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RADIOCARBON DATED PULSE AND CEREAL CROPS INDICATE DIACHRONIC USE OF IRON AGE EXTREME UPLAND SITES IN THE WESTERN CARPATHIANS, SLOVAKIA

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Abstract
Mountain summits in the Slovak part of the Western Carpathians bear evidence of human presence from the Late Bronze to the Late Iron Age. According to fire-induced changes in archaeological record and finds of weaponry, some of the extreme upland sites (EUS) were viewed as places of safety or *refugia* violently destroyed within a short period. We have focussed on three sites with summits at 1300–1550 m a. s. l. and found out that two of them were used in 650–400 calBC and 390–150 calBC, respectively. By the first systematic use of ^{14}C dating and targeted ^{14}C sampling, we have overcome the inherent chronological imprecision of their artefactual record and opened new vistas for interpretation of this type of sites.

Keywords
radiocarbon, cereal and pulse crops, mountain summit sites, Hallstatt Period, La Tène Period

1. Introduction

This paper presents chronometric research at three Iron Age extreme upland sites (EUS) in the Western Carpathians, North Slovakia (**Figs. 1 and 2**; Supplementary Online Material, SOM 1). The EUS occur in the regions of Liptov and Kysuce at 1000–1600 m a. s. l. (Pieta, 1981, 1983, 2000; Šedo, 1981–1982) and in the middle Váh river valley and Turiec region at around 600–900 m a. s. l. (Pieta, 2006, 2014). They represent the local culture of the Late/Final Bronze Age, Hallstatt, and La Tène periods and are parts of settlement systems organised along the mountain ridges (**Fig. 2**). Such a settlement system consists of unfortified settlement(s) on the basin or valley floor, hillfort(s) on lower promontories and finally EUS (Pieta, 1981: 58, 59, 61, 1983: 44; Benediková, 2006, 2017; Benediková and Pieta, 2020).

The EUS are in the literature referred to as places of safety or *refugia* with possibly also other functions as seasonal shelters for animal herds (Pieta, 1981, 1983). We hypothesise that some of them may also have served as *Brandopferstätte*. These specific upland sacrificial sites for burnt offerings are known from Alpes-de-Haute-Provence to Styria and are dated from the Late Bronze Age to the Roman Period (Heiss, 2014: 343; Ballmer, 2017: 82). By now, they have not been considered for the Western Carpathians (Benediková *et al*., in preparation).

In the Liptov basin, up to 10 EUS are known (Benediková *et al*., in preparation). Three of them yielded rich finds of charred plant remains (Demänovská hora, Končitý vrch

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***Fig 1**. The view from the Liptov basin towards the Nízke Tatry mountain range. 1 – Demänovská hora (known also as Demänovská Poludnica, cadastre of Demänovská Dolina and Liptovský Mikuláš-Ploštín), 2 – Končitý vrch (cadastre of Závažná Poruba), 3 – Iľanovská Poludnica (cadastres of Závažná Poruba and Liptovský Ján), 4 – Bodová, 5 – Roháčka, 6 – Pod Roháčkou. © Photo by Lucia Benediková, modified by Mária Hajnalová.*

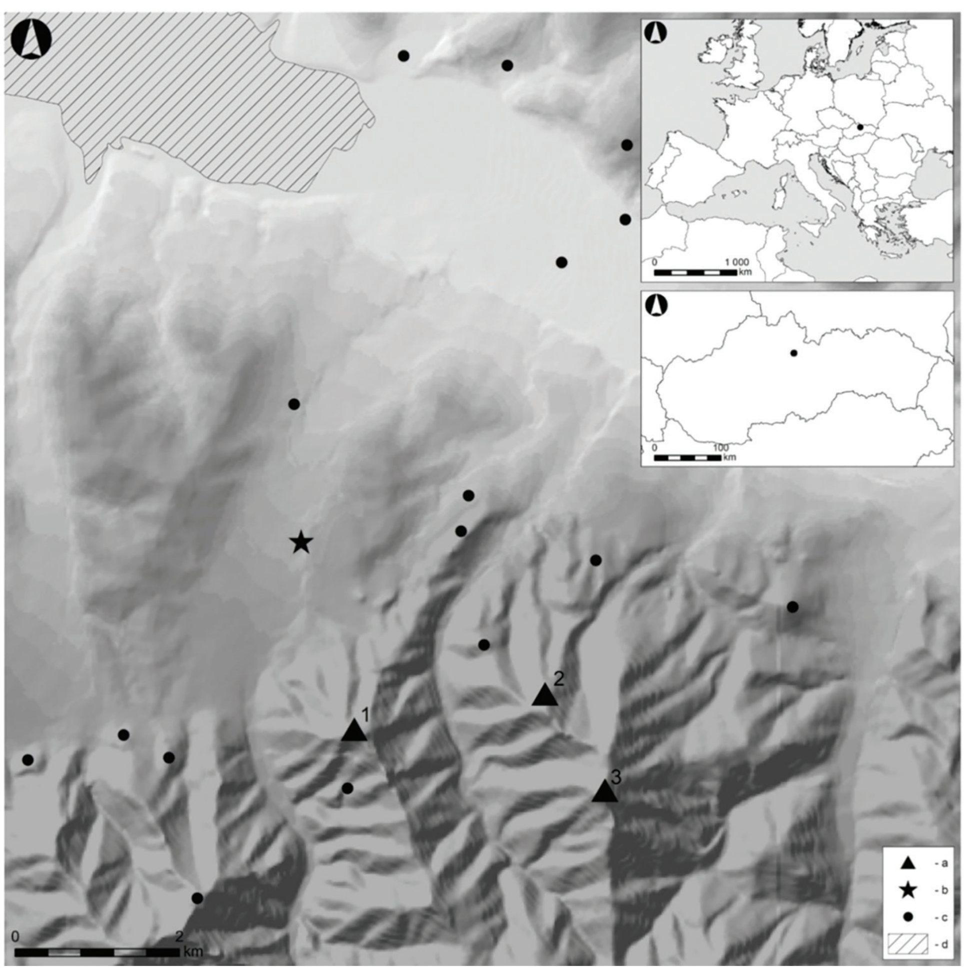

***Fig 2**. Location of sites discussed in the text and other contemporary sites. 1 – Demänovská hora, 2 – Končitý vrch, 3 – Iľanovská Poludnica; a – sites discussed in the text, b – local pollen core of Demänovská slatina currently under study, c – archaeological sites dated to the period from Late Bronze Age to the Early La Tène period, d – the Liptovská Mara water reservoir. © Map by Jakub Tamaškovič.*

and Predný Choč; Pieta, 1983: 39–40). This is in strong contrast to coeval settlements on the valley floor, which did not produce similar finds (Benediková *et al*., in preparation). The occurrence of large quantities of charred cereal and pulse crops was interpreted as food stores charred during 'catastrophic events', but have not been addressed in detail by now. In the literature, the 'catastrophic events' were associated with the arrival of Eastern nomadic tribes towards the end of the Hallstatt Period or with the emergence of bearers of La Tène culture (Pieta, 1981: 62, 1983: 44; Pieta *et al*., 2021).

We focus on the temporal aspect of the charred pulse and cereals crops at three EUS: Demänovská hora, Končitý vrch and Iľanovská Poludnica. The first two, with typo-chronologically identical pottery (**Fig. 3**) and metal finds (e.g. bronze arrowheads of eastern type, bronze boat-shaped brooches, bronze S-shaped ear rings of eastern type, iron rolled headed pin; **Fig. 4**; Benediková, 2006, 2017: 357; Furman *et al*., 2019; Pieta *et al*., 2021), have yielded very rich assemblages of charred plant macro-remains dominated by pulse crops from very well cleaned stores (Benediková *et al*., in preparation).

With accelerator mass spectrometry (AMS) ^{14}C dating of the charred crops, our aim is to test the narrative of short-event destructions in the Late/Final Hallstatt or Early La Tène periods. We are pursuing two main research questions:

(1) Are the finds of crops at all sites contemporary?
(2) Do the plant macro-remains reflect an archaeological event of short duration?

2. The Sites

The three studied EUS are situated in the mountain massif on the northern slopes of the Nízke Tatry mountain range. Going from lower to upper elevations, they occupy the summits of the second (Demänovská hora, Končitý vrch) and third lines of peaks (Iľanovská Poludnica) on the main ridges rising southwards from the Liptov basin. All are well protected hard-to-reach places clearly visible from the valley (**Fig. 1**). Based on their location, fortification, material culture and other archaeological evidence, they have been interpreted as *refugia* – the last retreat places of prehistoric communities in the times of danger (Pieta, 1981, 1983).

