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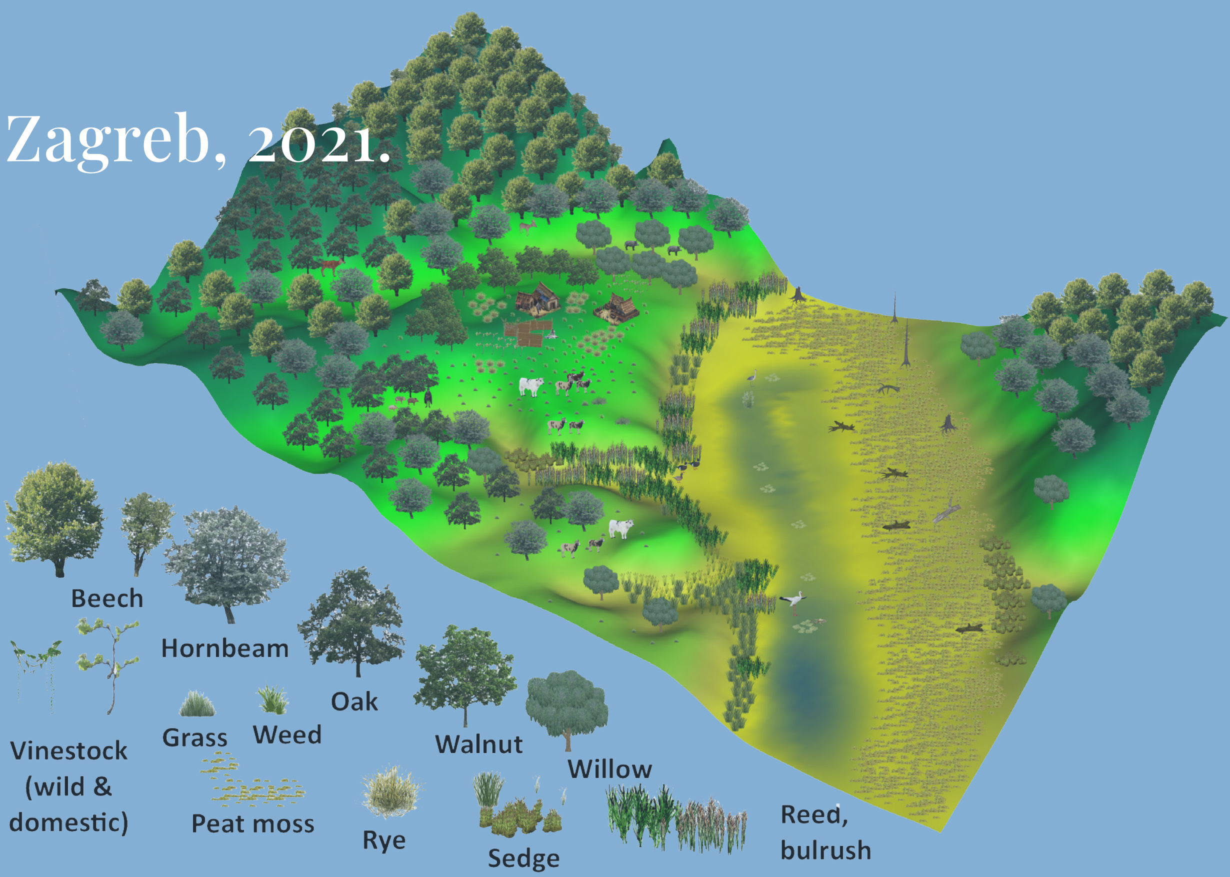
USING LANDSCAPE IN THE MIDDLE AGES IN THE LIGHT OF INTERDISCIPLINARY RESEARCH

KORIŠTENJE KRAJOLIKA U SREDNJEM VIJEKU U SVJETLU INTERDISCIPLINARNIH ISTRAŽIVANJA

Zagreb, 2021.



