RADIOCARBON DATING OF GRAVES 1/08 AND 5/09 FROM THE ÚNĚTICE CULTURE CEMETERY IN ŠOPORŇA (DIST. GALANTA, SLOVAK REPUBLIC)

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Keywords: *Únětice culture, inhumation graves, radiocarbon dating, archaeological event, time of death of individual, HBCO correction, intra-individual chronological modelling*

Abstract: *The article focuses on chronometric dating of two archaeological events represented by the time of death of individuals inhumed in graves 1/08 and 5/09 at the Únětice culture cemetery in Šoporňa. The research aim is to refine chronological resolution in the period, when radiocarbon calibration curve produce wide date distributions. Vague-prior calibrated ages with uncertainty 25–45 BP-years from contexts of Únětice culture in Slovakia give typically ranges of 170–270 years. To improve this we have tested employment of intra-individual chronological modelling. Preliminarily, we have reduced the calibrated date range for the time of death of 1/08 individual down to 92–101 years and suggest for interments of the deceased in graves 1/08 and 5/09 interval 1980–1860 cal BCE.*

Site and sampled contexts

The Early Bronze Age cemetery in Šoporňa in the Váh River valley comprises fourteen mostly reopened burials. It represents the Únětice culture, what was concluded rather on the basis of circumstantial evidence and spatial distribution of the Únětice cemeteries in the region than according to culturally diagnostic artefacts. These are almost virtually absent at the site (*Bartík 2018*). In order to absolute-chronologically characterise the only grave with the diagnostic artefact, the excavator J. Bartík selected grave 1/08 for radiocarbon dating. The second radiometrically dated grave 5/09 lacks any culturally clear-cut grave-goods and represents a typical burial in the cemetery.

Grave 1/08 is a reopened inhumation of individual (sex acc. to culturally-determined position of the body: female, sex acc. to DNA analysis: male) aged maturus–senilis with damaged and fragmentarily preserved skeleton, equipped with a bone awl and a decorated pottery vessel, the latter with an analogue in the Lower Austrian–Moravian group of Únětice culture (*Bartík 2018*, *Šefčáková et al 2018*). In 2013, J. Bartík and A. Šefčáková collected from the human remains for ^{14}C dating a small fragment of bone from lower extremity.

Grave 5/09 is a reopened inhumation of male aged maturus II with damaged but well preserved skeleton including ribs, equipped with a simple pottery bowl and a fragment of ornament from bronze wire (*Bartík 2018*, *Šefčáková et al 2018*). R. Pinhasi and D. Reich took a sample from the skull for DNA research and submitted it also for radiometric analysis (*Šefčáková et al 2018*).

Dating question, chronological resolution, and research strategy

The published Únětice culture ^{14}C determinations with uncertainties 25–45 BP-years measured on bones from Slovak sites give after vague-prior calibration ranges of 170–270 years (95.4% probability) in the time-window from 21th to early 17th century calBC (IntCal13, *Reimer et al 2013*; *Barta et al. 2013*). Similarly, the planned radiocarbon dates from Šoporňa were thought to turn out to be of coarse chronological resolution due to ^{14}C production, what is seen also in the simulated data (Fig. 1, OxCal 4.2, *Bronk Ramsey 2014*; IntCal13 with 5-year resolution, *Reimer et al 2013*).

In attempt to better estimate the archaeological event (*Barta 2008*), which is in the Early Bronze Age cemetery the time of death of deceased, one can opt for collagen turnover correction (*Geyh 2001*, *Barta and Štolc 2007*, *Grootes et. al. 2015*). This, however, does not necessarily improve chronological resolution. As a rule, refinement of chronological resolution of calibrated radiocarbon dates is achievable by employment of typological and stratigraphic constraints, but the paucity of archaeological data prevents it here.

