the opacifier (SnO_2) and a higher content of manganese and iron; (b) a group with a higher MgO content and low MnO up to 250 ppm (balteus fittings from Litoměřice and Plotiště, fibulae from Češov, Lipec, bead no. 9 and 11 from Plaňany); and (c) samples not meeting the previous criteria (balteus fitting from Jenikovice and fibula from Chotělice).

Higher MgO contents (c. 3.3% MgO) were also described for white enamels in the work of Henderson (1991, 69–70), albeit without more specific conclusions. This clearly distinguishes the analysed glasses in the presented work, indicating different workshops or raw materials. As noted above, in our white enamels with higher MgO, a relatively low Mn content was also determined (max. 300 ppm), whereas in the other samples this is nearly 600 ppm, or even higher (even this could be a certain fingerprint). Schibille (et al. 2020, 6) also describes similar conclusions for white glass tesserae of the 4th century (from the Roman villa at Noheda, Spain). The glass tesserae contain MgO (2.76% on average) and low amounts of Al_2O_3 (1.95%) and MnO (c. 300 ppm). Based on this, the author concludes that these samples may be Roman-Sb glass (similar to ours). On the other hand, a slightly

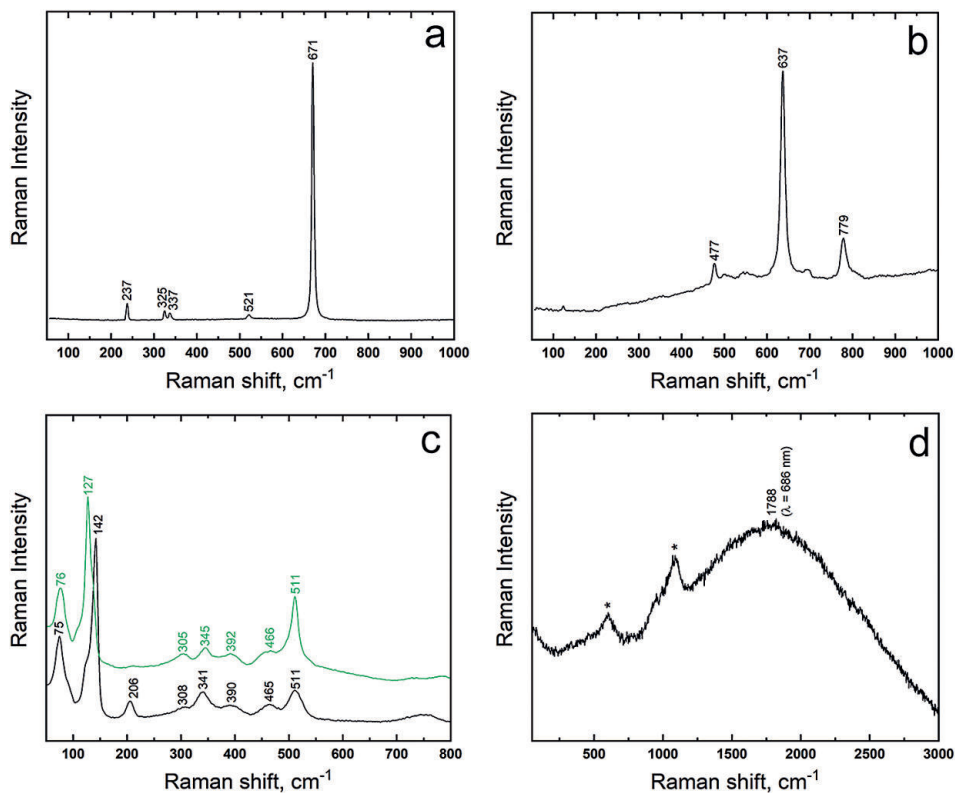


Fig. 7. Examples of Raman spectra for opacifiers contained in enamels: a – CaSb_2O_6 , balteus fitting from Jenikovice; b – SnO_2 phase, seal box lid; both white colours; c – $\text{Pb}_2\text{Sb}_2\text{O}_7$ (green line, green enamel); $\text{Pb}_2\text{Sb}_{2-x}\text{Sn}_x\text{O}_{7-x/2}$ (black line, yellow enamel; both balteus fittings from Jenikovice; d – Cu^0 phase; red enamel, fibula from Chotělice.

higher amount of lead (tenths of a percent) was detected in samples with a lower magnesium content (e.g. the balteus fitting from Jenikovice).

The colouring of most white glasses is caused by the presence of calcium antimonate crystals (white crystals). The Sb_2O_3 levels are mainly in the range of c. 4% up to 9% (the fitting from Jenikovice, part of the millefiori segment, see Fig. 5: E). The Raman spectroscopy method confirmed the $\text{Ca}_2\text{Sb}_2\text{O}_7$ and/or CaSb_2O_6 phases in the white glasses (see Fig. 7 and Online Supplementary Materials 4). Similar phases were also found, e.g. in the work of Gedzevičiūtė et al. (2009) on Roman millefiori glasses, and in a paper evaluating mosaic cubes from the 2nd century AD (Basso et al. 2014). Gedzevičiūtė et al. (2009) describe the individual phases, including the Raman bands, as follows: hexagonal CaSb_2O_6 is characterised by Raman bands at 234, 323, 517 and 666 cm^{-1} and orthorhombic $\text{Ca}_2\text{Sb}_2\text{O}_7$ displays characteristic Raman bands at 318, 367, 472, 624, 781 and 821 cm^{-1} (in the cited author's work, these are synthetically prepared phases). Similarly, Basso et al. (2014) states that the CaSb_2O_6 phase shows a strong band at 670 cm^{-1} , followed by less intense bands at 236, 323, 340, and 520 cm^{-1} . For $\text{Ca}_2\text{Sb}_2\text{O}_7$ it is then 480 and 633 cm^{-1} and less intense at 322, 370, 790 and 832 cm^{-1} (for a comparison with our samples, see Fig. 7: A, B). The results measured

for the glasses evaluated in this work correspond well to these data. Opacifiers of the calcium antimonate type were also commonly used for other colours to dampen their hue.

A completely different opacifier was found in the white glass of the seal box lid. This was SnO_2 , which is also confirmed by the tin content detected by the LA-ICP-MS method (nearly 14,000 ppm Sn compared to tens of ppm found in other white glasses). Typical Raman bands are at 474, 633 and 775 cm^{-1} according to *Gedzevičiūtė et al. (2009, 27)*.

Opaque blue glass

The blue colouring of glasses is the subject of many works (*Gratuze et al. 2018; Zlámalová Cílová et al. 2021*), which also discuss the various raw materials used over the centuries. Blue opaque glass was represented on fibulae from Sokoleč, Češov, Lipeč and Chotělice and baltei fittings from Jeníkovice and Plotišť. The blue colouring of these glasses is produced by cobalt (c. 850–2,000 ppm Co) and copper (c. 1,000–2,600 ppm Cu).

The contents of these colouring ions are completely different in bead no. 11 from Plaňany, namely only 39 ppm Co and a relatively high Cu content (9,851 ppm). Due to the higher content of Sn (1,179 ppm) and Zn (924 ppm) in the glass of the bead compared to mostly units of ten with other glasses (or enamels), it is possible to conclude that copper was added 'in the form of the oxide scale formed upon heating scrap bronze', or brass (e.g. after *Freestone 2021*). A difference in the white glass compared to the other white glasses/enamels in the assemblage was also found for this bead. The detected Sb content is c. 9,000 ppm, while for white enamels this value starts at c. 27,000 ppm Sb. It is obvious that the bead is different from the other glasses in the assemblage. A higher tin content (c. 1,200 ppm Sn) was also found in the blue-green enamel on the lid of the seal box. Enamel contains high amounts of copper (nearly 22,000 ppm Cu), but cobalt is again present in relatively small amounts (units of ppm).