Based on the bronze and iron ornaments, weaponry, pottery vessels and coins discovered at these sites, it can be ascertained that they were in use in the Late and Final Bronze Age, Late and Final Hallstatt and Early La Tène period, and in the Middle Ages.

The studied EUS are understood as an integral part of the local Bronze and Iron Age settlement hierarchy (Pieta, 1981: 58, 59, 61, 1983: 44; Benediková, 2006, 2017; Benediková and Pieta, 2020). The Late and Final Bronze Age artefacts are known only from Iľanovská Poludnica and might connect this EUS with a hillfort on Bodová (Pieta, 2002: 156–158). The Hallstatt and Early La Tène finds were recovered at all three EUS (Benediková, 2006; Pieta, 1981, 1983; Pieta *et al*., 2021). During that time, Demänovská hora (1304 m a. s. l.) formed a settlement system with a hillfort on Rohačka (857 m a. s. l.) and an open settlement Pod Rohačkou (650–700 m a. s. l.) (Pieta, 1980, 1981, 1983; Šimková, 2004; Benediková, 2008; Benediková *et al*., 2019: **Fig. 1**). Since their lowland settlements and hillforts are unknown by now, Končitý vrch (1310 m a. s. l.) and Iľanovská Poludnica (1549 m a. s. l.) seem to stand so far in isolation in what we see as the Iron Age landscape. The mediaeval human activity is known only from Končitý vrch, where a coin forgery workshop has been found (Furman, 2020).

3. Material and Methods

Soil samples with plant macro-remains come mainly from 2015 and 2018–2020 excavations targeted at acquisition of controlled archaeological ^{14}C samples and new artefactual evidence (Furman *et al*., 2018, 2019; Benediková *et al*., 2020: 38, 39; Furman and Benediková, 2020; Benediková *et al*., in preparation). The recent fieldworks were conducted after evaluation of published archaeological data from excavations and surveys carried out through 1970s, 1990s, and in 2001 and 2004 (Pieta, 1980, 1981, 1983, 2002; Šimková, 2004; Benediková, 2006; Pieta *et al*., 2021). The plant macro-remains from earlier excavations investigated Eva Hajnalová (Hajnalová, 1979, 1980, 1981, 1993), whereas those from the recent fieldworks Mária Hajnalová. In 2015 at Demänovská hora and Končitý vrch, soil samples were taken from dark anthropogenic layer, a thin deposit accumulated between the grass turf and limestone bedrock with its crevices, at most 50 cm below the present surface (**Figs. 5A and 5B**). In the sampled spots, neither stratigraphy nor indications of spatial distribution of activities were observed. Charred seeds for ^{14}C dating were selected from deeper soil samples. In 2020 at Iľanovská Poludnica, the soil sample was taken from the anthropogenic layer at the depth of 15–30 cm from the present surface. Its colour and texture were very similar to the two above-mentioned sites (**Fig. 5C**). The sampled deposit, which was collected from the layer containing pottery and iron pin from the Iron Age, was partially over and partially within the concentration of granite pebbles representing sling or throwing stones.

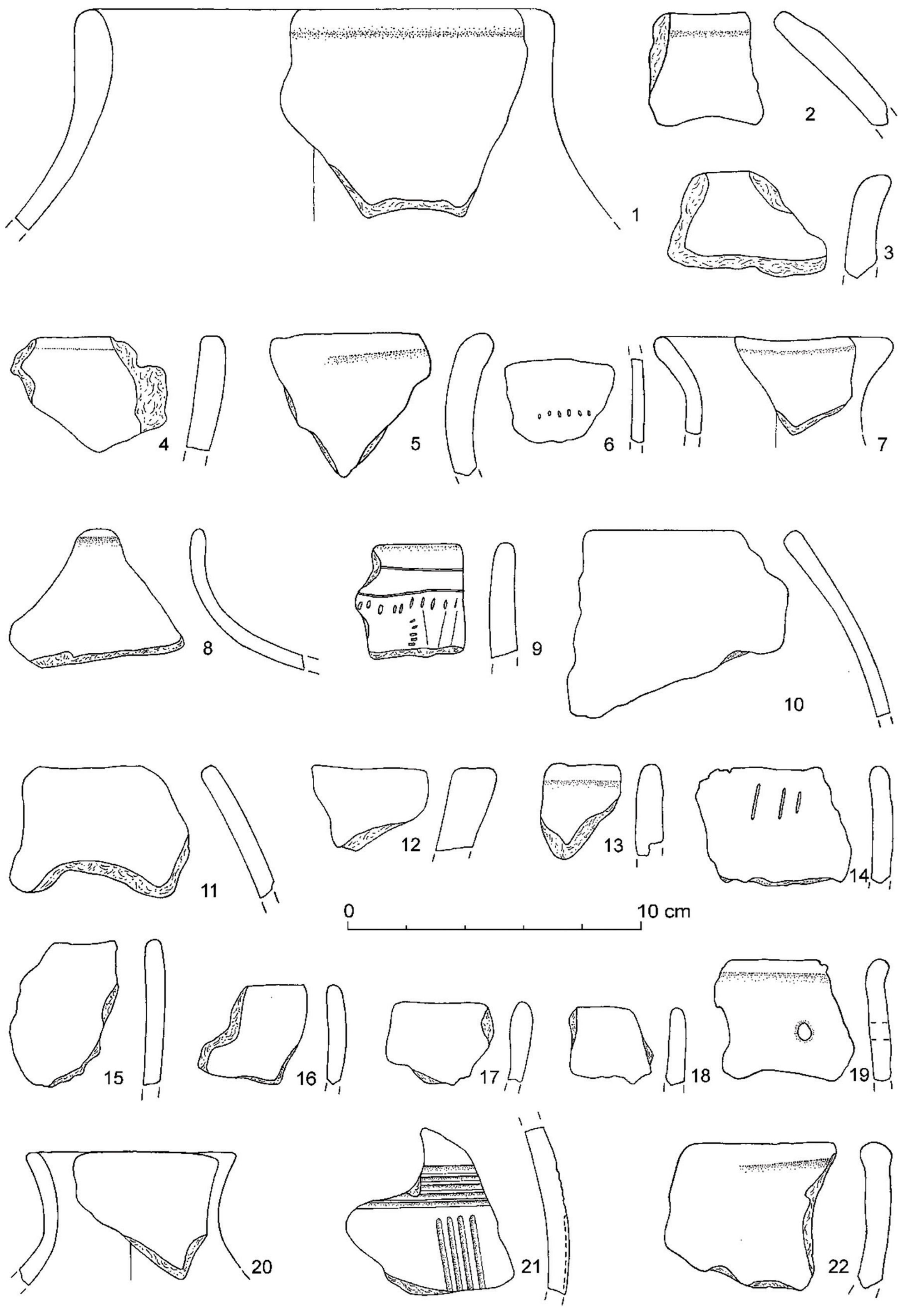

***Fig 3**. Pottery from excavations in 2015. 1–12 – Demänovská Dolina – Liptovský Mikuláš-Ploštín (Demänovská hora); 13–22 – Závažná Poruba (Končitý vrch). Drawn by Jana Gajdošíková. After Benediková et al., 2020, Figs. 20 and 21, modified.*