Under these conditions, in the only grave (1/08) with culturally well defined artefact we have tested the intra-individual chronological modelling as a means to get better estimate of time of death with finer chronological resolution. First, models (OxCal 4.2, *Bronk Ramsey 1995*; *Bronk Ramsey 2014*) of sequences with a time gap (with and without uncertainty associated with the gap) for the buried maturus–senilis individual were filled with simulated radiocarbon dates. They were simulated for two different stages of the individual's lifetime: the early teens and the age at death. After motivating outcomes of the simulations (i.e. death estimate in intervals of around 100 years), in October 2017 the canine sample was collected and together with the lower extremity bone sample sent to the HEKAL laboratory in Debrecen (*Molnár et al 2013a*). Here we present our first research results with the measurements completed by mid-January 2018.

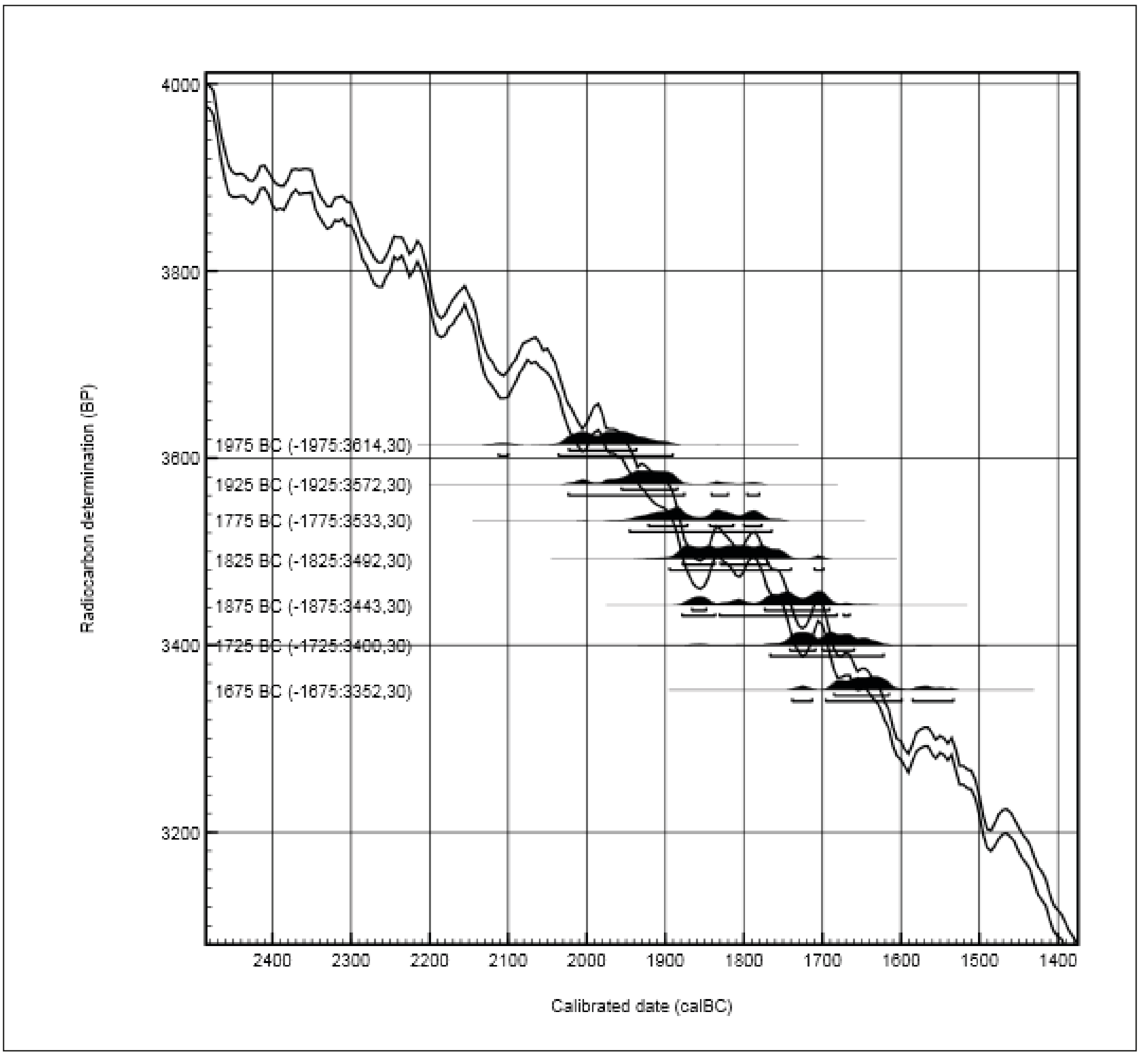

Fig. 1 Curve plot with vague-prior calibrated ^{14}C dates (IntCal13). The radiocarbon dates are simulated with uncertainty 30 BP-years for calendar years 1975, 1925, 1875, 1825, 1775, 1725, and 1675 BC. The chronological resolution of calibrated dates at 95.4% probability is coarse (144–199 calendar years) as a result of wiggles and plateaux on IntCal13. Moreover, it is clear that archaeological events, which took place 50 or even 100 calendar years apart (here shown results for 1975 and 1925 BC; 1775, 1825, and 1875 BC; 1725 and 1675 BC) may well remain indistinguishable when represented by ^{14}C determinations on samples without mutual typological or stratigraphic relationship.

Analysed samples

From human remains in grave 1/08 two samples were taken for atomic C:N ratio, IRMS analysis (C, N), and AMS ^{14}C measurement. The first sample collected was a small fragment from a not exactly classifiable long bone of lower extremity (fibula?, tibia?), containing mainly cortical tissue. The second sample was the only preserved tooth in the grave, lower right canine (43). The tooth with the root caries has damaged surface with completely abraded enamel on the biting surface (*Šefčáková et al 2018*). It was sawn longitudinally in vestibulo-oral direction through the crown and root by diamond cutting disc and one half of the tooth was submitted to HEKAL.