Another difference in this assemblage appeared in the PbO content. While for non-opacified blue glasses the value of Pb was determined to be 39 ppm, for the glass of bead no. 11 from Plaňany it was 1,990 ppm, for the enamel of the lid from Stradonice c. 3,400 ppm, so for most opacified glasses the values are considerably higher (even over 20,000 ppm Pb). Even in the aforementioned mosaic cubes from Noheda, PbO was determined in the range 1.00% < PbO < 2.13% for certain blue and turquoise glasses. *Schibille (et al. 2020)* states that this may be due to the use of a lead-rich antimony ore, a calcination procedure that involved the use of lead to refine the antimony minerals, or simply the result of recycling processes.

As another possible criterion for classifying blue glasses (or determining raw materials), *Gratuze et al. (2018, 5)* mentions the CoO/NiO ratio. His work charts the use of cobalt-based dyes in glass during the first millennium AD. For Roman glass, the following range of the ratio $24 < \text{CoO/NiO} < 54$ is given, which at the end of the 4th century AD changes to lower values. A relatively consistent value of c. 26 was found for blue enamel fibulae from Sokoleč, Češov, Lipeč and the balteus fitting from Plotišť. A higher value (40) was determined for the balteus fitting from Litoměřice (blue in millefiori decoration) and the range of the value was beyond the limit for bead no. 11 from Plaňany (only 2) and the fibula from Chotělice (~17).

However, the resulting colour shade of all opacified samples was affected by the presence of an opacifier based on calcium (calcium antimonates). In addition to this opacifier, the mineral romeite $(\text{Ca,Fe,Mn,Na})_2(\text{Sb,Ti})_2\text{O}_6(\text{O,OH,F})$ was identified in the turquoise

enamel of the lid of the seal box. *Basso et al. (2014, 241)* describes the occurrence of the romeite phase separately and together with calcium antimonate opacifiers.

Yellow and green glasses

Another group of evaluated glasses/enamels is in shades of yellow or green (see *Fig. 5: F*). The green colour of the glasses is certainly influenced by the Cu content (up to nearly 30,000 ppm compared to about 400 ppm for yellow glasses). A clear connection was found between the content of antimony and lead (components of opacifiers of green and yellow glasses). Some glasses also have higher tin contents (hundreds higher, up to nearly 2,000 ppm for sample 6). *Schibille (et al. 2020, 12)* assumes the introduction of tin with a lead raw material (for the yellow tesserae). The dependency of lead and tin was also found in yellow glasses in our assemblage and can therefore be added to this observation. However, in the case of green glasses, there is more of a connection between the content of copper and tin, so the possibility of introducing tin together with copper, e.g. in the form of a copper alloy or some slag, comes into consideration.

Both green and yellow enamels have a relatively high PbO content (higher percentage units of PbO; the exception is bead no. 9 from Plaňany), which is related to the identified opacifier. $\text{Pb}_2\text{Sb}_2\text{O}_7$ was confirmed by Raman spectroscopy. Raman bands of this phase at 142, 332, 450 and 506 cm^{-1} were described, for example, in *Gedzevičiūtė et al. (2009, 26)*. In combination with blue glass, this yellow opacifier produces the resulting green shades. In the case of yellow glass, the contents are copper (max. 300 ppm Cu) and cobalt (single-digit ppm Co), so the blue component of the glass has no effect and only the colouring caused by yellow opacifier remains.

A certain shift was generally observed between the Raman spectra of green and yellow enamels. While the characteristic intense band at 140 cm^{-1} (stretching vibration of Pb-O) was determined (by us) in the case of yellow enamels, the band shifts to c. 127 cm^{-1} in the case of green enamels. As mentioned above, both types of enamels contain tin and certain modifications of the structure (in the sense of Sn-modified lead antimonates) can therefore be expected. According to the literature (*Vandini – Fiorentino 2020*), the spectrum (*Fig. 7: C*) shows a typical decrease of the band at about 511 cm^{-1} (symmetric stretching of the SbO_6 octahedron), which indicates lead antimonate with tin. Lead-tin antimonate is quite uncommon in Roman mosaic glass, and authors (*Basso et al. 2014, 242*) propose a hypothesis of the *corpo* (opacifier-rich glass added to the base glass) as a technological expedient, because the intentional addition of lead and antimony compounds to a soda-silicate glass would cause the dissolution of lead oxide and the crystallisation of calcium antimonate instead of lead antimonate. The raw materials used to prepare the *corpo* were mainly lead and antimony compounds, probably sulphides, such as galena (PbS) and stibnite (Sb_2S_3). Tin, present in the crystal lattice of antimonates, could have been introduced in the batch from the gangue of minerals used as raw materials for the preparation of the *corpo*. Other traits typical for this substitution include a shoulder at about 450 cm^{-1} and appearance/increase band at about 330–350 cm^{-1} (*Basso et al. 2014, 241*).

Red glasses

The red enamel samples have a different composition than ordinary natron glass. The contents of MgO , P_2O_5 , K_2O , SrO are higher – these components are indicators of plant

ashes. Again, glasses have higher contents of lead, but also of iron. In the case of red glasses, lead helps achieve the red colour. Moreover, enamels containing lead have a lower viscosity, which facilitates workability; the lead content is also undoubtedly adjusted for good enamel-metal substrate thermal expansion mismatch agreement. *Henderson (1991, 73)* also describes a higher iron content (1.87%) in red enamels with a similar composition. It is the content of iron or another reducing agent (including plant ash) that is necessary for the creation of a red colour.

According to the literature (e.g. *Basso et al. 2014, 239; Schibille et al. 2020, 7*), the red glasses of this period are coloured and simultaneously opacified with elemental copper or Cu_2O (cuprite) particles. The second phase forms dendrites in the glass, which were not observed, and thus the presence of copper particles can be assumed.

In red glass coloured by copper metallic particles, the Raman spectra may indirectly reveal the presence of Cu^0 nanoparticles only through the modification of the polymerisation degree of the silica network around the metallic particle (*Basso et al. 2014, 244*). This is evident in *Fig. 7: D*. According to *Colomban and Schreiber (2005, 888)*, it can be added that the discussed polymerisation degree is visible in Raman spectra of red $(\text{Cu}^0)_n$ -containing glasses at c. 550 and 1,080 cm^{-1} cm.

Schibille et al. 2018 states that copper particles are more likely to form in glass with a lower copper content in the presence of a reducing agent² such as iron, as previously noted. Conversely, the formation of cuprite particles is common in glasses with high copper and lead contents. Sub-micrometric particles varying from 100 to 200 nm in size, homogeneously interspersed in the glassy matrix, were found, e.g. in a red mosaic cube dated to the 2nd century AD (*Basso et al. 2014, 243*). Similar particles are also visible in our sample see *Fig. 6: D*.

All the samples (in our work) coloured by Cu contain minor amounts of Sn mainly between 1,148 ppm (bead no. 10 from Plaňany) to 12 972 ppm (enamel lid of seal box from Stradonice). This could be taken as an indicator of the use of bronze instead of pure copper as an admixture to the glass melt (*Basso et al. 2014, 244*; this work lists for Sn glasses ~1,600–2,900 ppm). However, the enamel of the Stradonice³ artefact again differs in its overall composition; nearly 13,000 ppm Sn was found compared to the other enamels with values in the range of c. 1,250–3,500 ppm. In contrast, a very low Sn content was found in bead no. 11 from Plaňany (22 ppm). Both of these samples also differ from the others in their Sb content, where 653 ppm Sb was determined for the seal box and 11,614 ppm for the bead (the other samples are in the range of c. 1,100–4,180 ppm). Differences were also found in the PbO content, which is up to 0.5% in the beads, up to 10% in enamels.

