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

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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. Shrnuta 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 vyplívají.

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,

https://doi.org/10.35686/AR.2025.260

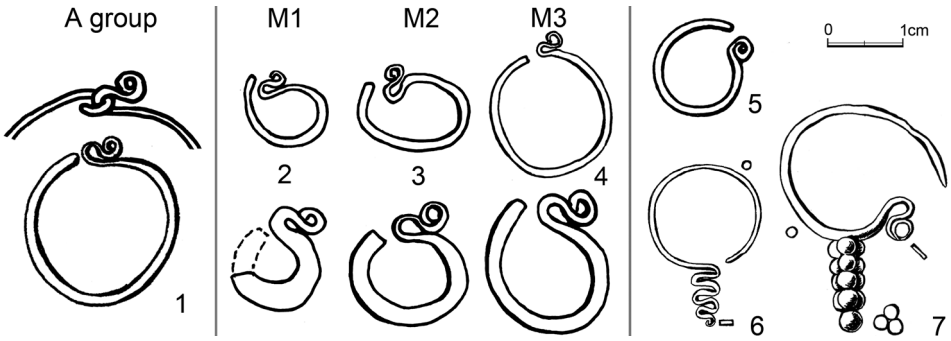


Fig. 1. Types of analysed jewellery. 1–4 – S-shaped temple rings; 5 – temple ring with an eyelet; 6 – meander-shaped earring; 7 – earring of Jízdárna type (after *Tomková et al. 2020a*, Fig. 94, 95, 98, 102, and 112, modified).

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.

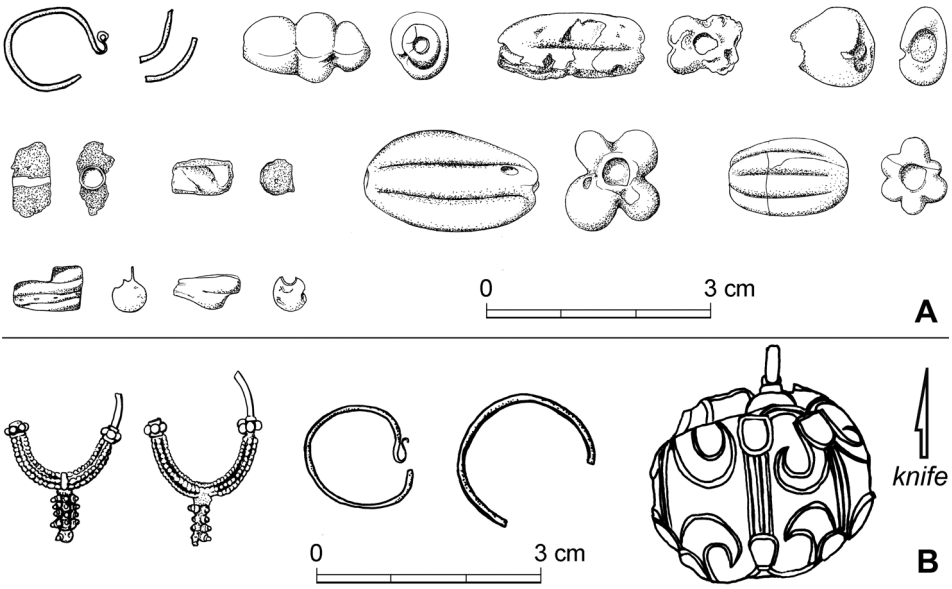


Fig. 2. Grave goods of radiocarbon-dated graves with S-shaped temple rings from Prague – Milady Horákové Street. A – grave 48; B – grave 83 (drawn by V. Pincová and M. Housková).

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. Píč 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 Píč – 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 Stehelčeves 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

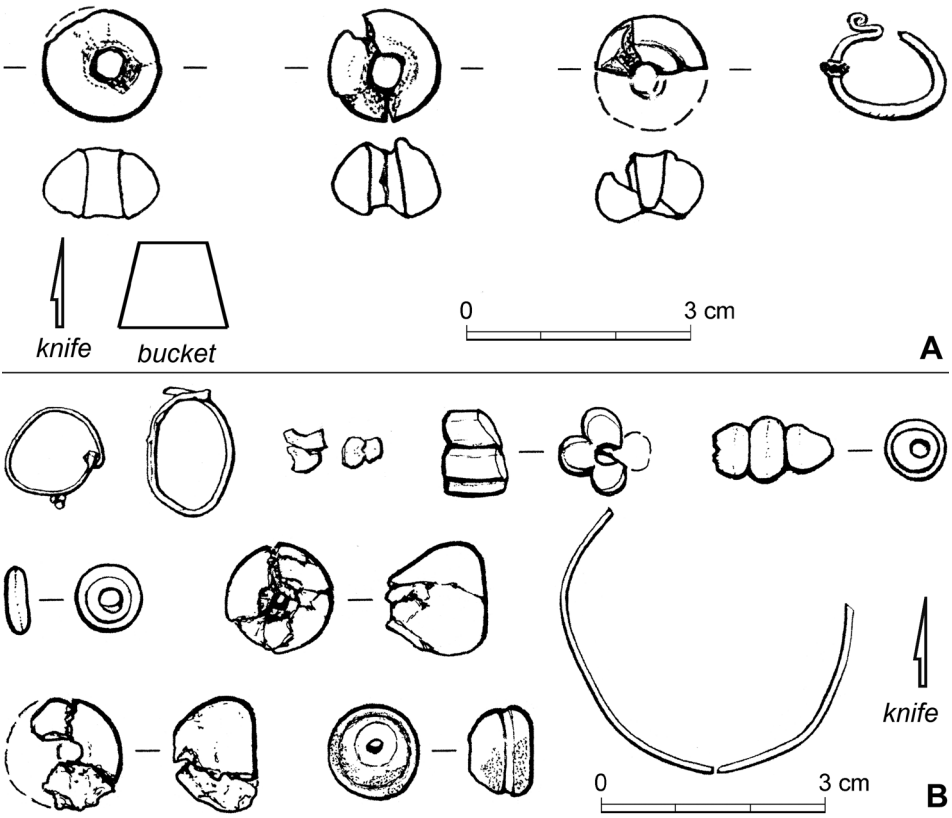


Fig. 3. Grave goods of radiocarbon-dated graves with hybrid earrings from Prague-Lahovice. A – grave 30-1/55; B – grave 389 (after *Krumphanzlová et al. 2013*, tab. 55, 94, modified by M. Housková).