From the skeleton of male in grave 5/09 D. Reich and R. Pinhasi took a sample for ^{14}C dating from *pars petrosa s. pyramis* and the sample was pretreated and analysed at the Radiocarbon AMS Laboratory of the Pennsylvania State University (*Šefčáková et al 2018*).

Results and discussion: grave 1/08

From the fragment of lower extremity cortical tissue, collagen was extracted according to the HEKAL bone pretreatment protocol (*Molnár et al 2013b*). Atomic C:N ratio (3.4) testifies to good collagen preservation (*DeNiro 1985*).

The measured value of $\delta^{13}C$ (-19.5 ± 0.02 ‰) suggests C_3 biom (*Hajnalová 2011*) derived diet and $\delta^{15}N$ (10.4 ± 0.02 ‰) might be indicative of freshwater fish consumption in this micro-region with major river (Váh). The observed depletion of $\delta^{15}N$ value (-0.8‰) in the collagen from the long bone cortex in comparison to that from the canine dentin (see below) is similar to changes in $\delta^{15}N$ intra-individual subudalt–adult data from the Polish Únětice sites (*Pokutta and Howcraft 2015*) but due to the turnover rate we cannot in our case decide whether the difference is indicative of little variation in diet (cf. *Pokutta and Howcraft 2015*). The isotopic signature in the collagen of maturus–senilis (40–ω years) individual in the tissue type analysed is a result of long-term dietary behaviour; since the isotopic composition of collagen as documented in the adult femoral mid-shaft reflects individual's diet over a much longer time than 10 years and includes a substantial portion of collagen from adolescence (*Hedges et al 2007*), possible short-term (even if dramatic) changes of diet would in the adult cortical bone probably remain undetectable. Since we have no analysis of contemporary faunal remains from the region and with respect to the measured $\delta^{13}C$ value we do not count with the reservoir age in this sample, even though we feel that its presence should be suspected.