Metals

Fibulae from Sokoleč, Lipec and Chotělice, as well as balteus fittings from Jeníkovice and Plotišť nad Labem, were made of a lead-tin bronze alloy with a small share of zinc ($\text{Zn} = 1.7\text{--}4$ wt%) (for details, see *Online Supplementary Materials 5 – Tab. 3*). The Sn content is relatively uniform in the 8.5–11 wt% range. According to the share of lead, two

² An oxidising atmosphere produces divalent Cu and therefore a light blue translucent glass (*Gedzevičiūtė et al. 2009*).

³ The sample also contains a higher amount of As (833 ppm compared to lower tens in the other samples).

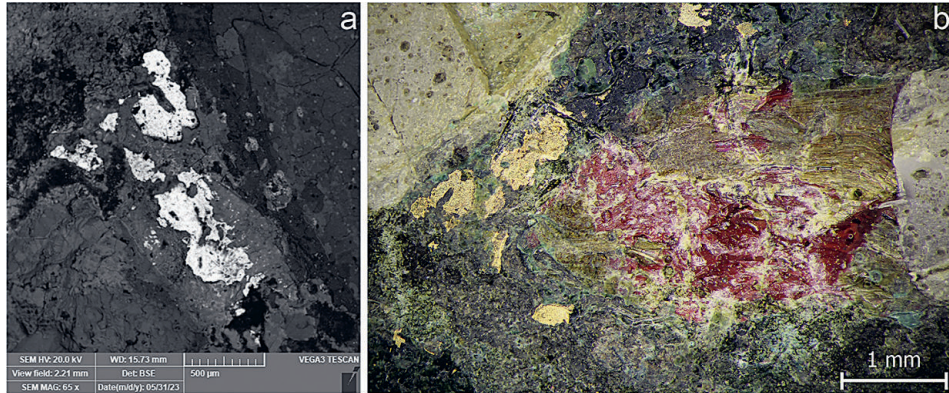


Fig. 8. a – Detail of traces of gilding on seal box lid from Stradonice, Tescan Vega 3 LMU scanning electron microscope (SEM); b – detail of gilding with Olympus SZX9 stereo microscope.

basic groups can be divided with a higher proportion of Pb from 7.4 to 9.1 wt% (Lipec, Chotělice and Češov) and with a lower proportion of Pb from 2.9 to 3.6 wt% (Sokoleč, Jenkovice and Plotiště). The studied artefacts can be assigned to groups 20/21 after *Riederer (1998, 200)*. The high content of lead in the alloy in this group of artefacts indicates the deliberate alloying of bronze with lead. A lead-tin bronze alloy with a lower share of zinc was widely used in Roman-provincial products (cf. *Vích et al. 2020, 177*). A lower share of zinc indicates subsequent recycling of brass and other copper alloys, which is typical of 2nd–3rd-century AD finds (*Rehren 2002, 150*). This phenomenon can be observed both in the Roman-provincial territory and also in the Barbaricum (see e.g. *Vích et al. 2020, 176–177; Čistáková – Beneš 2024, 43–52*).

A lead-tin brass alloy (CuZnSnPb) was identified for the fibula from Češov and the balteus fitting from Litoměřice; (Zn = 7.3–7.9 wt%). Tin contents vary between 6.8 and 9.5 wt%, and in the range of 5.1–7.4 wt% in the case of lead. On the reverse side of the balteus fitting from Litoměřice, a thread was soldered with lead solder, which in its elemental composition corresponds to lead brass with an approximate zinc content of Zn = 22.3 wt% and lead Pb = 7.9 wt% (here it is appropriate to consider evidence of secondary repairs). These quaternary alloys of copper, tin, lead with a medium share of zinc (5–10%) can be assigned to category 21 after *Riederer (1998, 200)*. Ancient brass (aurichalcum) could contain from 5 to 28 (30) wt% Zn in the alloy. In Bohemia, we encounter artefacts with a higher share of Zn as early as the Late La Tène period (*Bursák et al. 2022, 2–3*). In the 1st century AD, we still encounter finds with a higher share of Zn = 23 wt%. In the course of the 2nd and 3rd centuries, the zinc content in brass begins to decrease, and already in the 3rd century a significant decrease is seen in the concentration of zinc in brass to 5–7 wt% (*Droberjar – Frána 2004, 444*). The use of brass as a substrate for enamel is debatable, as the released zinc diminishes the adhesion of the vitreous substance to the metal substrate (*Bateson 1981, 86; Hložek et al. 2015, 41*). In the case of our finds, it is brass with a lower share of Zn, which may not have affected the final product as a result.

The seal box from Stradonice made of lead bronze is somewhat different in its elemental composition. However, the bronze alloy in this case contains only a trace amount of zinc, probably an impurity from the ores used in the production of copper. The lead

content of this artefact is also high and represents a deliberate alloying of the bronze alloy with lead. The surface of the artefact was gilded with a gold alloy in some places, especially in the area of the decorative circle (*Fig. 8*). The gold alloy contains c. 6.1 wt% Ag and 3.2 wt% Cu. The analysis also confirmed the high content of mercury Hg = 9.3 wt% in the gilding layer. The analyses indicate that the artefact was fire gilded, a technique well known from the Hellenistic period from the 3rd century BC in the Mediterranean area. Traces of mercury gilding are less numerous on Republican and Early Imperial finds, but amalgam gilding becomes the most common method already in the 2nd century (*Giunlia-Mair 2020, 5–7*).

Discussion

Finds of artefacts decorated with combined or millefiori enamel belong to the group of Roman-provincial products, which are also documented in the territory of the Barbaricum. Their production required specific skills associated with glassmaking technology. Standing out from the examined assemblage is the lid of the seal box from Stradonice, which is characterised by an unclear provenance, a specific technological design, but also a different composition of enamels. Here it is appropriate to think not only about the possibility of a foreign origin, i.e. that the artefact was assigned to the Stradonice collection by mistake, but at the same time the possibility of a period forgery cannot be ruled out. However, the production technology, which is typical for the Roman-provincial environment, testifies against this conjecture. Amalgam gilding was used from the Hellenistic period until the middle of the 19th century (*Giunlia-Mair 2020, 5*). The composition of the used enamel also corresponds to Roman products, even though the white segment was represented by a different opacifier compared to the other enamels. The detected SnO₂ opacifier was used since the 2nd century BC (*Wedepohl 2003, 28; Henderson 2013, 77*). Ca₂Sb₂O₇ and/or CaSb₂O₆ were detected in the remaining finds. The use of antimony as an opacifier began already in the middle of the 2nd millennium BC, specifically in Egypt and the Middle East, and over time it also appeared in Europe in the Late Iron Age and in the Antique environment (*Moretti – Hreglich 2013, 31*).