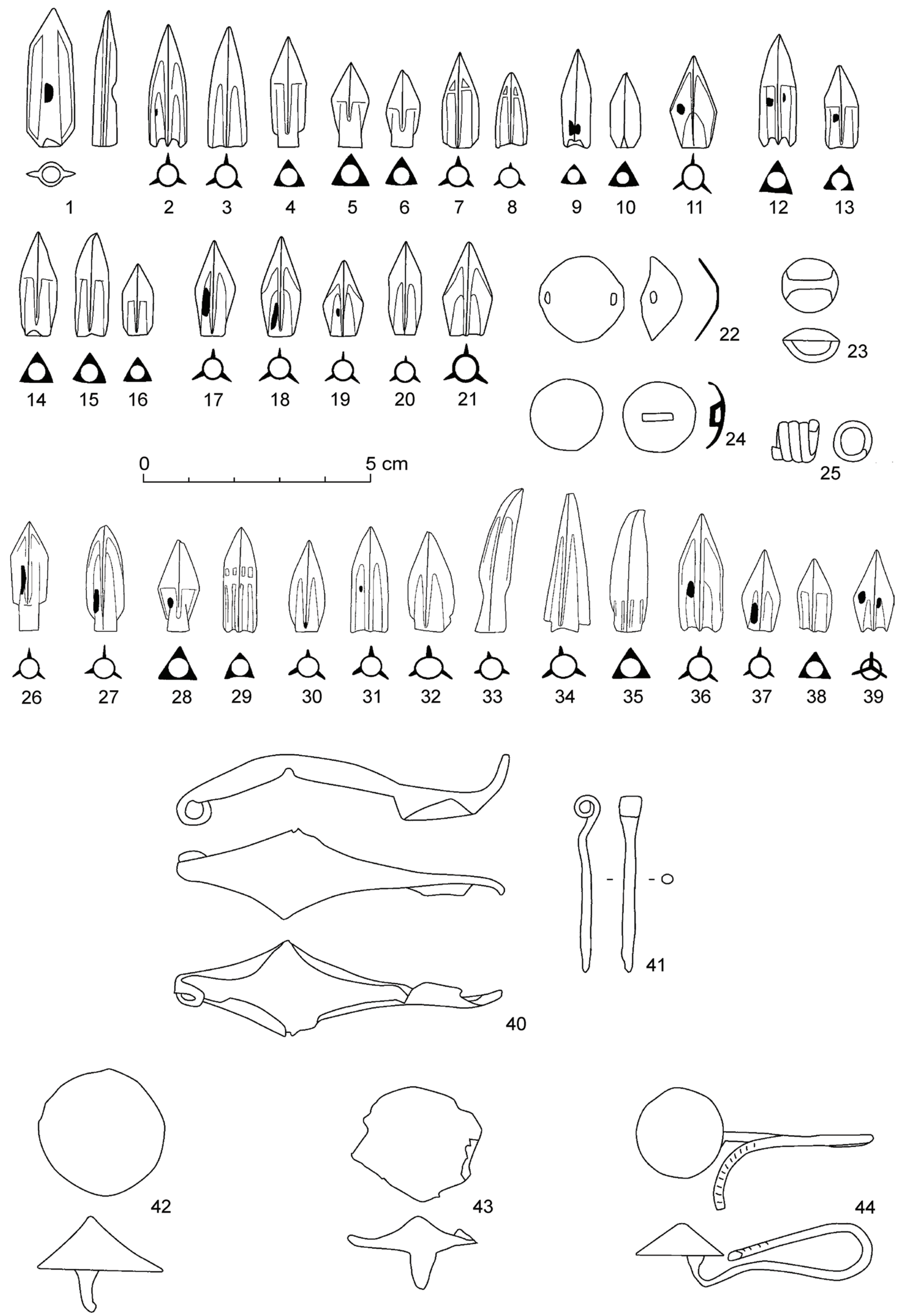

***Fig 4**. Metal finds from surveys at Demänovská hora. 1–25, 40–44 – finds from 2018 survey; 26–39 – finds submitted to the Monuments Board Žilina office by treasure hunters. 41 – iron; others, bronze. Drawn by Martin Furman. After Furman et al., 2019, Figs. 2 and 3, modified.*

***Fig 5**. Homogenous non-stratified cultural layer at excavated sites. **A** – Demänovská hora, trench III (2015); **B** – Končitý vrch, trench II (2015); **C** – Iľanovská Poludnica, trench 1 (2020). Scale in the trenches are 20 cm (1 and 2) and 5 cm (3) © Photo by Lucia Benediková.*

The plant macro-remains for ^{14}C dating were extracted from deposits using water flotation. We have also analysed the plant remains from the 1974 samples rich in charred seeds and also used one already measured ^{14}C determination on sample from the 1974 fieldworks (**Table 1**). To get enough material for dating, most radiocarbon samples consist of more than one seed (**Table 1**). The seeds for each ^{14}C determination were selected according to archaeobotanical expertise that they represent remains of a single archaeobotanical context (e.g. grain store; Benediková *et al*., in preparation).

Samples for dating have not been characterised by IRMS. Graphite targets were prepared in the radiocarbon laboratories in Prague, Debrecen and Vienna (**Table 1**). AMS analysis was performed in Vienna (Kutschera *et al*., 1997; Wild *et al*., 1997) and in Debrecen (Molnár *et al*., 2013), where also targets from Prague (Kučera *et al*., 2022) were analysed. All chronological models and computations have been carried out in OxCal Program version 4.4.4 (Bronk Ramsey, 1995, 2009) with calibration curve IntCal20 (Reimer *et al*., 2020) set to a 5-year resolution. The outcomes of computations were in interpretations rounded to the nearest 10 years.

4. Results

4.1. Demänovská hora

All dated charred macro-remains of peas, lentil, spelt and barley belong to the Iron Age (SOM 2). Due to the absence of informative priors and assuming uniform distribution of events (Bronk Ramsey, 1995), we have investigated the start and end of activities leading to charring of cereals and pulses at Demänovská hora by the uniform phase model (**Fig. 6**, SOM 3). The medians of start and end boundaries date to 647 calBC and 403 calBC.

Despite the coarse chronological resolution caused by the shape of the calibration curve (**Fig. 7**), we tried to ascertain whether samples from the 2015 and 1974 excavations, which comprise different cereals and pulse crops, can be said to represent one or more archaeological events. For this we have employed the tool for combination

Table 1. *Information on AMS dated plant macro-remains. Numerical codes (e.g. 19_348) represent samples pre-treated and graphitised in the radiocarbon laboratory in Prague, whereas other samples were prepared and measured in Debrecen (DeA) and Vienna (VERA) laboratories.*

Lab code	BP	Sigma	Abbrev.	Site	Year	Sample No.	Taxa	Material	No. of finds
VERA-892	2385	30	DH74PS1	Demänovská hora	1974	no data	*Pisum sativum*	Seed	unknown
19_349	2397	21	DH74HV	Demänovská hora	1974	611	*Hordeum vulgare*	Grain apex	2
19_348	2520	20	DH74PS2	Demänovská hora	1974	611	*Pisum sativum*	Seed fragment	2
19_356	2421	19	DH15LC	Demänovská hora	2015	1	*Lens culinaris*	Seed fragment	1
19_357	2445	18	DH15TS	Demänovská hora	2015	1	*Triticum spelta*	Grain	2
19_350	2236	20	KV74PS	Končitý vrch	1974	605	*Pisum sativum*	Seed fragment	6
19_358	2150	18	KV15PI	Končitý vrch	2015	1	*Pinus* sp.	Charcoal*	1
19_359	2166	18	KV15PS	Končitý vrch	2015	1	*Pisum sativum*	Seeds	13
DeA-29815	849	21	IP201	Poludnica	2020	1	*Pinopsida indet.*	Charcoal**	1
DeA-29816	842	21	IP202	Poludnica	2020	1	*Pinopsida indet.*	Charcoal***	1

*Fragment of unknown position within tree (11 tree rings).

**Twig (12 tree rings).

***Fragment of unknown position within tree (five tree rings).

AMS, accelerator mass spectrometry.