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 rings[1] 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	*Borkovský 1947*, 146–147; *Tomková 2005*, 82–83, obr. 3/8
Klecany I	22/05 (male)	1		1						axe, knife, bucket, flint stone	*Profantová et al. 2015*, 88–89; *Profantová et al. 2010*, Tab. 18–19
Zákolany	4 (child)	2			2		Jízdárna type/2	x		2 earrings of unspecified type; pendant	*Šolle 1982*, 185, 188, 19, obr. 11: 1–8; questionable finding context
Prague 6 – Hradčany, Milady Horákové	83/2013 (child)	1			2	1				knife, iron artefact	*unpublished*
Prague 1 – Hradčany, Lumbe garden	99 (9/75, child)	2+6 damaged				2				crystal bead; knife	*Frolík – Smetánka 2014*, 165–167
Prague 1 – Hradčany, Lumbe garden	84 (4/72, child)	2			6	2			14	finger ring; segmented glass beads; egg; knife	*Frolík – Smetánka 2014*, 151–153
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	*Profantová et al. 2010*, Tab. 97, Fototab. 81 a 94, *Profantová et al. 2015*, 144
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	*Mařík 2009*, 89–90, Tab. 42

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).

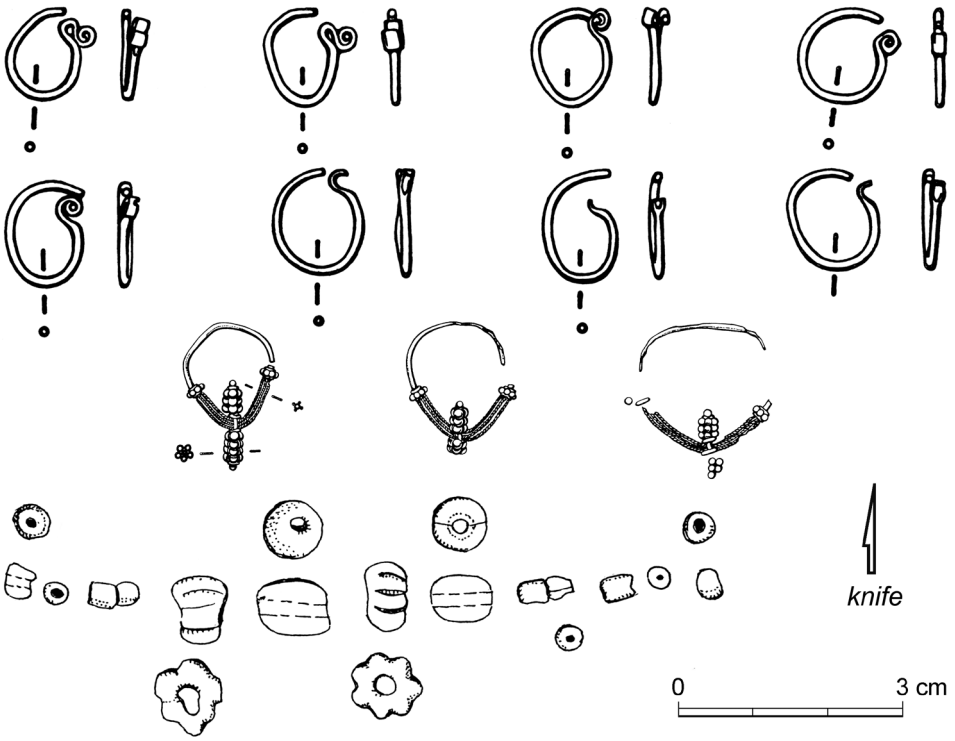


Fig. 4. Grave goods of grave 28 from Klecany II. Set combining S-shaped temple rings, temple rings with an eyelet, and granulated jewellery (after *Profantová et al. 2010*, Fig. 97, modified by L. Raslová).

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*).

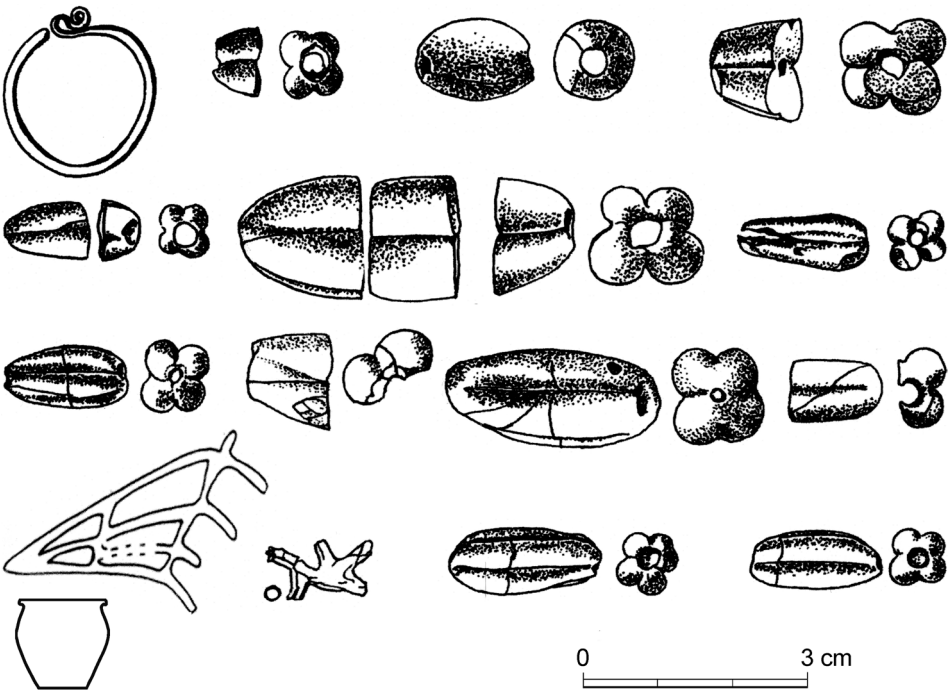


Fig. 5. Grave goods of radiocarbon-dated grave 33 from Žalov – Na Panenské containing S-shaped temple rings of group A (after *Tomková 2012b*, Fig. 157, modified by M. Housková).