Although fibulae and balteus fittings at first glance represent a relatively uniform assemblage, differences can also be found here. Fibulae from Sokoleč and Lipec are characterised by decorative enamel made with the millefiori technique (*Fig. 5: C, D*). Despite the apparent similarity of these two fibulae, attention should be drawn to minor differences in design, where the fibula from Lipec is characterised by the uneven arrangement of a chequerboard pattern. A highly interesting element is the use of red glass to join the millefiori blocks in the fibulae from Lipec and Sokoleč (and many other Exner III 30-type fibulae found in the Barbaricum). This is a technological element, since the softening point of red lead glass is lower (650–750°C) than that of ordinary glass (800°C) (*Bateson 1981, 86; Henderson 1991, 65*). The red glass powder could thus serve as a kind of binder for the small cubes of the millefiori pattern, when the pattern was created, for example, using individual blocks of millefiori glass that could be joined together using glass powder. The glass mass was subsequently connected to a monochrome substrate by heating (*Henderson 1991, 65–67*). At the same time, it is a visually effective element, serving as a contrasting background for the blue and white pattern. Red glass used in enamelling is considered one of

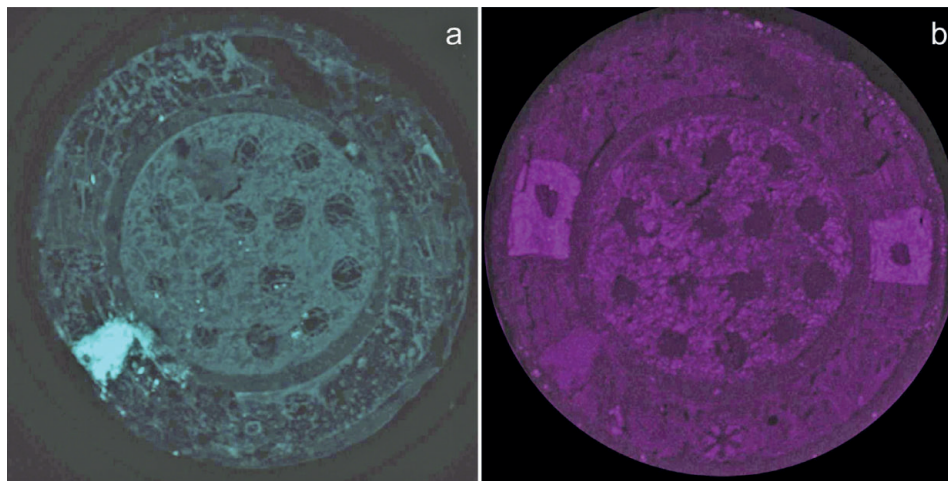


Fig. 9. Surface mapping of surface enamel layer of the fibula from Chotělice by micro-ED-XRF: a – Fe; b – Mn.

the most difficult colours to produce. In the case of all red glasses, this is a specific type characterised by a higher share of K_2O , MgO and P_2O_5 , which indicate the use of ash. In this case, we can rule out accidental contamination during melting, as this is a procedure associated with achieving better conditions for reduction and would improve the formation of the red colour, acting as a nucleant for the Cu particles (Bandiera 2022).

The study of the plate fibula from Chotělice revealed interesting findings regarding its original pattern. For the non-destructive survey of individual elements, surface element mapping was used (see Fig. 9). The survey revealed decoration in the form of the mosaic technique and small elements produced by the millefiori technique. An iron inlay was also identified. In the case of enamel fibulae, this is an atypical element, and we can assume that it was used for the purpose of repairing damage to the pattern. The edge border formed by a yellow-turquoise chequerboard pattern is close to a similar element from the balteus fitting from Jeníkovice and belongs to other popular patterns in the millefiori technique (Bateson 1981, 92–93). $Pb_2Sb_2O_7$ was detected, which was used both to opacify glass and to colour it yellow since the Bronze Age (Freestone 2021, 249–251) and was commonly used in prehistoric Egypt and Mesopotamia (Wedepohl 2003, 22). From a technical perspective, it is a fibula with coarser craftsmanship characterised by asymmetrical and poorly legible patterns.

In contrast, balteus fittings from Litoměřice and Jeníkovice were finely crafted products. We can observe artfully executed patterns on the fitting from Jeníkovice in the form of a coloured chequerboard. The fitting from Litoměřice is also characterised by finer patterning and it also features other motifs typical of the millefiori technique – eyes. Yet another element can be observed on the fitting from Litoměřice – a floral motif, which also appears on the fibula from Čěšov. Even in this case, it is a relatively popular and frequent motif for millefiori enamel.

A separate group consists of beads from Plaňany produced using the millefiori and mosaic glass technique. The internal structure of the beads was determined using a CT survey (Fig. 10). Bead no. 9 is characterised by the fact that the pattern is formed by sintering