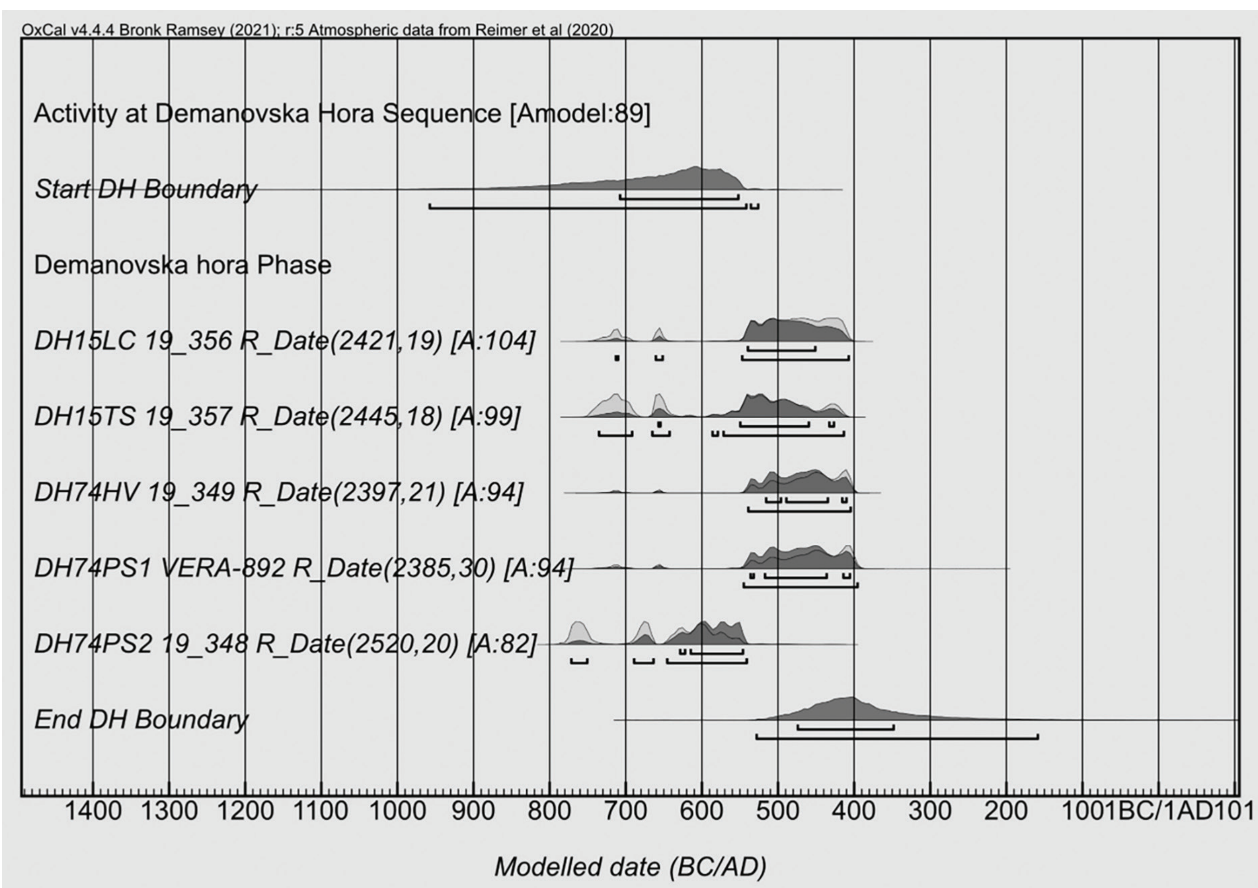

Fig 6. *Demänovská hora. Likelihood (light grey) and posterior probability (dark grey) of [14]C dates in uniform phase. All dates are included in the model. © Figure by Peter Barta.*

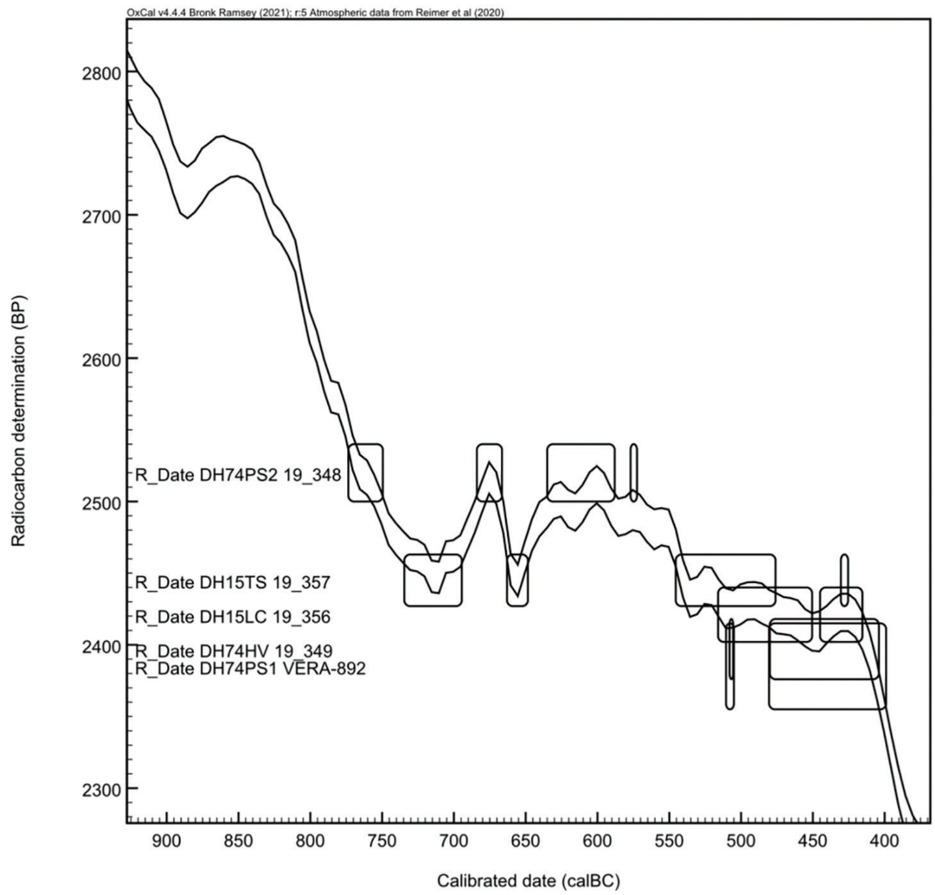

Fig 7. *Demänovská hora. Individually (vague-prior) calibrated ^{14}C ages of charred seeds from excavations in 1974 and 2015. For visual clarity 68.3% probability ranges are shown. No stratigraphic relations are supposed between dated samples of crops. © Figure by Peter Barta.*

before calibration (Ward and Wilson, 1978) incorporated in OxCal Program (R_Combine). As for two samples from the 2015 excavations, they could represent the same sample (grains of spelt 19_357 and seed of lentil 19_356, R_Combine (2434,14)X^2-Test: df = 1 T = 0.8(5% 3.8)). As for three samples from Demänovská hora the 1974 excavations, however, seeds of peas 19_348 statistically proves not to be a part of the same sample with peas VERA-892 and barley 19_349 – the test fails at 5% (X^2-Test: df = 2 T = 23.313(5% 6.0)). When 19_348 is excluded, two remaining samples are statistically coherent and could originate from the same sample (R_Combine (2393,18) X^2-Test: df = 1 T = 0.1(5% 3.8)). Accordingly, when 19_348 is excluded, four samples from the Demänovská hora 1974 and 2015 fieldworks could represent a single archaeological event, for instance a single store of cereals and pulses (Test 4 R_Combine (2419,11)X^2-Test: df = 3 T = 4.5(5% 7.8); details on all testing results are given in Supplementary Online Material SOM 4). However, atmospheric concentration of radiocarbon in 750–400 BC as known from IntCal20 causes that the same value of conventional radiocarbon age can be representative of different archaeological events that may be hundreds of calendar years apart (as shown by simulations for two arbitrary chosen dates 730 BC and 430 BC; SOM 5). Further, statistical scatter of observations of one event by radiocarbon method means more estimates (Buck *et al*., 1996), which, in the period under discussion, may look as though pertaining to non-contemporaneous archaeological events. Thus, conventional radiocarbon ages that are statistically same *sensu* Ward and Wilson (1978) but are physically from different samples may have been produced by archaeological events that were not contemporary. And conversely, even if the test shows that the radiocarbon ages are statistically different – which can indicate that the archaeological events reflected by the samples are different – we cannot rule out that the dated samples are of the same age. Therefore, as for the number of observable archaeological events in our ^{14}C dated samples, we can merely speculate that charred peas 19_348 could represent an older archaeological event, while the rest of the seeds a younger one.

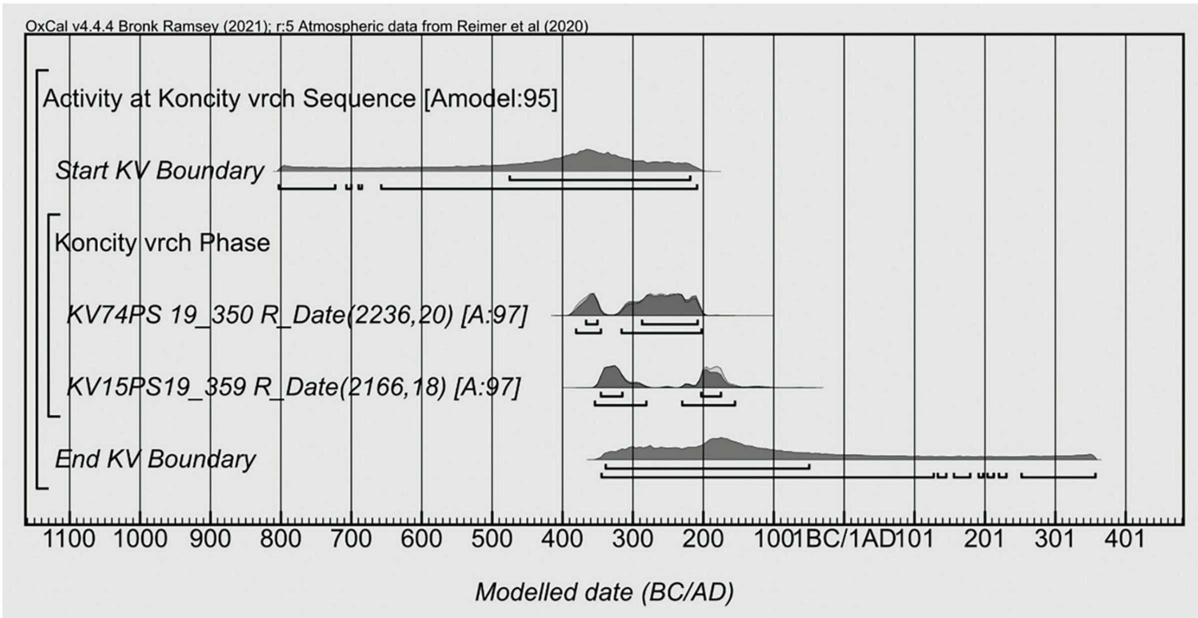

Fig 8. *Končitý vrch. Likelihood (light grey) and posterior probability (dark grey) of ^{14}C dates in uniform phase. Date on the charcoal fragment (19_358) is excluded from the model. © Figure by Peter Barta.*

As we assume no detectable time-gap between production of the crops, their transportation, storing and charring on the mountain summit, we date activity or activities leading to charring of vast amounts of pulse and cereal crops to the time window 650–400 calBC. Owing to the calibration curve shape and the lack of informative priors, the chronological resolution of radiocarbon dating remains coarse. Whether the earliest date measured on peas 19_348 is a statistical outlier or it represents a truly earlier archaeological event could be investigated if samples with strong archaeological priors would be available.