Vague-prior calibration of conventional age DeA-13533: 3586 ± 30 BP gives 1972–1894 calBC (68.2% probability) and 2029–1881 calBC (95.4% probability; OxCal 4.2, *Bronk Ramsey 2014*; IntCal13, *Reimer et 2013*; Fig. 2, uppermost row). The calibrated date would give the time of death, if the individual died at the age of 1–20 years or slightly after this range. However, as the collagen turnover in human bone slows from 5–15% per year in individuals below 20 years of age to 1.5–4% in adults (*Hedges et al 2007*, *Geyh 2001*), the above-given calendar date measured in the maturus–senilis individual is a terminus post quem for the time of death and subsequent interment of the body with grave-goods. To estimate the time of death we have used the human bone collagen offset (HBCO) correction sensu Geyh (*2001*) and Barta and Štolc (*2007*). Since the state of bone preservation does not enable to assign the human remains to a single skeletal age class (*Šefčáková el al 2018*), we present the correction for all possibilities (maturus I, II, and senilis, Fig. 2). If, for instance, the individual was 60–79 years old at death, she/he died in one of the following three intervals: 2009–2001, 1976–1863, and 1851–1772 calBC (Fig. 2, lowermost row). In such a case, the difference between the interval of uncorrected date (2029–1881 calBC) and the two major intervals of HBCOcorrected date (1976–1863 calBC, 1851–1772 calBC) would be -53 and -178 years for their starts, and -18 and -109 years for their ends (95.4% probability), respectively.

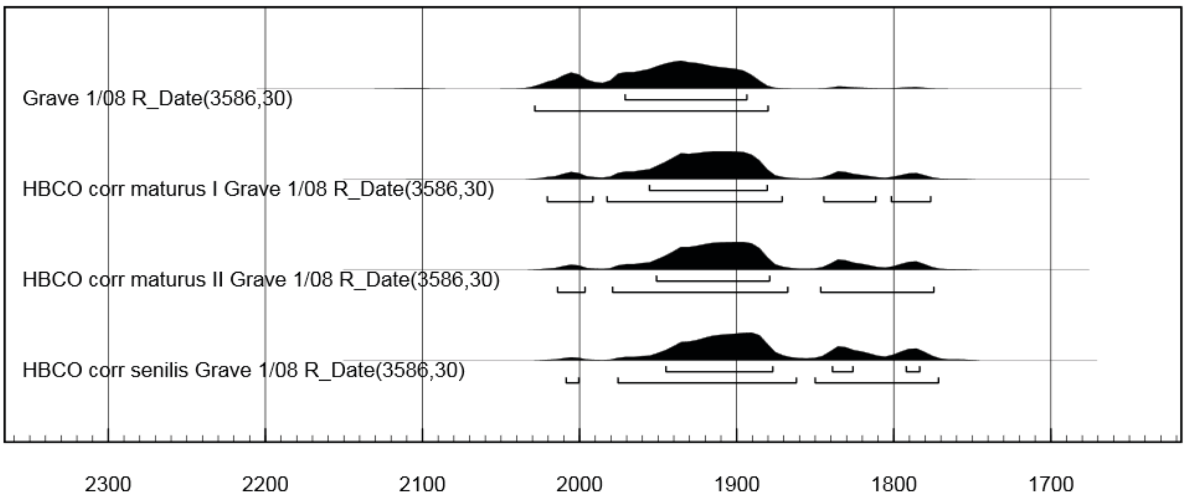

Fig. 2 Šoporňa, grave 1/08, HBCO correction for ^{14}C date of cortical tissue from lower limb (fibula?, tibia?; DeA-13533: 3586 ± 30 BP). HBCO-correction values are based on the anthropologically estimated age at death (maturus–senilis, *Šefčáková et al 2018*). This estimate comprises three skeletal age classes: maturus I (40–49 yrs), maturus II (50–59 yrs), and senilis (60–ω yrs; here computed for 60–79 yrs). The human bone collagen offset correction is based on development of original M. Geyh's (*2001*; *Barta 2006*) observation and follows Model B of Barta and Štolc (*2007*). In each row, upper and lower lines below posterior distributions indicate 68.2% and 95.4% probability, respectively.