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 – Žďárská 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),

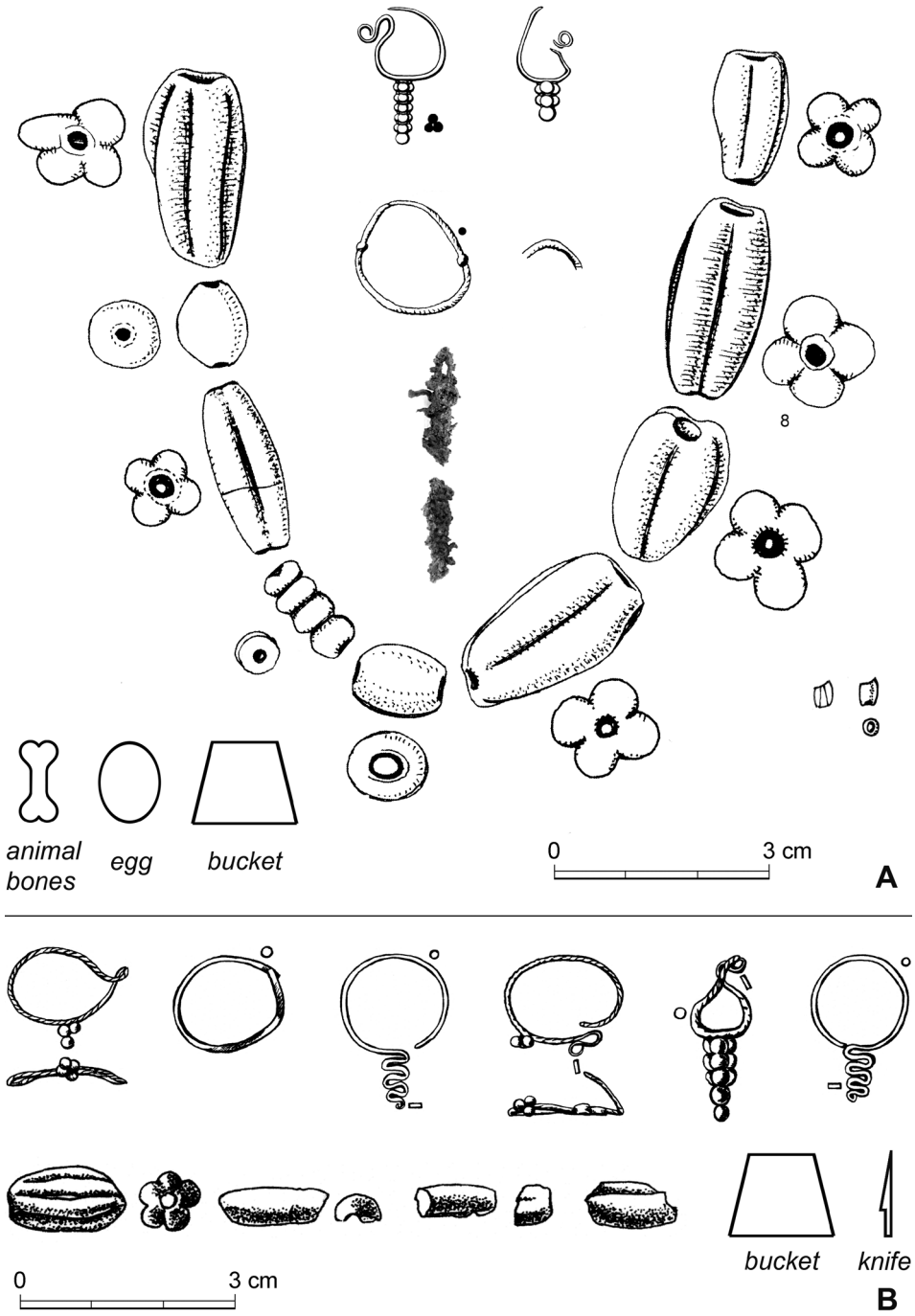


Fig. 6. Grave goods of radiocarbon-dated graves with Jízdárna-type earrings. A – Klecany I, grave 54; B – Žalov – Na Panenské, grave 24, also with meander-shaped earrings (after *Profantová et al. 2010*, Fig. 45 and *Tomková 2012b*, Fig. 149, modified by L. Raslová and M. Housková).

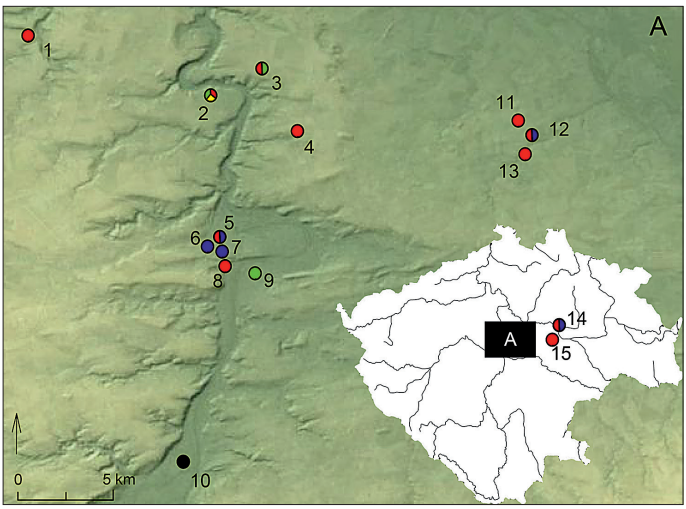


Fig. 7. Map of radiocarbon-dated sites. 1 – Kováry – Na Týnici; 2 – Žalov – Na Panenské, 3 – Klecany I; 4 – Dolní Chabry; 5 – Prague – Milady Horákové Street; 6 – Prague–Triangl, 7 – Prague Castle – Church of the Virgin Mary; 8 – Prague – Vratislav Palace; 9 – Prague-Klementinum; 10 – Prague–Lahovice; 11 – Přezletice; 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, Vinoř – V Žabokřiku, and Přezletice). 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 *Bíšková 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.