4.2. Končitý vrch

From Končitý vrch, we have two radiocarbon dates on pea seeds and a date on a fragment of pine wood charcoal (SOM 6). Without informative priors about the samples we could here estimate the timing of charring of the crops by the uniform phase model (Bronk Ramsey, 1995) with two ^{14}C dates on peas (SOM 7, **Fig. 8**). The medians of the start and end boundaries gave 391 calBC and 148 calBC (**Fig. 9**). As we have assumed no detectable time-gap between the production of crops in the lowland and their charring on the summit, we date the charring to 390–150 calBC.

The variety of crops, good preservation of seeds and their high density in the sampled matrix suggest that the context was not severely taphonomically altered. As supportive evidence on context's taphonomic integrity, we view also a ^{14}C date on the charred pinewood 19_358, which is statistically same as that on pea 19_359 (R_Combine (2158,13)X^2-Test: df = 1 T = 0.4(5% 3.8)) (SOM 8). Not to overinterpret the ^{14}C determinations, we restrained from using the charcoal fragment in the model as *terminus post quem*, even if archaeological context did not rule out an interpretation of a wooden receptacle for the crops.

4.3. Time Difference between Charring of the Crops at Demänovská hora and Končitý vrch

The above-given results indicate a time-gap between charring of the crops at Demänovská hora and Končitý vrch. According to multiple runs of the models, the median of Demänovská hora phase end boundary and the median of Končitý vrch phase start boundary are separated by around 10 years.

To estimate the minimal time-gap between activities at both sites, we have investigated the difference between closest directly and indirectly dated events, respectively.

If we viewed the charring of samples at each site as individual unrelated events, then potentially closest archaeological events took place in the latest year of the latest vague-prior calibrated date from Demänovská hora (DH74PS1 VERA-892:2385 ± 30 BP, SOM 2) and the earliest year of the earliest vague-prior calibrated date from Končitý vrch (KV74PS 19_350: 2236 ± 20 BP, SOM 6). Then, the latest alternative for charring events at Demänovská hora is 393 calBC and the earliest alternative for charring events at Končitý vrch is 382 calBC (95.4% probability). Both charring events are thus separated by around 10 years.

We also have investigated the difference between these latest and earliest directly dated events (Difference command of OxCal). The estimated difference between the two

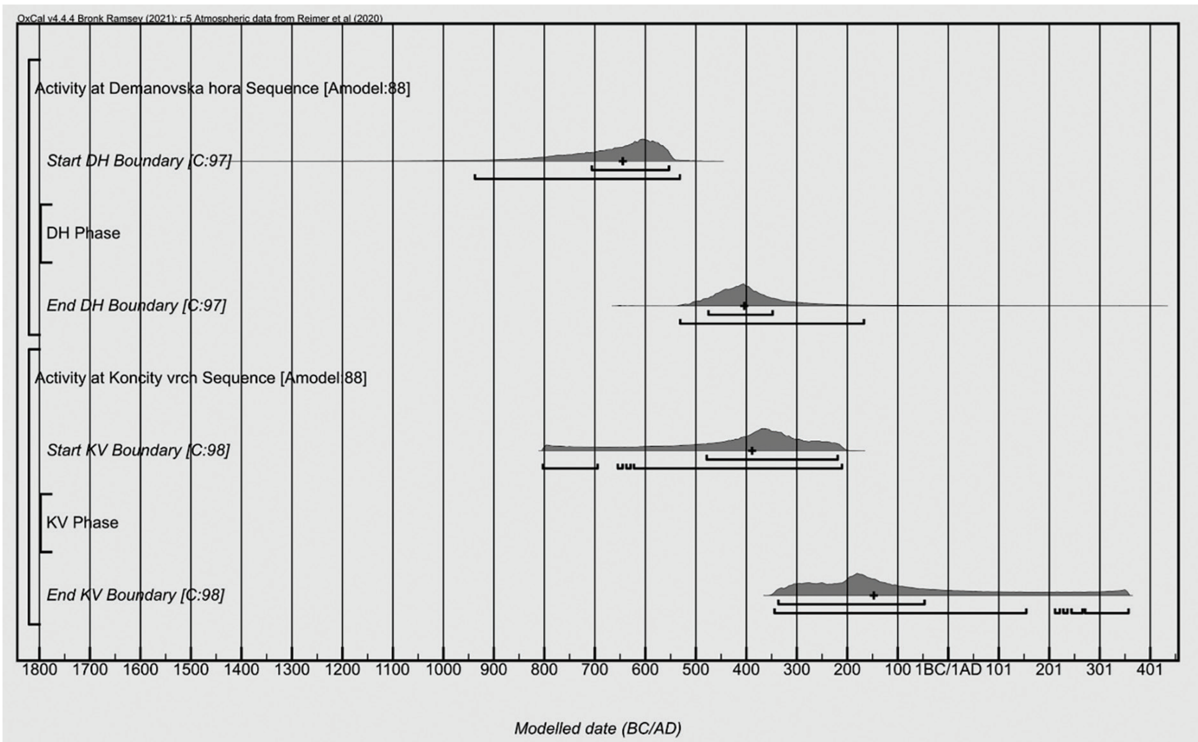

Fig 9. *Demänovská hora and Končitý vrch uniform phases. Start and end boundaries medians indicated with crosses. © Figure by Peter Barta.*

events is from 22 years to 456 years (95.4% probability; SOM 9).

As there are neither stratigraphic nor artefactual records usable as prior information about the samples, we could have not modelled time-relation (**Fig. 9**) between the sites. Accordingly, we have investigated the difference between the end boundary of the Demänovská hora uniform phase, i.e. the last indirectly dated event at this site, and the start boundary of the Končitý vrch uniform phase, i.e. the first indirectly dated event here. The analysis gave under 68.3% probability values from –156 years to 180 years and under 95.4% probability from –432 years to 240 years. The highest probability density was for the interval from 25 years to 80 years (SOM 10 and raw output of analysis, code in SOM 10). The results with negative values are of notice, as they also imply contemporaneity and reversal of the investigated events. However, the negative values here are the consequence of the shape of probability density functions, especially the long-tailed distribution of the start boundary of Končitý vrch (Boundary Start KV) covering the whole of the Hallstatt plateau (**Fig. 9**). Considering, first, the time-relation between directly (^{14}C determinations) and indirectly (boundaries) dated events, and second, the shape of probability density functions of the boundaries, we do not see the proof of synchronicity in our ^{14}C dates.

To sum up, our analyses indicate that activities leading to charring of crops at both sites were not contemporary. According to the analysis of difference between potentially closest directly dated archaeological events (i.e. charring activities), there is at least 20 years between them. As for the difference between the potentially closest indirectly dated events, the most probable result is from 25 to 80 years, according to the raw output from difference analysis (code in SOM 10).

4.4. Iľanovská Poludnica

A small twig and a fragment of wood, both of coniferous taxa, are thought to represent locally grown trees. Even if the soil sample originates from layer bearing prehistoric artefacts, both charcoals are medieval and document anthropogenic or natural events leading to charring of the wood between the mid-12th to mid-13th century calAD (**Fig. 10**, SOM 11). Contrary to the artefactually dated archaeological evidence from the studied context of the Late Bronze Age to the Hallstatt Period, the charcoals are of mediaeval origin.