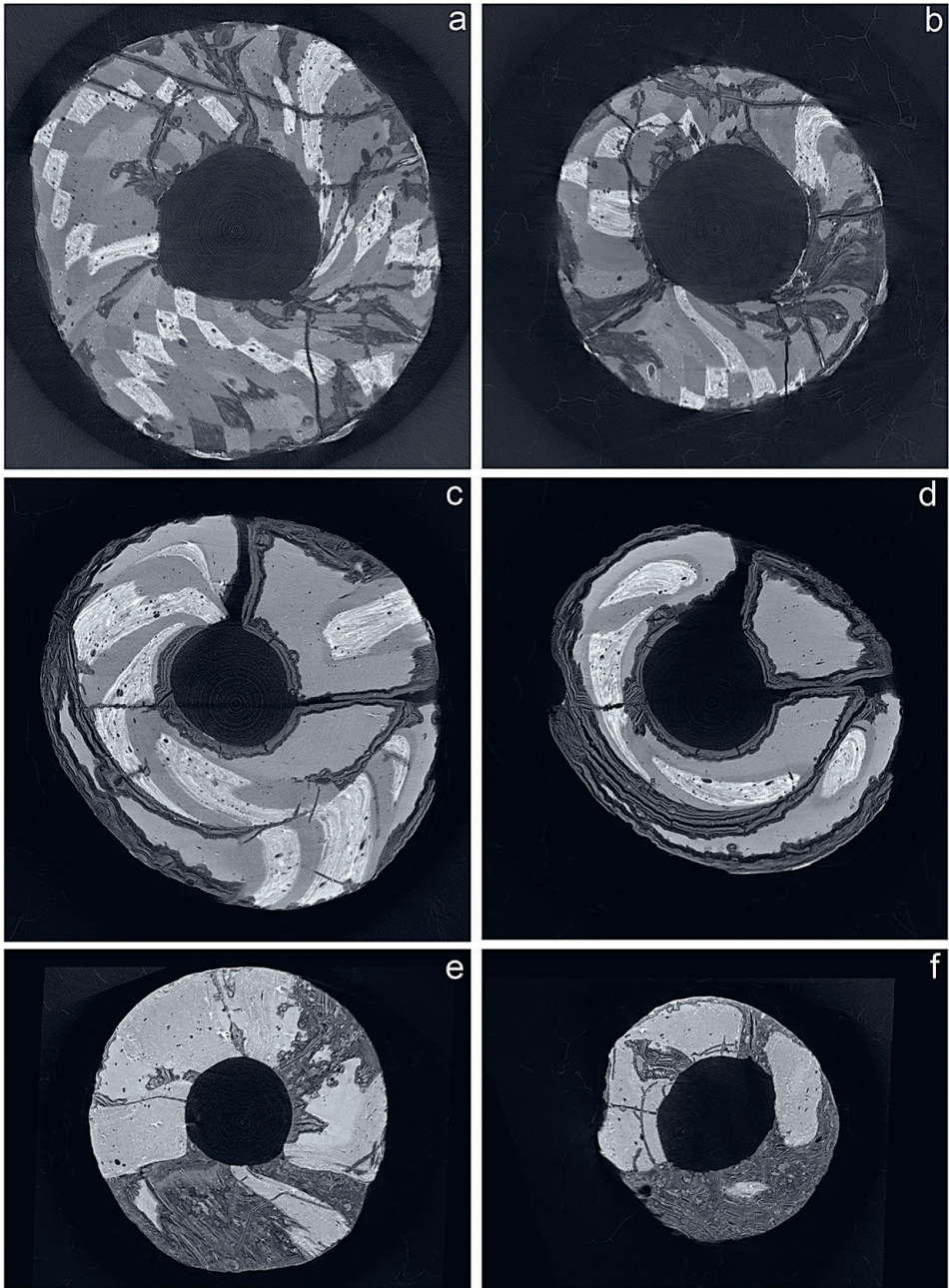


Fig. 10. a – Typical millefiori decoration in cross-section of bead no. 9. The different representation of shades of grey corresponds to glass segments with a distinct composition. b – The image of the section from the edge part of the bead clearly shows that the decoration is represented in the entire matrix. c – From the section of bead no. 10, one can infer the application of millefiori elements in red glass. Visible in the upper right is a nested segment made up of two types of glass; the three light stripes correspond to the white glass of the flower, while due to the streaking in the lower left it is clear that the segments with motifs are altered due to the shaping of the bead. d – In the border of the segment, it is evident that the flower decoration is no longer represented in the upper right part. e – The internal structure of bead no. 11 is more difficult to understand and considerable damage due to corrosion processes is evident (dark areas); however, the cutting of the individual glasses is visible in the right part, with the glass without white dots corresponding to the red glass and the white dots representing the larger opacifiers. For bead no. 10 and 11, the application of layers/decoration on the core can be ruled out based on the radial structure. f – In the edge parts, the glass of the bead is very corroded, and from all the photos (authors' archive) it appears that red glass is the least resistant glass to corrosion.

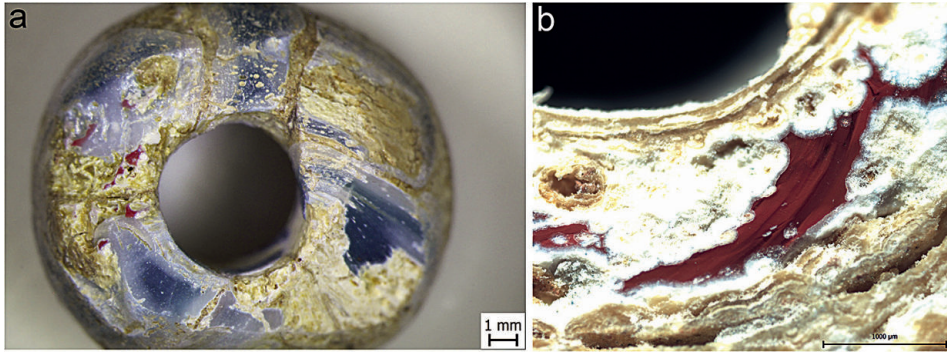


Fig. 11. Photography of red glass: a – bead no. 10, Plaňany; b – bead no. 11, Plaňany. Olympus SZX9 stereo microscope.

coloured rods into the desired patterns, as is known on millefiori vessels (Antonaras 2012, 19). Subsequently, the glass was shaped, resulting in the deformation of part of the patterns. In the case of bead no. 10 and 11, the individual coloured segments were set in a basic matrix of red glass, a technique that is also known with enamel (Bateson 1981, 92–93). In addition, it was revealed during the investigation that the examined beads were originally made of red glass, which changed its colour to white and/or yellow due to aggressive corrosion (Fig. 11).

The fibulae and balteus fittings presented here are typical representatives of Roman-provincial products, both in terms of their morphology and the material used in their production. For the individual artefacts, specific technological traits can be observed in the decoration, but also in the composition of enamels, thus testifying to the existence of different workshops. At the same time, two basic groups of glass from Egypt and the Levant can be recognised; these are the primary workshops that supplied the Roman-provincial glassworks. Based on the experimental production of enamel decoration, an open hearth or a smaller simple furnace would have been sufficient for the secondary workshops. For enamel workshops, we still lack direct evidence of this production activity. This craft activity can also be associated with glass workshops. Thierry (1962, 66) considers that the main production of artefacts with millefiori could have been concentrated in the territory of Gaul and in the Rhine provinces, i.e. areas famous for their glassworks. For example, such workshops can be assumed in the area around Cologne, a renowned glassmaking centre. Workshops may also have existed in Trier and Mainz (Riha 1979, 30). The production of fibulae is documented in Brigetio, where it is also assumed that enamel fibulae were produced (Sáró 2020, 117–118). In the territory of today's Belgium, we can mention a hypothetical workshop in the Roman Villa d'Anthée in the province of Namur (Pelpel – Vernou 2019, 260). Four ingots (blocks) of red opaque glass used for the production of red enamels were found in a vicus in Castelford (England). This material could also have been used as a foundation for millefiori. Based on numerous finds of fibulae, the existence of an enamel workshop can be assumed in the 1st–2nd century AD (Bayley 2005, 71–74). Evidence of enamel production also comes from the Dacian camps of Ilişua and Tibiscum (Benea 2016, 782–786, Abb. 6: 3, 4).

Conclusion

Artefacts decorated with mosaic and millefiori glass – imports originating from various Roman-provincial workshops – rank among visually attractive artefacts of the Roman Period. On the other hand, disc fibulae with millefiori enamel are typical representatives of plate fibulae and are found almost throughout the entire Barbaricum. Their concentrations in the Tisza and Elbe river regions show that they were especially popular here, almost exclusively in the furnishings of women's graves. After all, various plate fibulae are typical for them, whether they were artefacts of domestic (barbarian) or Roman-provincial origin. In the period around the Marcomannic Wars and in the first half of the 3rd century, various fibulae decorated with enamel represent a very widespread group; at the same time, this is the period in which imports of Roman-provincial fibulae to Bohemia culminated. Roman-provincial imports of militaria – represented in our case by circular baltei fittings with millefiori decoration – also peak at this time. However, due to the unclear provenance of the seal box found at the Stradonice oppidum, we can assume its origin outside the territory of the Czech Republic. Millefiori and mosaic glass decoration also appears on a group of glass beads, represented by three finds from a rich female grave from Plaňany dated to the second half of the 3rd century. Glass beads are among typical grave goods in women's graves of the Late Roman Period, though millefiori (and mosaic) beads rank among the less common bead types in our country.

A comprehensive archaeometric approach to artefacts of this type is rare not only in the Czech Republic. Specifically, less attention is paid to the study of enamels and information on their chemical composition, including trace elements, is nearly absent. The study determined that the composition of the glass used for the production of mosaic or millefiori enamel corresponds to Roman soda-lime-silica glass, i.e. so-called soda glass, which was produced in the Middle East and Egypt using natural natron. The exception is red glass, which is characterised by a higher percentage of PbO and a higher iron content; thus, additional raw materials added to the basic natron glass can be assumed. Higher shares of K₂O, MgO and P₂O₅ were also detected, indicating the use of plant ash as a reducing agent.

The analysed enamels contain a wide range of known dyes and opacifiers used in the colouring of Roman glass (specific phases were confirmed by Raman spectroscopy). The determined composition of the glasses indicates the use of different colouring raw materials and therefore different production workshops. This was evident in the case of blue glasses, which were also evaluated based on the CoO/NiO ratio, and then with white glasses, when various 'subtypes' of glasses could be distinguished on the basis of MgO. The represented opacifiers were predominantly antimony-based, with the exception of the determination of SnO₂, which is found in smaller quantities in glasses from this period. The antimony-based opacifiers make it impossible to classify the glasses into the typical groups of this period (Roman-Sb, Roman-Mn, or the recycled Roman-Sb-Mn type of glass). This fact should be taken into account when evaluating this type of opacified glass. It cannot be ruled out that the introduced raw material, or rather the admixtures and impurities, does not affect the overall composition of the soda glass. Glass corrosion and mechanical damage have a significant impact on the resulting colour of studied artefacts, e.g. the original red colour of the beads from Plaňany was heavily altered by corrosion process and was finally identified only on a micro-section.