The half of the lower right canine (43) underwent also the collagen extraction protocol (*Major 2018, Molnár et al 2013b*). Due to the small initial mass (270 mg) all material including crown and root was consumed by the pretreatment (*Major 2018*). Assuming from the overall poor preservation of the skeleton (no ribs and column vertebrae preserved; *Bartík 2018*), macroscopically observed damaged surface of the tooth (*Šefčáková et al 2018*), and surface cleaning of the sample (*Molnár et al 2013b*), no cementum survived and the extracted collagen came from the dentin in root and crown. According to the atomic C:N ratio (3.5), the dentin collagen is well preserved (*DeNiro 1985*) and suitable for palaeodietary investigations. Measured value of $\delta^{13}C$ (-19.7 ± 0.02 ‰) represents C_3 (*Hajnalová 2011*) terrestrial diet but δ[15]N (11.2 ± 0.02 ‰) might be interpretable also as indication of freshwater fish consumption (cf. *Sander lucioperca* δ[15]N value, *Pokutta and Howcraft 2015,* Fig. 2). Similarly to the cortical bone sample, we do not count with the fresh-water reservoir offset in the dentin either.

Conventional radiocarbon age measured on the dentin collagen DeA-13461: 3609 ± 27 BP brings after vague-prior calibration intervals 2019–1931 calBC (68.2% probability) and 2031–1895 calBC (95.4% probability; OxCal 4.2, *Bronk Ramsey 2014*; IntCal13, *Reimer et al 2013*). After formation, dental tissues are little changed during the lifetime, unless affected by use-wear or diseases (*Hillson 2014*). Lower canines in humans form during childhood; according to Nelson (*2015*) the age of crown completion is 6–7, of eruption 9–10, and the age of root completion is 12–14 years. Here, we have used the value of 13 years as the estimate for average crown and root completion of lower canines (cf. *Cook et al 2015*). In sum, we have assumed that the collagen from canine 43 in grave 1/08 mediates [14]C age on the period when the individual was around 13 years old, and accordingly, the calibrated date is an estimate of that time.