5. Discussion and Conclusion

Our new ^{14}C dates represent the first systematically collected chronometric evidence on human activities (cf. Barta and Pieta, 2004; Barta *et al*., 2013) at hard-to-reach upland localities in the North of Slovakia. At three studied sites with artefacts from the Early and Late Iron Age (Demänovská

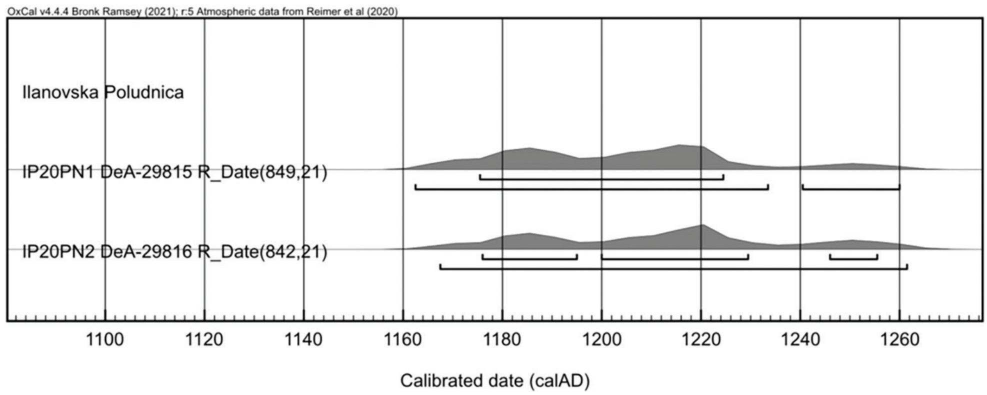

Fig 10. *Iľanovská Poludnica. Results of vague-prior calibration. © Figure by Peter Barta.*

hora, Končitý vrch, Iľanovská Poludnica) as well as from the Late/Final Bronze Age (Iľanovská Poludnica) we focused on ^{14}C dating of the crops. The cereals and pulses from Demänovská hora and Končitý vrch were dated to the Iron Age. At Iľanovská Poludnica we found only charcoal fragments, which turned out to be of mediaeval date.

In our ^{14}C dates we see no indication that the activities leading to charring of the crops at Demänovská hora and Končitý vrch were contemporary. According to a simple comparison of closest vague-prior calibrated date ranges, they are separated by 10 years (SOM 2, SOM 6). According to the analysis of difference between the closest directly dated events from both sites, the time-lapse between closest charring events is 20–330 years (SOM 9). The difference analysis of the closest indirectly dated events confirmed this result with highest probability density for the interval of 25–80 years (raw output from analysis, code in SOM 10).

Taking the medians of boundaries in uniform phases as representative for reporting the results for estimating the activity producing the large amount of charred pulse and cereal crops, we can conclude the following. At Demänovská hora, the charring is dated to 650–400 calBC (**Fig. 9**) and could have occurred as a single (all excluding sample 19_348) or repeated activity (sample 19_348 included) (**Fig. 6**). At Končitý vrch, charring occurred in 390–150 calBC (**Fig. 9**). Whether it was a single or repeated activity (**Fig. 8**) cannot be decided due to the absence of arguments for identification of artefacts of the calibration curve.

Presently, the characteristics of samples and absence of strong archaeological priors prevent us from dating the charred crops with fine chronological resolution. If the charring activities occurred repeatedly, they may have been of diverse nature. The violent destruction at Demänovská hora is strongly supported by the artefactual evidence (weaponry and fire destruction). At Končitý vrch the evidence for violent destruction is weaker and the finds of weaponry are less frequent (Pieta, 1981: 55, 1983: 40; Furman, 2020). Apart from their role as *refugia*, the hypothesis that the sites were used also as burnt offering places seems possible as well (more in: Benediková *et al*., in preparation).

Ultimately, the activities leading to large amounts of charred crops at the mountain summit sites of Demänovská hora (1304 m a. s. l.) and Končitý vrch (1310 m a. s. l.) were not contemporary and were not a consequence of a single short-time event. Even if the details remain elusive, the non-contemporaneity may well point to diverse reasons tied with local or regional cultural–historical circumstances during or at the end of the Early and during the Late Iron Age (e. g. Bujna, 1994: 9; Chochorowski, 2014; Kozubová, 2019; Teržan, 1998: 518, 519).

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SUPPLEMENTARY ONLINE MATERIAL

SOM 1. *Studied sites as viewed from the main ridge of the Nízke Tatry to the north. 1 – Demänovská hora, 2 – Končitý vrch, 3 – Iľanovská Poludnica. © Photo by Jaroslav Moravčík, edited by Mária Hajnalová.*

SOM 2. *Demänovská hora – vague-prior calibration of all radiocarbon dates. Output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

DH15LC 19_356 R_Date(2421,19)
68.3% probability
516BC (46.7%) 451BC
446BC (21.5%) 416BC
95.4% probability
726BC (5.8%) 701BC
664BC (3.6%) 650BC
546BC (86.0%) 406BC
DH15TS 19_357 R_Date(2445,18)
68.3% probability
735BC (21.4%) 695BC
664BC (8.4%) 649BC
546BC (36.5%) 476BC
431BC (1.9%) 426BC
95.4% probability
749BC (26.4%) 686BC
666BC (10.6%) 640BC
570BC (58.4%) 412BC
DH74HV 19_349 R_Date(2397,21)
68.3% probability
508BC (1.6%) 506BC
480BC (66.7%) 404BC
95.4% probability
541BC (95.4%) 400BC

SOM 2. *Continued*

DH74PS1 VERA-892 R_Date(2385,30)
68.3% probability
511BC (3.1%) 506BC
481BC (65.1%) 400BC
95.4% probability
719BC (1.8%) 708BC
662BC (1.4%) 653BC
544BC (92.2%) 393BC
DH74PS2 19_348 R_Date(2520,20)
68.3% probability
774BC (20.1%) 750BC
684BC (14.1%) 667BC
636BC (31.8%) 588BC
578BC (2.3%) 573BC
95.4% probability
779BC (24.5%) 743BC
692BC (18.3%) 663BC
646BC (52.6%) 548BC

SOM 3. *Demänovská hora – calibrated dates of the uniform phase model based on all dates from the site. Edited output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

Start DH Boundary
DH15LC 19_356 R_Date(2421,19)
68.3% probability
516BC (46.7%) 451BC
446BC (21.5%) 416BC
95.4% probability
726BC (5.8%) 701BC
664BC (3.6%) 650BC
546BC (86.0%) 406BC
DH15TS 19_357 R_Date(2445,18)
68.3% probability
735BC (21.4%) 695BC
664BC (8.4%) 649BC
546BC (36.5%) 476BC
431BC (1.9%) 426BC
95.4% probability
749BC (26.4%) 686BC
666BC (10.6%) 640BC
570BC (58.4%) 412BC
DH74HV 19_349 R_Date(2397,21)
68.3% probability
508BC (1.6%) 506BC
480BC (66.7%) 404BC
95.4% probability
541BC (95.4%) 400BC
DH74PS1 VERA-892 R_Date(2385,30)
68.3% probability
511BC (3.1%) 506BC
481BC (65.1%) 400BC
95.4% probability
719BC (1.8%) 708BC
662BC (1.4%) 653BC
544BC (92.2%) 393BC
DH74PS2 19_348 R_Date(2520,20)
68.3% probability
774BC (20.1%) 750BC
684BC (14.1%) 667BC
636BC (31.8%) 588BC
578BC (2.3%) 573BC
95.4% probability
779BC (24.5%) 743BC
692BC (18.3%) 663BC
646BC (52.6%) 548BC
Phase Demanovska hora
End DH Boundary
Sequence Activity at Demanovska Hora
Posterior (MCMC 30000)
Overall agreement 87.9%
Dynamic agreement 89.0%
Start DH Posterior
68.3% probability
732BC (1.4%) 726BC
708BC (66.9%) 553BC
95.4% probability
952BC (95.4%) 526BC

SOM 3. *Continued*

DH15LC 19_356 Posterior
68.3% probability
540BC (68.3%) 452BC
95.4% probability
661BC (1.4%) 652BC
547BC (94.1%) 408BC
Agreement 104.0%
DH15TS 19_357 Posterior
68.3% probability
658BC (1.7%) 654BC
550BC (64.2%) 460BC
433BC (2.4%) 426BC
95.4% probability
736BC (7.1%) 692BC
666BC (5.9%) 643BC
586BC (0.6%) 580BC
573BC (81.8%) 414BC
Agreement 98.9%
DH74HV 19_349 Posterior
68.3% probability
516BC (17.0%) 496BC
488BC (47.0%) 436BC
416BC (4.3%) 410BC
95.4% probability
540BC (95.4%) 404BC
Agreement 93.9%
DH74PS1 VERA-892 Posterior
68.3% probability
536BC (3.5%) 531BC
516BC (59.1%) 437BC
414BC (5.6%) 406BC
95.4% probability
546BC (95.4%) 396BC
Agreement 94.1%
DH74PS2 19_348 Posterior
68.3% probability
629BC (3.7%) 622BC
615BC (64.6%) 546BC
95.4% probability
772BC (3.9%) 750BC
689BC (8.4%) 664BC
646BC (83.2%) 542BC
Agreement 82.4%
End DH Posterior
68.3% probability
476BC (68.3%) 348BC
95.4% probability
532BC (95.4%) 159BC
MCMC (504000)