It was confirmed during the investigation of the production technology of the studied artefacts that red glass, due to its composition and related properties, was used as a certain fixation medium/material. The use of micro-CT was highly useful in the study of manufacturing technologies. Using this method, the production of the Plaňany beads was clearly determined and the application of a mosaic strip to the glass core was ruled out.

Due to the composition and microscopic analysis of the surface, it was possible to focus on the technological specifics of millefiori glass production. Several objects belonging to the same typological group, such as fibulae from Lipec and Sokoleč, were probably produced in different workshops. A similar situation could be observed on the beads from the Plaňany female grave, where millefiori beads were made of different glass and with the use of various colouring raw materials. The fibula from Chotělice is characterised by poor craftsmanship, and there was also a later repair in the form of an iron inlay. Here it is appropriate to consider various provincial workshops that produced beads, fibulae and fittings for the barbarian market. It is thought that these workshops were located primarily on the Roman Limes, from where they could distribute products both within the provinces and beyond – into the Central European Barbaricum. A documented example of this type is represented by the workshops in Tibiscum (1st-century Tibiscum) on the border of the province of Dacia (*Benea 2004*). Judging by the distribution map of Exner III 30 plate-type fibulae presented here (*Fig. 3*), these workshops can be assumed on the Danube opposite the Sarmatian settlement in the Tisza Valley and in the Upper and/or Middle Danube Region opposite settlements of the Elbe Germans in Bohemia and in central and northern Germany. Since this is one of the first studies of Roman millefiori (enamel) artefacts in Central Europe, we cannot define the manufacturing circuits. For these purposes, it is necessary to expand the sampling set based on various artefacts with enamel decoration.

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References

- Adler, H. 1994:* KG Ringelsdorf, OG Ringelsdorf-Niederabsdorf, VB Gänserndorf. *Fundberichte aus Österreich* 33, 583.
- Antonaras, A. C. 2012:* Fire and sand. Ancient Glass in the Princeton University Art Museum. Princeton University Art Museum.
- Bandiera, M. 2022:* Technological study and chemical-archaeometric characterization of Roman opaque red glass from opus sectile decoration in the Lucius Verus Villa, 2nd century AD. Lisboa: Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa. Unpublished PhD thesis.
- Basso, E. – Invernizzi, C. – Malagodi, M. – La Russa, M. F. – Bersani, D. – Lottici, P. P. 2014:* Characterization of colorants and opacifiers in roman glass mosaic tesserae through spectroscopic and spectrometric techniques. *Journal of Raman Spectroscopy* 45, 238–245. <https://doi.org/10.1002/jrs.4449>
- Bateson, J. D. 1981:* Enamel-working in Iron Age, Roman and Sub-Roman Britain. The Products and Techniques. *British Archaeological Reports British Series* 93. Oxford: British Archaeological Reports.
- Bayley, J. 2005:* Roman enamel and enamelling: new finds from Castleford, Yorkshire. In: *Annales du 16e Congrès de l'Association Internationale pour l'Histoire du Verre*, London 2003, Nottingham: AIHV, 72–74.
- Becker, M. – Bemmman, J. – Laser, R. – Leineweber, R. – Schmidt, B. – Schmidt-Thielbeer, E. – Wetzel, J. 2006:* *Corpus der römischen Funde im europäischen Barbaricum. Deutschland. Band 6. Land Sachsen-Anhalt.* Bonn: Dr. Rudolf Habelt GmbH.

- Bemmann, J. – Hahne, G. 1994:* Waffenführende Grabinventare der jüngeren römischen Kaiserzeit und Völkerwanderungszeit in Skandinavien. Studie zur zeitlichen Ordnung anhand der norwegischen Funde. Bericht der Römisch-Germanischen Kommission 75, 283–640.
- Benea, D. 2004:* Die römischen Perlenwerkstätten aus Tibiscum. Timișoara: Excelsior Art.
- Benea, D. 2016:* Werkstätten für Buntmetallverarbeitungen in der Provinz Dakien. In: H.-U. Voß – N. Müller-Scheeßel (eds.), Archäologie zwischen Römern und Barbaren. Kolloquien zur Vor- und Frühgeschichte 22,1. Bonn: Dr. Rudolf Habelt GmbH., 777–792.
- Blažek, J. 1995:* Die jung- und spätkaiserzeitlichen Skelettgräber in Nordwestböhmen. Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege 37, 139–161.
- Boschetti, C. – Kindberg Jacobsen, J. – Parisi Presicce, C. – Raja, R. – Schibille, N. – Vitti, M. 2022:* Glass in Rome during the transition from late antiquity to the early Middle Ages: materials from the Forum of Caesar. *Heritage Science* 10, 95. <https://doi.org/10.1186/s40494-022-00729-y>
- Böhme, A. 1972:* Die Fibeln der Kastelle Saalburg und Zugmantel. Saalburg-Jahrbuch 29, 5–112.
- Brems, D. – Degryse, P. 2014:* Trace Element Analysis in Provenancing Roman Glass-Making. *Archaeometry* 56, 116–136. <https://doi.org/10.1111/arc.12063>
- Bursák, D. – Danielisová, A. – Magna, T. – Pajdla, P. – Míková, J. – Rodovská, Z. – Strnad, L. – Trubač, J. 2022:* Archaeometric perspective on the emergence of brass north of the Alps around the turn of the Era. *Scientific Reports* 12, 374. <https://doi.org/10.1038/s41598-021-04044-7>
- Čistáková, V. – Beneš, Z. 2024:* The Vrbová Lhota Settlement – a Case Study of Germanic Elites in the 3rd Century AD in Central Bohemia. *Fontes Archaeologici Pragenses* 51. Praha: Národní muzeum.
- Colomban, P. – Schreiber, H. D. 2005:* Raman signature modification induced by copper nanoparticles in silicate glass. *Journal of Raman Spectroscopy* 36, 884–890. <https://doi.org/10.1002/jrs.1379>
- Derks, T. – Roymans, N. 2002:* Seal-boxes and the spread of latin literacy in the Rhine delta. In: A. E. Cooley (ed.), *Becoming Roman, writing Latin?* *Journal of Roman Archaeology, Supplementary Series* 48. Portsmouth, R.I.: IRA, 87–134.
- Droberjar, E. 2016:* Römische Fibeln aus Gräbern und Siedlungen des 1.–3. Jahrhunderts in Böhmen – eine Übersicht. In: H.-U. Voß – N. Müller-Scheeßel (eds.), *Archäologie zwischen Römern und Barbaren. Kolloquien zur Vor- und Frühgeschichte* 22. Bonn: Dr. Rudolf Habelt GmbH., 495–510.
- Droberjar, E. – Frána, J. 2004:* Antická mosaz (aurichalcum) v českých nálezech časné doby římské. *Archeologie ve středních Čechách* 8, 441–462.
- Droberjar, E. – Motyková, K. 2023:* Třebusice. Žárové pohřebiště z doby římské ve středních Čechách. Díl I. *Archeologické prameny. Spisy Archeologického ústavu AV ČR Brno* 76. Brno – Nitra: Archeologický ústav AV ČR, Brno, v. v. i. – Archeologický ústav SAV, v. v. i.
- Dušek, S. – Becker, M. – Eberhardt, I. – Grasselt, T. – Heising, A. – Künzel, H. – Peschel, K. – Schlapke, M. – Seidel, M. 2017:* Corpus der römischen Funde im europäischen Barbaricum. Deutschland. Band 8,1. Freistaat Thüringen. Teil 1: Südhartzvorland, Saale-Elster-Region, Thüringer Wald. Wiesbaden: Dr. Ludwig Reichert Verlag.
- Ettlinger, E. 1973:* Die römischen Fibeln in der Schweiz. Bern: Francke Verlag.
- Exner, K. 1941:* Die provincialrömischen Emailfibeln der Rheinlande. Bericht der Römisch-Germanischen Kommission 29, 31–121. <https://doi.org/10.11588/berrgk.1941.0.39757>
- Feugère, M. 1985:* Les fibules en Gaule méridionale de la conquête à la fin du Ve siècle après J.-C. *Revue archéologique de Narbonnaise Supplément* 12. Paris: Éditions du Centre National de la Recherche Scientifique.
- Freestone, I. C. 2021:* Glass production in the first millennium CE: a compositional perspective. In: F. Klimscha – H. J. Karlsen – S. Hansen – J. Renn (eds.), *Glas und Glasproduktion in Ur- und Frühgeschichtlicher Zeit. Berlin Studies of the Ancient World* 67. Berlin: Edition TOPOI, 245–263.
- Freestone, I. – Stapleton, C. P. 2015:* Composition technology and production of coloured glasses from Roman mosaic vessels. In: L. Bayley – I. C. Freestone – C. Jackson (eds.), *Glass of the Roman World*. Oxford: Oxbow, 61–76.
- Furger, A. R. – Wartmann, M. – Riha, E. 2009:* Die römischen Siegelkapseln aus Augusta Raurica. *Forschungen in Augst* 44. Augst: Augusta Raurica.
- Gedzevičiūtė, V. – Welter, N. – Schüssler, U. – Weiss, C. 2009:* Chemical composition and colouring agents of Roman mosaic and millefiori glass, studied by electron microprobe analysis and Raman microspectroscopy. *Archaeological and Anthropological Science* 1, 15–29. <https://doi.org/10.1007/s12520-009-0005-4>