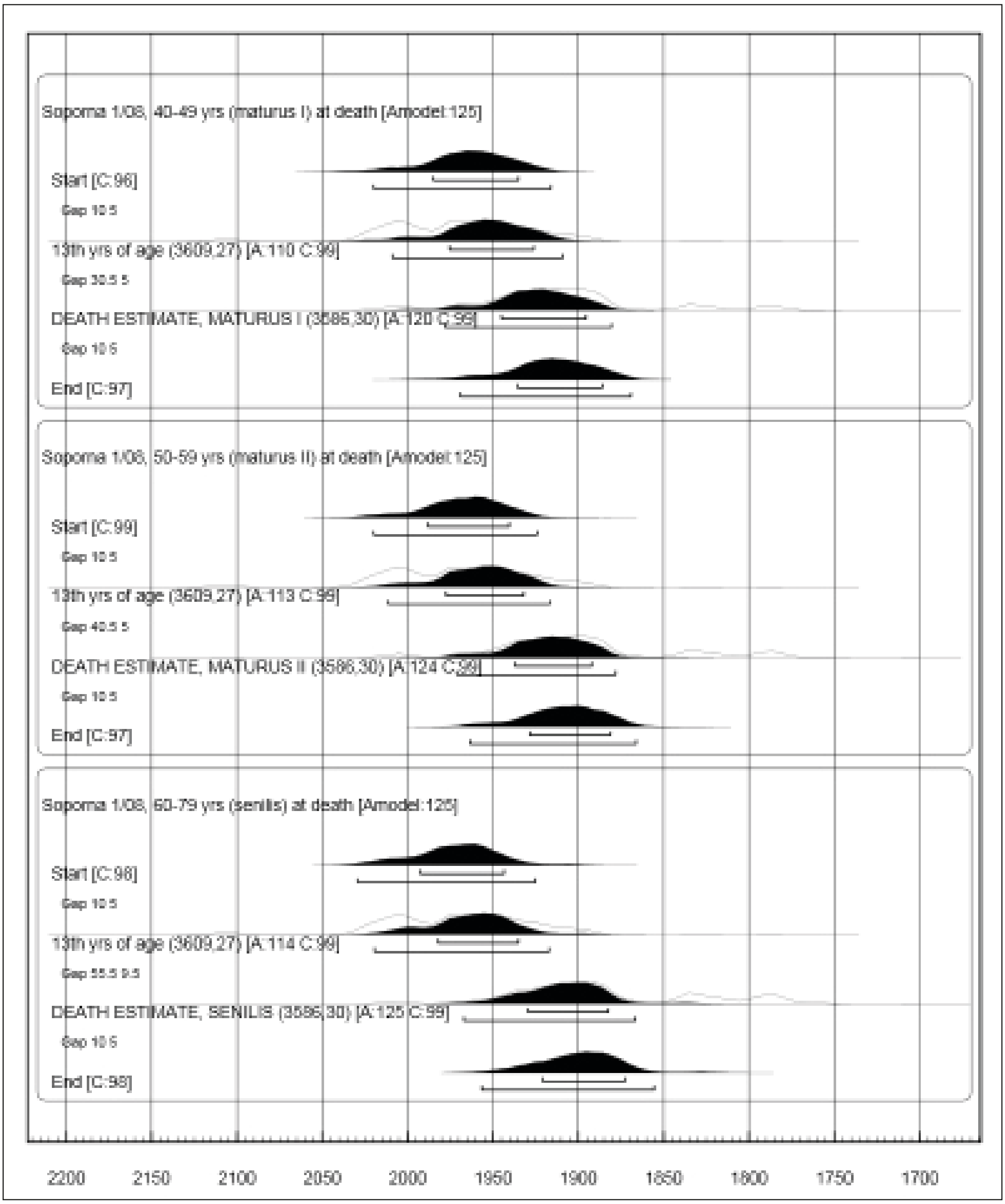

Fig. 3 Šoporňa, grave 1/08. Models for estimates of time of death (see DEATH ESTIMATE) for each skeletal age class according to the anthropological analysis. No remodelation of dentin is assumed. Upper and lower lines below the posterior distribution of calibrated dates indicate 68.2% and 95.4% probability, respectively.

To estimate the time of death of this individual we have used a model of bounded sequence of events separated by known age gaps with uncertainties (OxCal 4.2, *Bronk Ramsey* 1995; Bronk *Ramsey 2014*). After the boundary for start we have set 10-year gap with 5-year uncertainty and then the radiocarbon date measured for the collagen from the canine representing the 13th year of age of individual. Subsequently, we have set the second gap. The gap is equal to the number of years separating the 13th year of age and the central year (44.5, 54.5, 69.5) in interval of each of the three skeletal age class alternatives, to which this deceased may belong (maturus I, maturus II, and senilis). Uncertainties associated with the gaps were rounded to 5 years, except for the model senilis; that one was set to 9.5 years in accordance with the width of interval for which the correction term was computed (60–79 yars; Model B, *Barta and Štolc 2007*). After the second gap we have set the HBCOcorrected radiocarbon date measured on the collagen from the cortical tissue of lower extremity bone. The HBCO correction values were chosen for each of the three skeletal age alternatives, respectively (Model B, *Barta and Štolc 2007*, *Geyh 2001*). The sequence was closed with 10-year gap with 5-year uncertainty and the end boundary. In each modelling alternative (maturus I, maturus II, and senilis) we have used IntCal13 with 5-year resolution (*Reimer et al 2013*).

Ultimately, the estimates of time of death of individual in grave 1/08 are as follows. If the age at death of individual was 40–49 years (maturus I), the estimated time of death is in 1946–1896 calBC (68.2% probability) and 1979–1881 calBC (95.4% probability); for maturus II (50–59 years), the estimated time of death is in 1937–1892 calBC (68.2% probability) and 1971–1879 calBC (95.4% probability); for senilis, here computed for the range 60–79 years, the death estimate is in 1930–1883 calBC (68.2% probability) and 1969–1868 calBC (95.4% probability; Fig. 3).