SOM 4. *Demänovská hora – testing results for combination of radiocarbon dates from 2015 Test 1 (19_356, 19_357), from 1974 Test 2 (VERA-892, 19_349, 19_348), from 1974 Test 3 when the 19_348 is excluded (VERA-892, 19_349) and Test 4 from all 2015 and 1974 dates without 19_348. Output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

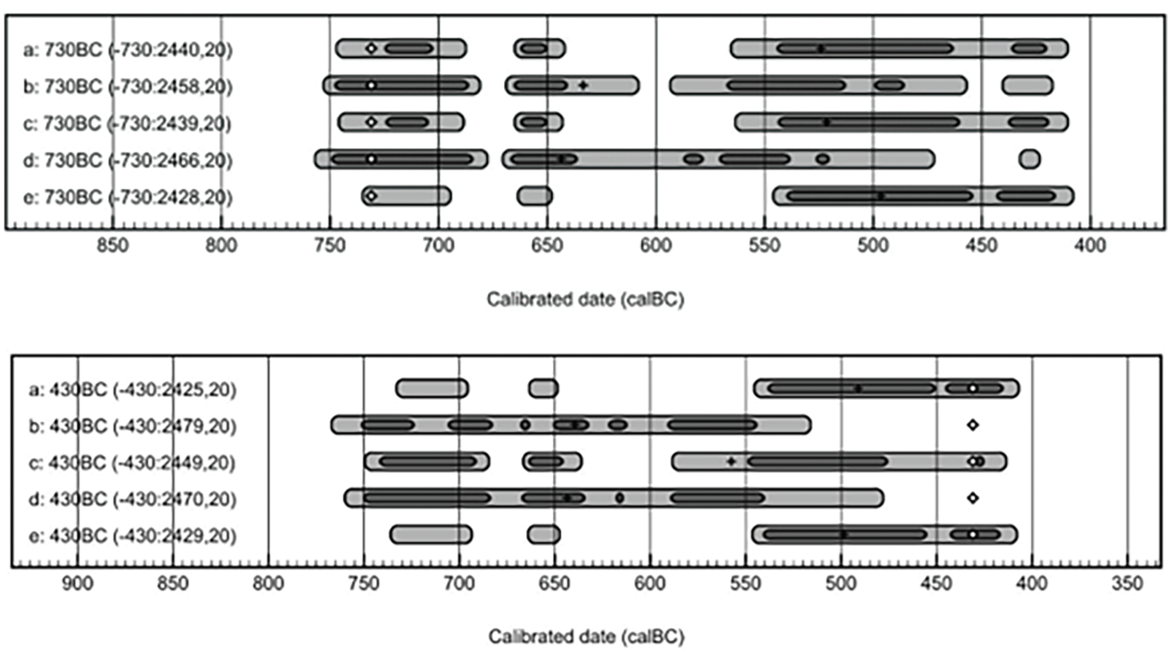
Test 1 R_Combine(2434,14)
68.3% probability
716BC (4.0%) 710BC
658BC (2.5%) 654BC
542BC (53.4%) 466BC
436BC (8.4%) 422BC
95.4% probability
733BC 12.2%) 696BC
664BC (6.3%) 650BC
546BC (76.9%) 412BC
X2-Test: df = 1 T = 0.8(5% 3.8)

Test 2 R_Combine(2448,14)
68.3% probability
736BC (27.1%) 694BC
664BC (10.6%) 648BC
546BC (21.5%) 512BC
502BC (9.0%) 484BC
95.4% probability
748BC (31.0%) 688BC
666BC (12.2%) 642BC
567BC (52.2%) 416BC
X2-Test: df = 2 T = 23.3(5% 6.0))
Warning! X-Test fails at 5% - DH74 X2-Test: df = 2 T = 23.313(5% 6.0)

SOM 4. *Continued*

Test 3 R_Combine(2393,18)
68.3% probability
477BC (68.3%) 403BC
95.4% probability
538BC (2.1%) 530BC
518BC (93.3%) 401BC
X2-Test: df = 1 T = 0.1(5% 3.8)

Test 4 R_Combine(2419,11)
68.3% probability
513BC (10.5%) 500BC
486BC (57.8%) 416BC
95.4% probability
541BC (95.4%) 410BC
X2-Test: df = 3 T = 4.5(5% 7.8)



SOM 5. *Simulated radiocarbon dates for 730 BC (above) and 430 BC (below). Probabilities of 68.3% (dark grey) and 95.4% (light grey) are shown. Diamonds represent simulated ages and crosses mean values of calibrated dates.*

SOM 6. *Končitý vrch – vague-prior calibration of all radiocarbon dates. Output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

KV15PI 19_358 R_Date(2150,18)
 68.3% probability
  342BC (21.2%) 322BC
  201BC (47.0%) 161BC
 95.4% probability
  349BC (26.8%) 310BC
  206BC (67.9%) 102BC
  66BC (0.7%) 60BC

KV15PS 19_359 R_Date(2166,18)
 68.3% probability
  346BC (33.0%) 316BC
  204BC (35.3%) 172BC
 95.4% probability
  354BC (46.8%) 284BC
  230BC (48.3%) 151BC
  128BC (0.3%) 124BC

KV74PS 19_350 R_Date(2236,20)
 68.3% probability
  372BC (15.1%) 352BC
  286BC (48.4%) 228BC
  218BC (4.7%) 210BC
 95.4% probability
  382BC (22.3%) 348BC
  312BC (73.2%) 206BC

SOM 7. *Končitý vrch – calibrated dates of the uniform phase model based on two dates (19_350 and 19_359) and excluding the charcoal fragment (19_358). Edited output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

Start KV Boundary
KV15PS 19_359 R_Date(2166,18)
 68.3% probability
  346BC (33.0%) 316BC
  204BC (35.3%) 172BC
 95.4% probability
  354BC (46.8%) 284BC
  230BC (48.3%) 151BC
  128BC (0.3%) 124BC
KV74PS 19_350 R_Date(2236,20)
 68.3% probability
  372BC (15.1%) 352BC
  286BC (48.4%) 228BC
  218BC (4.7%) 210BC
 95.4% probability
  382BC (22.3%) 348BC
  312BC (73.2%) 206BC
Phase KV
End KV Boundary
Sequence Activity at Koncity vrch
Posterior
MCMC(30000)
Overall agreement 95.9%
Dynamic agreement 95.7%
KV Posterior
 68.3% probability
  486BC (68.3%) 219BC
 95.4% probability
  800BC (7.2%) 722BC
  713BC (0.2%) 710BC
  686BC (0.4%) 682BC
  674BC (0.6%) 666BC
  659BC (87.0%) 210BC
KV15PS 19_359 Posterior
 68.3% probability
  346BC (38.7%) 315BC
  204BC (29.6%) 176BC
 95.4% probability
  354BC (53.0%) 282BC
  230BC (42.5%) 156BC
 Agreement 96.9%
KV74PS 19_350 Posterior
  367BC (11.3%) 352BC
  288BC (57.0%) 208BC
 95.4% probability
  381BC (19.9%) 346BC
  316BC (75.6%) 203BC
 Agreement 97.3%
End KV Posterior
 68.3% probability
  336BC (68.3%) 47BC
 95.4% probability
  344BC (85.6%) 164AD
  186AD (0.3%) 192AD
  216AD (0.7%) 226AD
  240AD (8.8%) 358AD
MCMC(480000)

SOM 8. *Končitý vrch – combination of radiocarbon dates for pine charcoal (19_358) and peas (19_359). Edited output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

```
R_Combine(2158,13)
 68.3% probability
  342BC (26.0%) 322BC
  200BC (42.2%) 172BC
 95.4% probability
  350BC (37.7%) 308BC
  207BC (56.6%) 150BC
  130BC (1.1%) 120BC
X2-Test: df = 1 T = 0.4(5% 3.8)
```