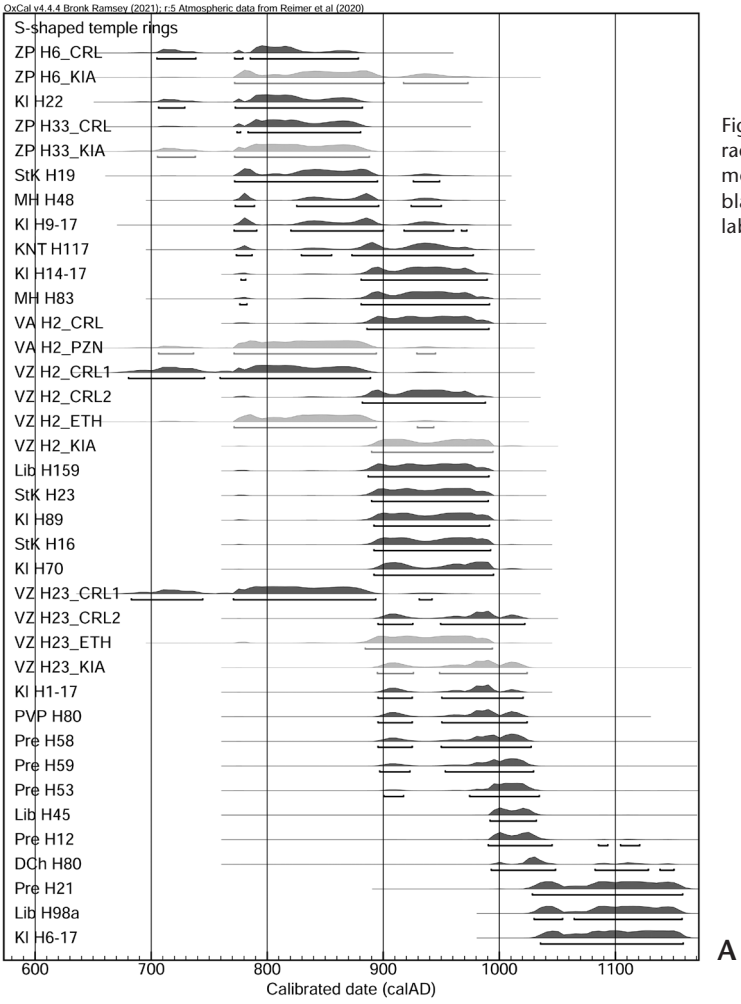
We dated only one sample for most of the burials. By this procedure, we aimed to obtain a larger set of data from different sites. We believe that this approach is sufficient to capture trends in the development of jewellery. If the obtained data did not correspond to the previous research, we made repeated 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).

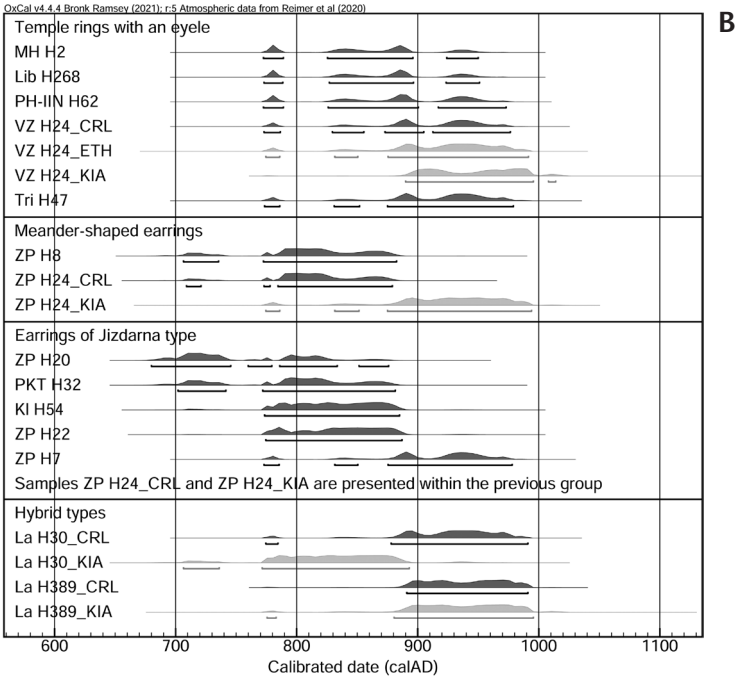
A. S-shaped temple rings					
Grave	Abbreviation	Grave goods	Anthropological determination	Anthropological inventory no., NM Prague	References
Dolní Chabry, Church of the Beheading of St. John the Baptist H80/1974	DCh H80	**1 silver S-shaped temple ring**, Ø 16x18 mm, wire thickness 3–3,3 mm; necklace with an 1 fluorite and 9 glass beads	child (3–4 years)	unspecified	*Dragoun – Tryml 2022*, 208, Obr. 219, Tab. 2, 5; *Havrda – Tryml 2021*, 295, Obr. 85–87; Tab. 1
Klecany I, H22/2005	Kl 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	*Profantová et al. 2010*, Tab. 14, 15; *Profantová et al. 2015*, 25, 26
Klecany I, H70/2007	Kl 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	*Profantová et al. 2010*, Tab. 64; *Profantová et al. 2015*, 36
Klecany I, H89/2008	Kl 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	*Profantová et al. 2010*, Tab. 80, 81; *Profantová et al. 2015*, 40–41
Klecany I, H1/2017	Kl 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	Kl H6-17	**1 S-shaped temple ring** (copper alloy ?), Ø 14x11mm (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	Kl 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	Kl 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 – Krutina 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	*Koštová 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 exeplars are silver plated)**, Ø up to 20 mm, wire thickness 1,8–4 mm	juvenis (16 years)	P7A 30 220	*Koštová 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 an corroded glass bead; amber biconical bead; iron fragments; 1 knife	child, infans II–III	P7A 31 113	*Koštová 2014*, 220–222, Tab. 7; *Turek 1978*, 62–64
Prague 1 – Lesser Town, Vratislav 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 – Tryml 2021*, 223–226; Obr. 6–7, 17; Tab. 1
Prague 6 – Hradčany, Milady 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, Milady 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 or temple ring; 2 silver earrings with a grape pendant; 1 silver damaged spherical button (gombík); 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 (gombík); 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 Žabokřiku, H2/2009	VZ H2_CRL1, VZ H2_CRL2, 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 Žabokřiku, 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
Přezletice, 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 thicknes of copper alloy items 2,1 and 2,2 mm	juvenis (12–14 years)	P7A 43 562	*Koštová et al. 2022*, 231, obr. 12
Přezletice, 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	*Koštová et al. 2022*, 202, 233, obr. 12
Přezletice, 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	*Koštová et al. 2022*, 244–245, obr. 12
Přezletice, 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	*Koštová et al. 2022*, 239–241, obr. 12
Přezletice, 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	*Koštová et al. 2022*, 246, obr. 12