Results and discussion: grave 5/09

The petrous part of temporal bone analysed at the Penn State AMS ^{14}C Laboratory gave conventional radiocarbon age PSUAMS-4007: 3600 ± 20 BP what is after vague-prior calibration under 68.2% probability 2011–2001 calBC (9.1%) and 1977–1924 calBC (59.1%), and under 95.4% probability 2022–1897 calBC. After employment of HBCO correction (*Geyh 2001*; *Barta and Štolc 2007*), the estimate of the time of death is under 68.2% probability 1942–1895 calBC and under 95.4% probability 2010–2000 calBC (2.0%) and 1977–1882 calBC (93.4%). Since we have not at hand the measurements of $\delta^{13}C$ and $\delta^{15}N$ for the sample, we cannot comment on the fresh-water reservoir effect in the sample (for comments on isotopic signature and residence time see results for grave 1/08).

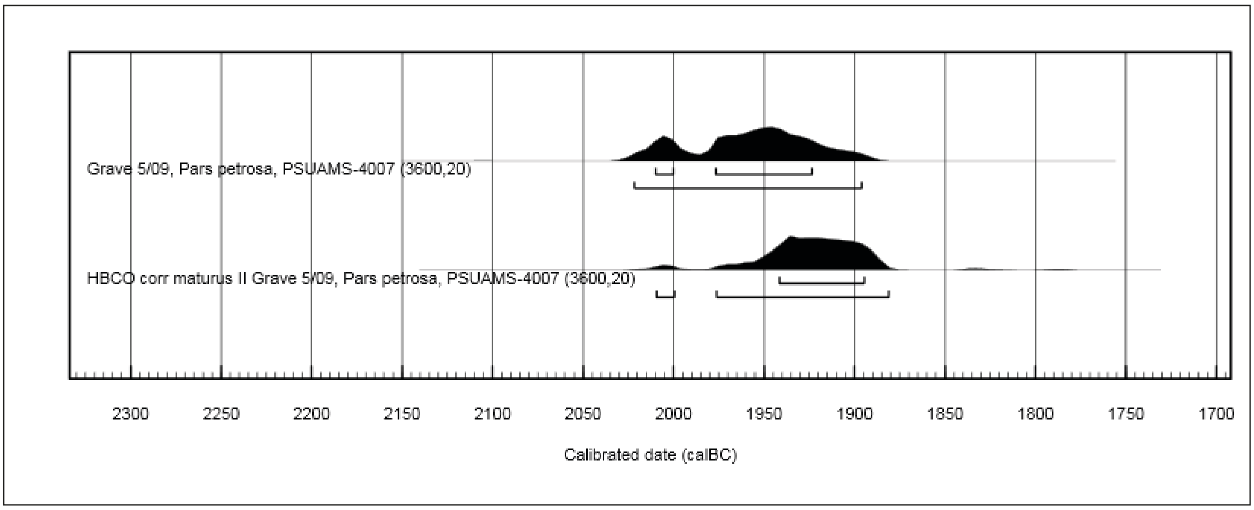

Fig. 4 Vague-prior calibration of PSUAMS-4007 and its HBCO corrected value for the skeletal age class maturus II.

Conclusion and outlook

We can conclude that graves 1/08 and 5/09 from the Únětice culture cemetery in Šoporňa were laid down in time-window 1979–1868 calBC; the short interval prior to 2000 (Fig. 4) is artefact of the radiocarbon calibration curve. Under assumption that dentin in canine 43 from grave 1/08 did not change in vivo since the time of completion of the tooth, the time of death of this individual for maturus I skeletal age class is 1979–1881 calBC, for maturus II 1971–1879 calBC, and for senilis (here computed for 60–79 years) 1969–1868 calBC (95.4% probability). The employed model has refined the chronological resolution of result by halving the ranges for the time of death from 194–202 to 92–101 years (compare Figs. 2 and 3; 95.4 % probability); the latter is also considerably shorter than the vague-prior calibrated date range (148 years, Fig. 2).