SOM 9. *Difference between the latest directly dated archaeological event from Demänovská hora (sample DH74PS1) and the earliest directly dated archaeological event from Končitý vrch (sample KV74PS). Code and edited output from OxCal v4.4.4 Bronk Ramsey (2021); atmospheric data from Reimer et al. (2020).*

```
Plot()
 {
  R_Date("DH74PS1 VERA-892", 2385, 30);
  R_Date("KV74PS 19_350", 2236, 20);
  Difference("End DH and Start KV", "KV74PS 19_350", "DH74PS1 VERA-892");
 };

DH74PS1 VERA-892 R_Date(2385,30)
 68.3% probability
  511BC (3.1%) 506BC
  481BC (65.1%) 400BC
 95.4% probability
  719BC (1.8%) 708BC
  662BC (1.4%) 653BC
  544BC (92.2%) 393BC
KV74PS 19_350 R_Date(2236,20)
 68.3% probability
  372BC (15.1%) 352BC
  286BC (48.4%) 228BC
  218BC (4.7%) 210BC
 95.4% probability
  382BC (22.3%) 348BC
  312BC (73.2%) 206BC
End DH and Start KV Difference(KV74PS 19_350,DH74PS1 VERA-892)
 68.3% probability
  106 (68.3%) 262
 95.4% probability
  22 (93.4%) 327
  350 (0.3%) 356
  416 (1.7%) 456
```

SOM 10. *Difference between the Demänovská hora phase end boundary and Končitý vrch phase start boundary. Code and edited output from OxCal v4.4.4 Bronk Ramsey (2021); atmospheric data from Reimer et al. (2020).*

```
Plot()
 {
  Sequence("DH")
  {
   Boundary("Start DH");
   Phase("DH")
   {
    R_Date("DH74PS2 19_348", 2520, 20);
    R_Date("DH15TS 19_357", 2445, 18);
    R_Date("DH15LC 19_356", 2421, 19);
    R_Date("DH74HV 19_349", 2397, 21);
    R_Date("DH74PS1 VERA-892", 2385, 30);
   };
   Boundary("End DH");
  };
  Sequence("KV")
  {
   Boundary("Start KV");
   Phase("KV")
   {
    R_Date("KV74PS 19_350", 2236, 20);
    R_Date("KV15PS19_359", 2166, 18);
   };
   Boundary("End KV");
  };
  Difference("End DH and Start KV", "Start KV", "End DH");
 };

Start DH Boundary()
DH74PS2 19_348 R_Date(2520,20)
 68.3% probability
  774BC (20.1%) 750BC
  684BC (14.1%) 667BC
  636BC (31.8%) 588BC
  578BC (2.3%) 573BC
 95.4% probability
  779BC (24.5%) 743BC
  692BC (18.3%) 663BC
  646BC (52.6%) 548BC
DH15TS 19_357 R_Date(2445,18)
 68.3% probability
  735BC (21.4%) 695BC
  664BC (8.4%) 649BC
  546BC (36.5%) 476BC
  431BC (1.9%) 426BC
 95.4% probability
  749BC (26.4%) 686BC
  666BC (10.6%) 640BC
  570BC (58.4%) 412BC
DH15LC 19_356 R_Date(2421,19)
 68.3% probability
  516BC (46.7%) 451BC
  446BC (21.5%) 416BC
 95.4% probability
  726BC (5.8%) 701BC
  664BC (3.6%) 650BC
  546BC (86.0%) 406BC
DH74HV 19_349 R_Date(2397,21)
 68.3% probability
  508BC (1.6%) 506BC
  480BC (66.7%) 404BC
 95.4% probability
  541BC (95.4%) 400BC
```

(*Continued*)

SOM 10. *Continued*

```
DH74PS1 VERA-892 R_Date(2385,30)
  68.3% probability
    511BC (3.1%) 506BC
    481BC (65.1%) 400BC
  95.4% probability
    719BC (1.8%) 708BC
    662BC (1.4%) 653BC
    544BC (92.2%) 393BC
(Phase DH
DH Phase()
) Phase DH
End DH Boundary()
(Sequence DH
DH Sequence()
) Sequence DH
Start KV Boundary()
KV74PS 19_350 R_Date(2236,20)
  68.3% probability
    372BC (15.1%) 352BC
    286BC (48.4%) 228BC
    218BC (4.7%) 210BC
  95.4% probability
    382BC (22.3%) 348BC
    312BC (73.2%) 206BC
KV15PS19_359 R_Date(2166,18)
  68.3% probability
    346BC (33.0%) 316BC
    204BC (35.3%) 172BC
  95.4% probability
    354BC (46.8%) 284BC
    230BC (48.3%) 151BC
    128BC (0.3%) 124BC
(Phase KV
KV Phase()
) Phase KV
End KV Boundary()
(Sequence KV
KV Sequence()
) Sequence KV
End DH and Start KV Difference(Start KV,End DH)
(MCMC(30000)
Overall agreement  87.4%
Dynamic agreement  88.1%
Start DH Posterior
  68.3% probability
    718BC (68.3%) 554BC
  95.4% probability
    949BC (95.4%) 526BC
DH74PS2 19_348 Posterior
  68.3% probability
    630BC (3.7%) 623BC
    615BC (64.5%) 547BC
  95.4% probability
    772BC (3.8%) 750BC
    690BC (8.7%) 664BC
    646BC (83.0%) 542BC
 Agreement  82.5%
DH15TS 19_357 Posterior
  68.3% probability
    658BC (1.7%) 654BC
    550BC (64.8%) 460BC
    432BC (1.8%) 427BC
  95.4% probability
    736BC (7.1%) 692BC
    666BC (5.9%) 642BC
    586BC (0.7%) 580BC
    572BC (81.7%) 414BC
 Agreement 98.9%
```

SOM 10. *Continued*

```
DH15LC 19_356 Posterior
  68.3% probability
    540BC (68.3%) 452BC
  95.4% probability
    661BC (1.4%) 652BC
    548BC (94.1%) 408BC
 Agreement 104.0%
DH74HV 19_349 Posterior
  68.3% probability
    516BC (66.6%) 436BC
    414BC (1.7%) 411BC
  95.4% probability
    540BC (95.4%) 404BC
 Agreement  93.5%
DH74PS1 VERA-892 Posterior
  68.3% probability
    536BC (2.5%) 532BC
    517BC (61.0%) 437BC
    414BC (4.8%) 406BC
  95.4% probability
    546BC (95.4%) 396BC
 Agreement 93.8%
End DH Posterior
  68.3% probability
    476BC (68.3%) 348BC
  95.4% probability
    530BC (95.4%) 133BC
Start KV Posterior
  68.3% probability
    484BC (68.3%) 220BC
  95.4% probability
    804BC (6.3%) 736BC
    730BC (1.1%) 716BC
    704BC (0.5%) 698BC
    688BC (0.2%) 684BC
    680BC (0.5%) 674BC
    666BC (86.9%) 210BC
KV74PS 19_350 Posterior
  68.3% probability
    368BC (11.6%) 352BC
    288BC (56.7%) 209BC
  95.4% probability
    381BC (19.8%) 346BC
    316BC (75.6%) 203BC
 Agreement  97.2%
KV15PS19_359 Posterior
  68.3% probability
    346BC (38.9%) 315BC
    204BC (29.3%) 176BC
  95.4% probability
    354BC (53.2%) 282BC
    230BC (42.2%) 155BC
 Agreement 96.8%
End KV Posterior
  68.3% probability
    336BC (68.3%) 44BC
  95.4% probability
    344BC (85.9%) 152AD
    160AD (1.4%) 182AD
    204AD (0.2%) 207AD
    218AD (0.2%) 220AD
    257AD (7.8%) 358AD
End DH and Start KV Posterior
  68.3% probability
    -156 (68.3%) 180
  95.4% probability
    -432 (95.4%) 240
) MCMC(480000)
```

SOM 11. *Iľanovská Poludnica – vague-prior calibration of all radiocarbon dates. Output from OxCal v4.4.4 (Bronk Ramsey, 2021); atmospheric data (Reimer et al., 2020).*

```
IP20PN1 DeA-29815 R_Date(849,21)
  68.3% probability
    1175AD (68.3%) 1224AD
  95.4% probability
    1162AD (87.6%) 1233AD
    1240AD (7.9%) 1260AD
IP20PN2 DeA-29816 R_Date(842,21)
  68.3% probability
    1176AD (21.3%) 1194AD
    1200AD (39.7%) 1229AD
    1246AD (7.2%) 1255AD
  95.4% probability
    1167AD (95.4%) 1261AD
```

References

Bronk Ramsey C, 2021. *OxCal Programme Version 4.4*. Oxford Radiocarbon Accelerator Unit, University of Oxford.

Reimer PJ, Austin WEN, Bard E, Bayliss A, Blackwell PG, Ramsey CB, Butzin M, Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kromer B, Manning SW, Muscheler R, Palmer JG, Pearson C, Plicht J van der, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM, Wacker L, Adolphi F, Büntgen U, Capano M, Fahrni SM, Fogtmann-Schulz A, Friedrich R, Köhler P, Kudsk S, Miyake F, Olsen J, Reinig F, Sakamoto M, Sookdeo A and Talamo S, 2020. The IntCal20 Northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon 62*(4): 725–757, DOI 10.1017/RDC.2020.41.