Stará Kouřim, U Libuše, 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 Kouřim, U Libuše, 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 Kouřim, U Libuše, H23/1956	StK H23	**1 S-shaped temple ring** made of copper alloy, Ø 13x13 mm, wire thickness 1 mm; necklace with an 3 amber beads, 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: 11 olive, 1 rounded and 2 polychrome (rounded and fr. of segemented 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 (kaptorga); 4 silver beads with granulation; 2 silver spherical buttons with bosses (gombík); 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	*Koštová 2014*, 292–298, Tab. 17–18; *Turek 1978*, 121–124
Prague 1 – Hradčany, Church of the Virgin Mary, H IIN062	PH-IIN 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, H2/2011	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 – Střešovice, 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 knifes	female?, adultus II – maturus I (30–45 years)	unspecified	*Frolíková-Kaliszová et al. 2023*, 59–62, Obr. 29–31
Prague 9 – Vinoř, V Žabokřiku, 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; *Koštová 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 Jízdárna 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	Kl H54	**2 copper/gilded-copper earrings of Jízdárna 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, Fototab. 39; *Profantová et al. 2015*, 32, 33
Prague 1 – Old Town, Klementinum, H32/2012	PKt H32	**1 gilded earring of Jízdárna type**; 1 earring with two wire knots made of copper alloy; 1 simple earring with hook-shaped flattened end	child, 12 years	unspecified	*Havrda – 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	female?, 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 Jízdárna type**; glass beads: 8 olive; 1 incomplete mille fjori bead; copper-alloy sheets from a pendant/ornament	umdetermined (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 Jízdárna 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 Jízdárna 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 Jízdárna 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.



A



B

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

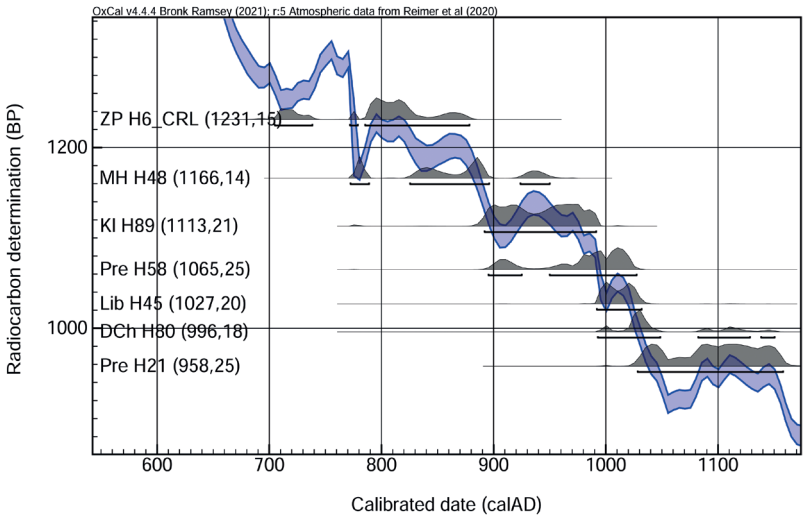


Fig. 9. The course of the calibration curve directly affects the resulting calibrated age.

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 $^{14}CO_2$ 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 Kl H22 was anthropologically determined to be male;

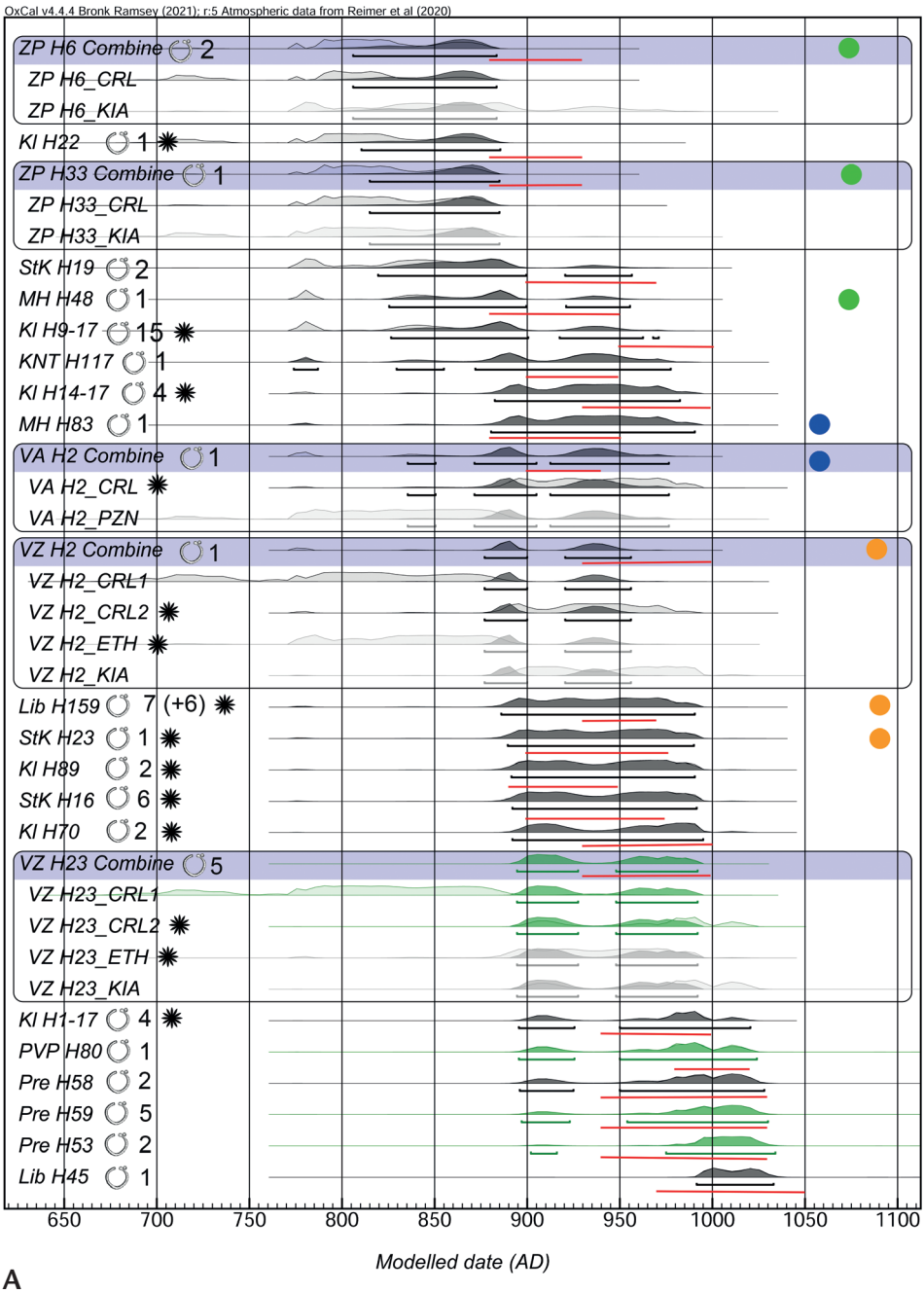
A. S-shaped temple rings					
Grave	**Abbreviation**	**Sample code**	**C^{14} age BP**	**±**	**AD cal after correction and modelling (95.4% probability)**
Dolní Chabry, Church of the Beheading of St. John the Baptist, H80/1974	**DCh H80**	CRL-17350	996	18	992–1048 (95.4%)
Klecany I, H22/2005	**Kl H22**	CRL-220382R	1223	19	820–894 (95.4%)
Klecany I, H70/2007	**Kl H70**	CRL-220383R	1096	19	906–1017 (95.4%)
Klecany I, H89/2008	**Kl H89**	CRL-220384R	1113	21	899–989 (95.4%)
Klecany I, H1/2017	**Kl H1-17**	CRL-17081A	1079	16	907–946 (26.0%); 964–1041 (69.4%)
Klecany I, H6/2017	**Kl H6-17**	CRL-17509	949	20	1031–1102 (95.4%)
Klecany I, H9/2017	**Kl H9-17**	CRL-220378R	1166	19	835–909 (66.7%); 925–969 (28.7%)
Klecany I, H14/2017	**Kl 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 Žabokřiku, 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	**Kl 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 Combine Table 3: B
	ZP H24_KIA	KIA-56867	1130	30	