Clearly, our intra-individual modelling results are rather experimental. Since the assumption that the dentin did not remodel might not be valid in this particular case (caries, severe enamel wear), and since only one tooth in the grave is preserved, we do not have the opportunity of testing our approach further for this grave. Hoping that the initial sample mass will enable measurement with uncertainty ≤30 BP-years we plan to submit a second sample from the remaining part of the tooth avoiding the tissue around the root caries and also the second sample from the cortical tissue of long bones.

The time of death of individual in grave 5/09 represent interval 1977–1882 calBC (93.4 % probability). Since we lack stable isotope values and have only single radiocarbon date at hand, we plan new AMS and IRMS analyses on the collagen from pre-selected tissues and use them for intra-individual chronological modelling.

In effort to substantiate our results in general, we would like to date and isotopically characterise the contemporary herbivorous local fauna (e.g., caprovid and bovine bones from graves 6/09 and 10/09), test more estimates of formation time of preserved tissues in humans, and test also a different methodology of the HBCO correction computation.

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RÁDIOUHLÍKARBONKOVÉ DATOVANIE HROBOV 1/08 A 5/09 Z POHREBISKA ÚNĚTICKEJ KULTÚRY V ŠOPORNI (OKR. GALANTA, SLOVENSKÁ REPUBLIKA)

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Predmetom nášho výskumu je absolútne datovanie doby smrti (*Barta – Štolc 2007*, *Geyh 2001*) dvoch jedincov uložených v hroboch 1/08 a 5/09 na pohrebisku únětickej kultúry v Šoporni, ktoré preskúmal J. Bartík (*Bartík 2018*).

Chronometrický výskum jedinca 1/08 sa zameral na zlepšenie chronologického rozlíšenia rádiouhlíkových dát nameraných na kolagéne. Kolagén sa extrahoval z kompakty a zuboviny odobratých zo zle zachovaného antropologického materiálu v hrobe, ktorý ako jediný na pohrebisku obsahoval diagnostickú keramiku (*Bartík 2018*, *Šefčáková et al 2018*). Na základe intraindividuálneho modelovania s rádiouhlíkovými dátami, ktoré pravdepodobne reprezentujú C_3 bióm, sa podarilo zjemniť chronologické rozlíšenie doby smrti jedinca 1/08 na úroveň zhruba 100 rokov pri 95,4% pravdepodobnosti rozsahu kalibrovaného veku. Oproti doterajšiemu datovaniu ľudských kostí z únětických hrobov z územia SR (*Barta et al 2013*) je to o 70 – 170 rokov lepší výsledok. Podľa troch možných alternatív kostrového veku tohto jedinca (*Šefčáková 2018*) sme vypočítali tri alternatívy doby jeho úmrtia, ktoré sa všetky nachádzajú medzi rokmi 1979 a 1868 calBC.

Pre datovanie doby úmrtia jedinca v druhom chronometricky skúmanom hrobe 5/09 sme použili iba HBCO korekciu (*Barta – Štolc 2007*, *Geyh 2001*) pre konvenčný rádiouhlíkový vek nameraný na kolagéne extrahovanom zo skalnej kosti (*Šefčáková 2018*). Dobu úmrtia tohto jedinca datujeme medzi roky 1977 a 1882 calBC (93,4% pravdepodobnosť).

Pohrebisko úňetickej kultúry v Šoporni s jediným diagnostickým artefaktom – rytím zdobenou šálkou z mladšieho stupňa únětickej kultúry (*Bartík 2018*) – je nateraz datované na základe chronometrického výskumu dvoch jedincov, ktorí boli pochovaní medzi rokmi 1979 a 1868 pred Kr.

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