- Giunlia-Mair, A. 2020:* Plating and Surface Treatments on Ancient Metalwork. *Advances in Archaeomaterials* 1, 1–26. <https://doi.org/10.1016/j.aia.2020.10.001>
- Gopkalo, O. V. 2008:* Busy i podveski chernyachovskoy kultury. Kyjiv: Institut archeologiji NAN Ukrainy.
- Gratuze, B. – Pactat, I. – Schibille, N. 2018:* Changes in the Signature of Cobalt Colorants in Late Antique and Early Islamic Glass Production. *Minerals* 8, 225. <https://doi.org/10.3390/min8060225>
- Grunzeza, L. 2015:* Cloisonné Brooches Discovered in Banat (Beginning of the Second Century A.D. – Last Third of the Third Century A.D.). *Ziridava Studia Archaeologica* 29, 191–214.
- Henderson, J. 1991:* Technological characteristics of Roman enamels. *Jewellery Studies* 5, 65–76.
- Henderson, J. 2013:* *Ancient Glass: An Interdisciplinary Exploration*. New York: Cambridge University Press.
- Hložek, M. – Komoróczy, B. – Trojek, T. 2015:* Techniky emailu v archeologii a jejich identifikace metodami SEM-EDX, XRF a micro-XRF. In: A. Selucká (ed.), *Výzdobné techniky kovů II*. Brno: Metodické centrum konzervace – Technické muzeum v Brně, 39–50.
- Humer, F. (ed.) 2009:* *Von Kaisern und Bürgern. Antike Kostbarkeiten aus Carnuntum*. Ausstellungskatalog. Wien: Amt d. NÖ Landesregierung.
- Jilek, J. – Horník, P. 2017:* Výzbroj a výstroj z doby římské ve východním Polabí. Hroby bojovníků a jejich interpretace. *Študijné zvesti Archeologického ústavu SAV* 62, 61–100.
- Jobst, W. 1975:* Die römischen Fibeln aus Lauriacum. *Forschungen in Lauriacum* 10. Linz: Oberösterreichisches Landesmuseum.
- Kaczanowski, P. 1992:* Bemerkungen zur Chronologie des Zustroms römischer Waffenimporte in das europäische Barbaricum. In: K. Godłowski – R. Madyda-Legutko (eds): *Probleme der relativen und absoluten Chronologie ab Latènezeit bis zum Frühmittelalter*. Kraków: Uniwersytet Jagielloński – Instytut archeologii, 171–186.
- Koch, U. 2001:* Das alamannisch-fränkische Gräberfeld bei Pleidelsheim. *Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg* 60. Stuttgart: Landesdenkmalamt Baden-Württemberg – Konrad Theiss Verlag.
- Kolník, T. 1965:* K typológii a chronológii niektorých spôn z mladšej doby rímskej na juhozápadnom Slovensku. *Slovenská archeológia* 13, 183–236.
- Kysela, J. 2020:* Things and Thoughts. Central Europe and the Mediterranean in the 4th–1st centuries BC. *Studia Hercynia, monographs* 1. Praha: Univerzita Karlova.
- Leineweber, R. 2021:* Zethlingen – ein Brandgräberfeld der spätrömischen Kaiserzeit aus der Altmark. Die Ausgrabungen der Jahre 1978–1988. Veröffentlichungen des Landesamtes für Denkmalpflege und Archäologie Sachsen-Anhalt – Landesmuseum für Vorgeschichte 83. Halle (Saale): Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt – Landesmuseum für Vorgeschichte.
- Lutovský, M. et al. 2023:* Terénní výzkumy Ústavu archeologické památkové péče středních Čech v roce 2022. *Archeologie ve středních Čechách* 27, 655–690.
- Mączyńska, M. – Urbaniak, A. 2006:* Prowincjonalnorzymska zapinka tarczowata z cmentarzyska kultury wielbarskiej w Babim Dole-Borczu, pow. kartuski. *Wiadomości archeologiczne* 58, 145–158.
- Meyer, E. 1969:* Das germanische Gräberfeld von Zauschwitz, Kr. Borna. *Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege Beiheft* 6. Berlin: VEB Deutscher Verlag der Wissenschaften.
- Moretti, C. – Hreglich, S. 2013:* Raw materials, recipes and procedures used for glass making. In: K. Janssens (ed.), *Modern methods for analysing archaeological and historical glass*. Chichester: John Wiley & Sons, Ltd., 23–47. <https://doi.org/10.1002/9781118314234.ch2>
- Musil, J. 1994:* Römische Waffen und Rüstung aus Böhmen. *Památky archeologické* 85, 5–14.
- Nowakowski, W. 2001:* *Corpus der römischen Funde im europäischen Barbaricum*. Polen. Band 1. Masuren. Warszawa: Institut für Archäologie der Warschauer Universität.
- Oldenstein, J. 1976:* Zur Ausrüstung römischer Auxiliareinheiten. Studien zu Beschlägen und Zierat an der Ausrüstung der römischen Auxiliareinheiten des obergermanisch-raetischen Limesgebietes aus dem zweiten und dritten Jahrhundert n. Chr. *Bericht der Römisch-Germanischen Kommission* 57, 49–284.
- Pelpel, L. – Vernou, Ch. 2019:* Vases émaillés d'époque romaine de la vallée de la Saône. *Revue archéologique de l'Est, Tome* 67, 249–266.
- Piř, J. L. 1892:* Žárové hroby na Třebické u Dobřichova z doby císařství římského. *Památky archaeologické a místopisné* 15, 561–598.
- Piř, J. L. 1903:* Čechy na úsvitě dějin. Svazek 2. Hradiště u Stradonic jako historické Marobudum. Starožitnosti země České díl II, sv. 2. Praha: J. L. Piř.