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*.

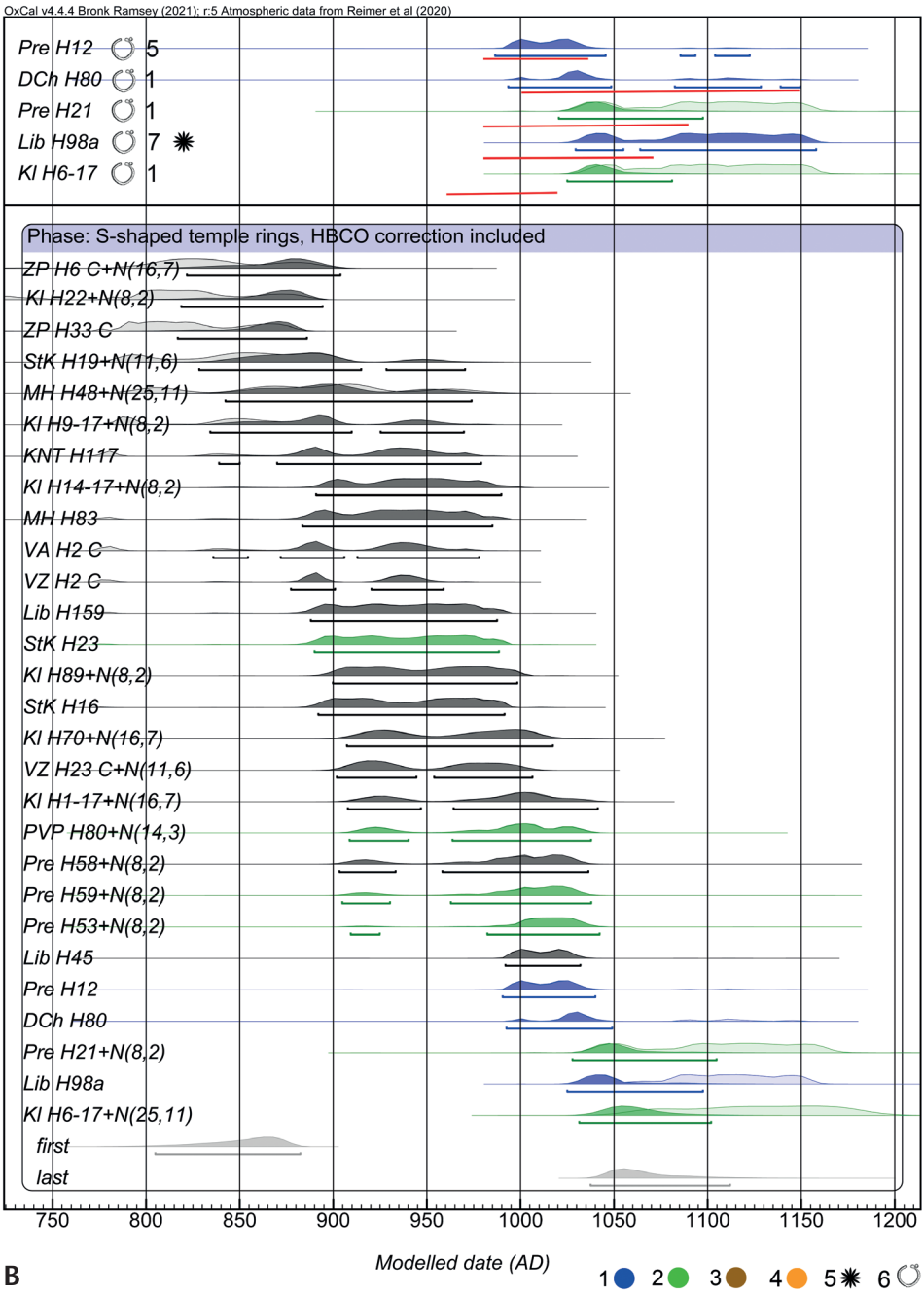
the jewellery was placed on the deceased's coffin at the time of burial and does not represent a later intrusion (*Profantová et al. 2015*, 25–26). Ultrafiltration was used on almost two-thirds of the samples. The quality of the bone samples was average, with only four samples showing lower values (VZ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

Calibrated and modelled radiocarbon dating shows that the first jewellery of this type appeared before the end of the 9th century (Kl 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.



A

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.



B

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 smal 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_KlA 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

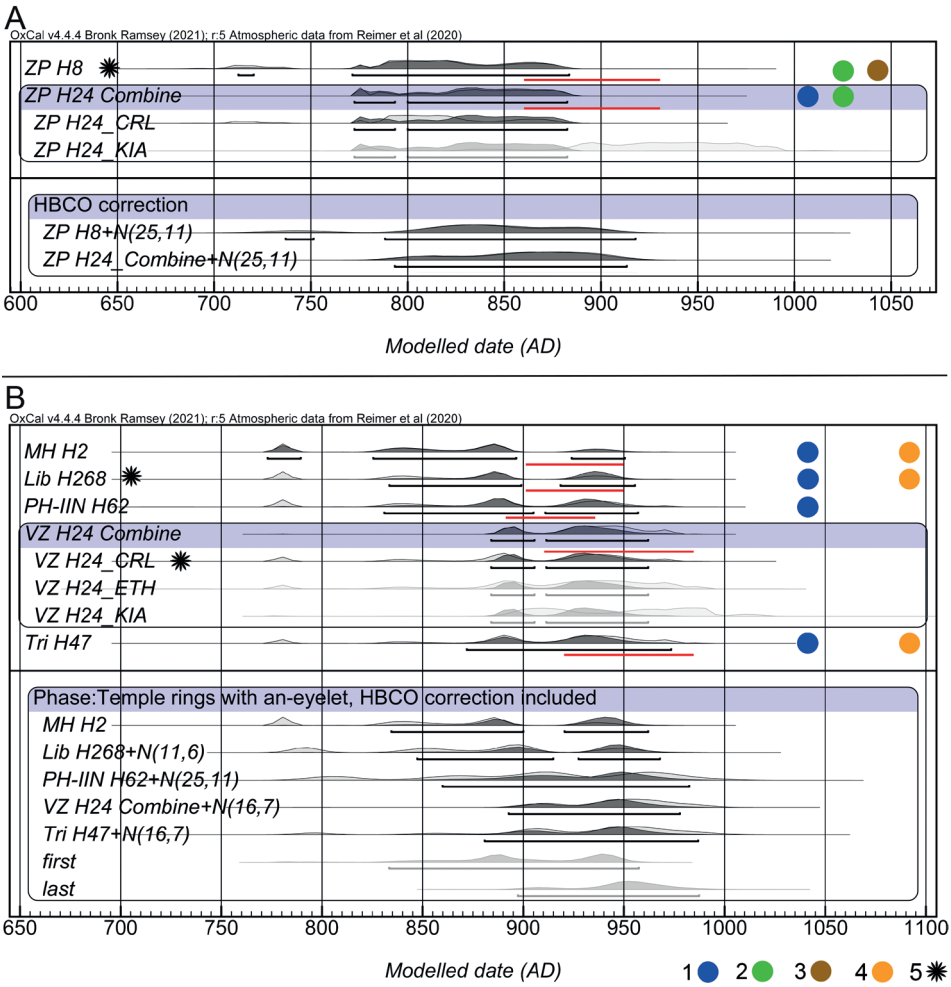


Fig. 11. One-phase model for wire jewellery: A – meander-shaped earrings; B – temple rings with eyelet. Grey – laboratory other than CRL (laboratory code is given after the sample abbreviation). The red line indicates the archaeological dating. Chronologically significant grave goods: 1 – jewel decorated 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).

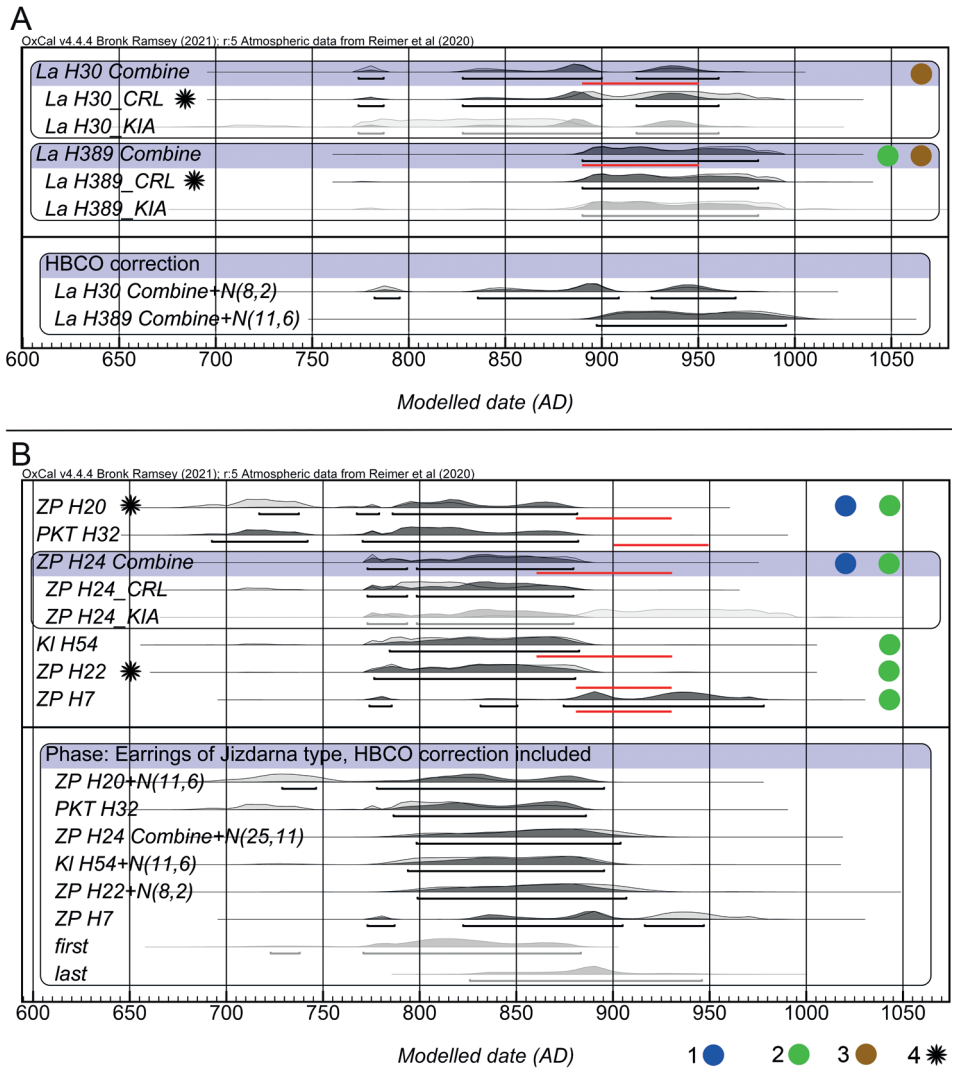


Fig. 12. One-phase model for hybrid types/earrings and other potential prototypes. A – samples from the Prague-Lahovice; B – Jízdárna-type earrings. Grey – laboratory other than CRL (laboratory code is given after the sample abbreviation). The red line indicates the archaeological dating. Chronologically 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 (Kl 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:

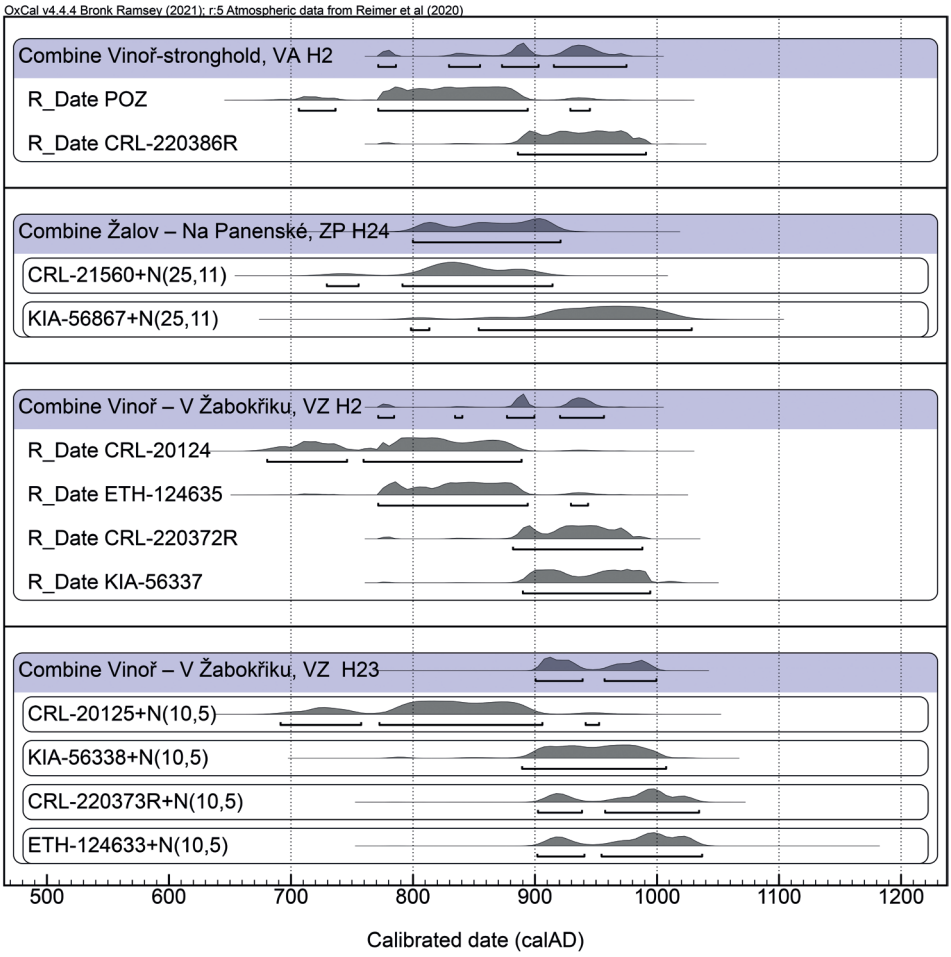


Fig. 13. Evaluation of repeated measurements (graphic differences with outliers).

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*; *Devièse 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*; *Bíšková 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

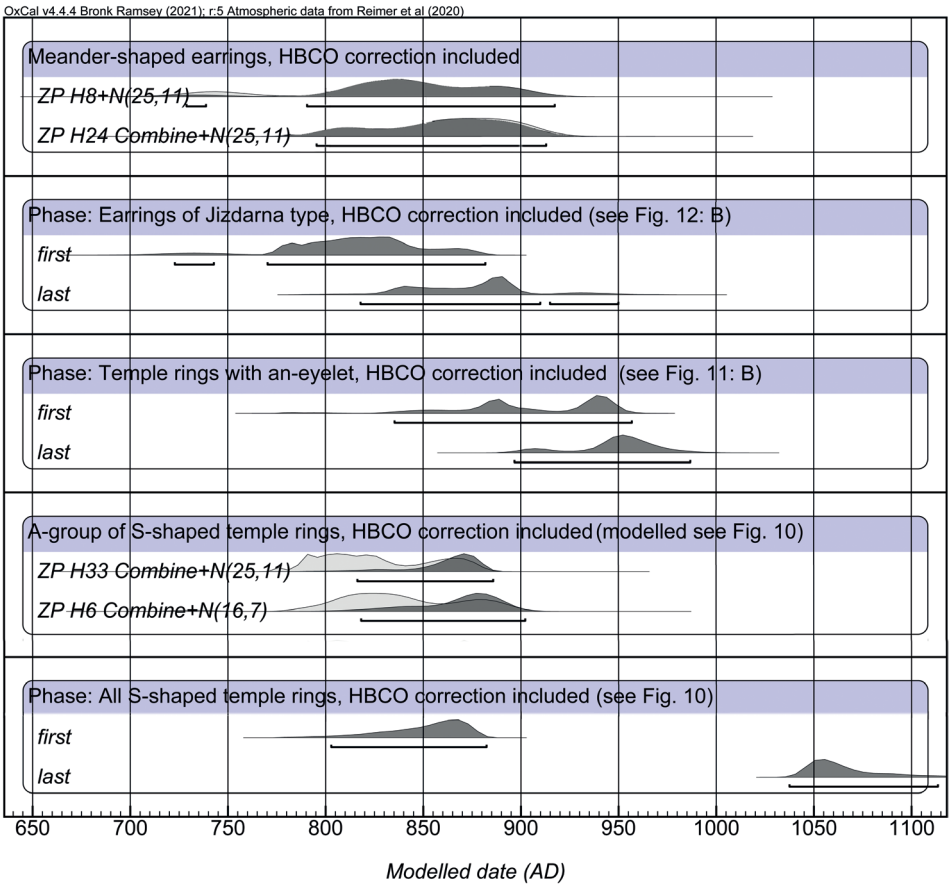


Fig. 14. Comparison of radiocarbon dating of different types of jewellery. Correction of bone tissue remodelling is included.

combined dates (if burials were dated repeatedly) with human bone collage 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 (*Bíšková 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 $^{14}CO_2$ 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), ultrafiltration, 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.

This publication was supported by OP RDE, MEYS, under the project 'Ultra-trace isotope research in social and environmental studies using accelerator mass spectrometry', 'Reg. no. CZ.02.1.01/0.0/0.0/16_019/0000728' and also by the Ministry of Education and Sport of the Czech Republic and European Union (MEYS and EU), RES-HUM project 'Ready for the future: understanding long-term resilience of the human culture', Reg. no. CZ.02.01.01/00/22_008/0004593.

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