- Pleinerová, I. 1995:* Opočno. Ein Brandgräberfeld der jüngeren und späten Kaiserzeit in Nordwestböhmen. Kraków: Instytut archeologii Uniwersytetu Jagiellońskiego.
- Preidel, H. 1930:* Die germanischen Kulturen in Böhmen und ihre Träger. Erster Band: Die Kulturen. Kassel/Wilhelmshöhe: Johannes Stauda.
- Price, J. 2002:* Two Vessels from Llandoverly, Carmarthenshire, and Piercebridge, County Durham: A Note on Flavian and later Polychrome Mosaic Glass in Britain. In: M. Aldhouse-Green – P. Webster (eds.), *Artefacts and Archaeology. Aspects of the Celtic and Roman World*. Cardiff: University of Wales Press, 112–131.
- Przybyła, M. J. 2010:* Bemerkungen zu einigen lokalen Formen der Schwertgürtelschliessen vom sog. Balteus-Typ aus dem Barbaricum. *Recherches Archéologiques NS 2*, 93–184.
- Rehren, T. 2002:* Metallanalysen an römischen Fibeln aus der CUT. In: U. Boelicke, *Die Fibeln aus dem Areal der Colonia Ulpia Traiana. Xantener Berichte 10*. Mainz: Verlag Philipp von Zabern, 146–147.
- Reszczyńska, A. 2017:* Destičkovitá spona ve tvaru kance z Trmic – Ústí nad Labem v kontextu obdobných nálezů. In: E. Droberjar – B. Komoróczy (eds.), *Římské a germánské spony ve střední Evropě (Archeologie barbarů 2012)*. Spisy Archeologického ústavu AV ČR Brno 53. Brno: Archeologický ústav AV ČR, Brno, v. v. i., 339–345.
- Rey-Vodoz, V. 1986:* Les fibules gallo-romaines de Martigny VS. *Jahrbuch der Schweizerischen Gesellschaft für Ur- und Frühgeschichte 69*, 149–198.
- Riederer, J. 1998:* Ergebnisse der Atomabsorptionsspektalanalyse zur Materialauswahl in der Antike. In: H. U. Voss – P. Hammer – J. Lutz (eds.), *Römische und germanische Bunt- und Edelmetallfunde im Vergleich. Archäometallurgische Untersuchungen ausgehend von elbgermanischen Körpergräbern. Bericht der Römisch-germanischen Kommission 79*. Darmstadt/Mainz: Verlag Philip von Zabern, 200–203.
- Riha, E. 1979:* Die römischen Fibeln aus Augst und Kaiseraugst. *Forschungen in Augst 3*. Augst: Amt für Museen und Archäologie des Kantons Basel-Landschaft.
- Riha, E. 1994:* Die römischen Fibeln aus Augst und Kaiseraugst. *Die Neufunde seit 1975. Forschungen in Augst 18*. Augst: Römermuseum Augst.
- Rybová, A. 1979:* Plotiště nad Labem. Eine Nekropole aus dem 2.–5. Jahrhundert u. Z. I. Teil. *Památky archeologické 70*, 353–489.
- Rybová, A. 1980:* Plotiště nad Labem. Eine Nekropole aus dem 2.–5. Jahrhundert u. Z. II. Teil. *Památky archeologické 71*, 93–224.
- Sakař, V. 1970:* Roman imports in Bohemia. *Fontes Archaeologici Pragenses 14*. Pragae: Museum nationale Pragae.
- Sáró, C. 2020:* The fibula production of Brigetio: clay moulds. *Dissertationes Archaeologicae ex Instituto Archaeologico Universitatis de Rolando Eötvös nominatae Ser. 3. No. 8*, 117–140. <https://doi.org/10.17204/dissarch.2020.117>
- Schibille, N. – Boschetti, C. – Valero Tévar, M. Á. – Veron, E. – de Juan Ares, J. 2020:* The Color Palette of the Mosaics in the Roman Villa of Noheda (Spain). *Minerals 10*, 272. <https://doi.org/10.3390/min10030272>
- Schibille, N. – Neri, E. – Ebanista, C. – Mohamed Ramzi, A. – Bisconti, F. 2018:* Something old, something new: the late antique mosaics from the catacomb of San Gennaro (Naples). *Journal of Archaeological Science: Reports 20*, 411–422. <https://doi.org/10.1016/j.jasrep.2018.05.024>
- Schibille, N. – Sterrett-Krause, A. – Freestone, I. C. 2017:* Glass groups, glass supply and recycling in late Roman Carthage. *Archaeological and Anthropological Science 9*, 1223–1241. <https://doi.org/10.1007/s12520-016-0316-1>
- Skorupka, T. 2001:* Kowalewko 12. Cmentarzysko birytualne ludności wielbarskiej (od połowy I w. n.e. do początku III w. n.e.). *Archeologiczne badania ratownicze wzdłuż trasy gazociągu tranzytowego. Tom II Wielkopolska*. Poznań: Wydawnictwo poznańskie.
- Svoboda, B. 1948:* Čechy a římské Imperium. *Sborník Národního musea v Praze svazek II – A – historický*. Praha: Národní museum v Praze.
- Tempelmann-Mączyńska, M. 1985:* Die Perlen der römischen Kaiserzeit und der frühen Phase der Völkerwanderungszeit in mitteleuropäischen Barbaricum. *Römisch-germanische Forschungen 43*. Mainz am Rhein: Verlag Philipp von Zabern.
- Thierry, N. 1962:* A propos d'une nouvelle pyxide d'époque romaine à décor d'émail «millefiori». *Antike Kunst 5*, 65–68.
- Thomas, S. 1966:* Die provinzialrömischen Scheibelfibeln der römischen Kaiserzeit im freien Germanien. *Berliner Jahrbuch für Vor- und Frühgeschichte 6*, 119–178.

- Urbanová, M. 2015: Průřez dějinami smaltu a nástin jeho současné podoby ve volné umělecké tvorbě. In: A. Selucká (ed.), *Výzdobné techniky kovů II*. Brno: Metodické centrum konzervace – Technické muzeum v Brně, 21–38.
- von Uslar, R. 1938: Westgermanische Bodenfunde des ersten bis dritten Jahrhunderts nach Christus aus Mittel- und Westdeutschland. Germanische Denkmäler der Frühzeit 3. Berlin: Walter de Gruyter & Co.
- Vaday, A. 2003: Cloisonné brooches in the Sarmatian Barbaricum in the Carpathian Basin. *Acta Archaeologica Academiae Scientiarum Hungaricae* 54, 315–421.
- Vandini, M. – Fiorentino, S. 2020: From Crystals to Color: A Compendium of Multi-Analytical Data on Mineralogical Phases in Opaque Colored Glass Mosaic Tesserae. *Minerals* 10, 609. <https://doi.org/10.3390/min10070609>
- Venclová, N. – Hulínský, V. – Jonášová, Š. – Frána, J. – Fikrle, M. – Vaculovič, T. 2015: Hellenistic mosaic glass vessels in Bohemia and Moravia. *Archeologické rozhledy* 67, 213–238. <https://doi.org/10.35686/AR.2015.11>
- Vích, D. – Jílek, J. – Kmošek, J. – Biborski, M. J. – Biborski, M. R. – Martinek, J. 2020: Soubor kovových předmětů z doby římské z Boršova na Moravskotřebovsku. *Památky archeologické* 111, 159–192. <https://doi.org/10.35686/PA2020.4>
- Wedepohl, K. H. 2003: *Glass in Antike und Mittelalter. Geschichte eines Werkstoffs*. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung.
- Zlámalová Čilová, Z. – Gelnar, M. – Randáková, S. 2021: Trends in Colouring Blue Glass in Central Europe in Relation to Changes in Chemical Composition of Glass from the Middle Ages to Modern Age. *Minerals* 11, 1001. <https://doi.org/10.3390/min11091001>

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