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UVODNA RIJEČ

U današnje vrijeme nemoguće je promatrati ljudsku prošlost bez promatranja suodnosa čovjeka i okoliša. S jedne strane, uočljiv je utjecaj okoliša pri izboru mjesta za formiranje naselja, u gospodarskoj djelatnosti koje neko naselje afirmira i razvija, kao i utjecaj o čovjeku neovisnih promjena (npr. klimatskih) koje su mogle uzrokovati i napuštanje nekih gospodarskih djelatnosti ili čak čitavih naselja. S druge strane, čovjek djeluje na modeliranje okoliša i krajolika jer su promjene u socijalnim strukturama, ekonomiji, proizvodnji, kulturnim i vjerskim izričajima svakako donosile promjene koje su uvelike sezale u prestrukturiranje i modificiranje izvornih krajolika. Za razumijevanje ovih promjena ključan je multidisciplinaran i interdisciplinaran pristup: korištenjem arheologije krajobraza i okoliša, geoarheologije, paleoekologije, paleoklimatologije i paleogeografije kako bi se rekonstruirali danas izgubljeni okolišni uvjeti te promatranjem novijeg krajobraza kao slojevite tvorevine povijesnih događanja korištenjem povijesnih izvora, bioarheoloških podataka itd. Tako se krajolik definira kroz međusoban odnos prirodnih procesa i ljudskih aktivnosti, a upravo je ovo bila tema šestog međunarodnog znanstvenog skupa srednjovjekovne arheologije održanog u Zagrebu 6. lipnja 2019. godine, pod nazivom *Korištenje krajolika u srednjem vijeku u svjetlu interdisciplinarnih istraživanja* u organizaciji Instituta za arheologiju. Tijekom skupa održano je 12 izlaganja i četiri poster prezentacije, a sudjelovalo je 37 znanstvenika, od kojih 16 iz Hrvatske te 21 iz Mađarske, Rumunjske, Rusije, Slovačke, Slovenije i Srbije. Cilj ovoga skupa bio je promatranje čovjeka u svom ekološkom, ekonomskom, kulturno-religijskom i povijesnom okruženju tijekom srednjega i novoga vijeka u svjetlu interdisciplinarnih istraživanja.

Dio predstavljenih radova obuhvaćen je ovim Zbornikom radova znanstvenog skupa. Radovi raznovrsno promatraju čovjekov krajolik: od rekonstrukcija okolišnih i ekoloških uvjeta, prostornih analiza naseljavanja, rekonstrukcija okoliša prema arheološkim kontekstima, do transformacije srednjovjekovnog grada, vodovoda kao dijela pomno planiranog gradskog krajolika te promišljanja kulturno-religijskih krajolika.

Prikupljanje radova ovoga Zbornika i priprema za tisak u vrijeme COVID-19 pandemije, potpunog zatvaranja svih djelatnosti, dva razaorna potresa (onog zagrebačkog u nedjelju 22. ožujka 2020. godine u 6 sati i 24 minute te onog petrinjskog u utorak 29. prosinca 2020. godine u 12 sati i 19 minuta) te njihovih dalekosežnih posljedica koje su prisilile Institut na promjenu adrese, činili su se gotovo nemogućim zadatkom. Stoga smo posebno zahvalni autorima radova okupljenih u ovoj publikaciji koja izlazi u seriji *Zbornik Instituta za arheologiju / Serta Instituti Archaeologici* (Vol. 18) i Ministarstvu znanosti i obrazovanja Republike Hrvatske na financijskoj potpori za izdavanje ovoga Zbornika u vrijeme globalne financijske krize. Zahvaljujemo svim sudionicima skupa, kolegama iz Instituta za arheologiju za pomoć pri organizaciji i recenzentima ove publikacije. Nadamo se da će ovdje prikupljeni radovi biti poticaj i inspiracija kolegama arheolozima, stručnjacima drugih znanstvenih područja, kao i generacijama koje dolaze, za promatranje i proučavanje različitih aspekata prostornog identiteta nekog područja. Tako bismo u konačnici bolje razumjeli prošlost te iz novog kuta sagledali okruženje u kojem živimo, a koje u svojoj srži baštini svu slojevitost međuodnosa čovjeka i prirodnih procesa.

Katarina Botić

FOREWORD

At present, it is impossible to observe the human past without observing the relationship between man and the environment. On the one hand, the influence of the environment is noticeable on the choice of places to form settlements, on the economic activity that affirms and develops a settlement, as well as the non-human influenced changes (e.g. climate) that could have caused the abandonment of some economic activities or even entire settlements. On the other hand, man influences modelling of the environment and the landscape, because changes in social structures, economics, production, cultural and religious expressions have certainly brought about changes that have largely restructured and modified the original landscapes. A multidisciplinary and interdisciplinary approach is vital to understand these changes: using landscape and environmental archaeology, geoarchaeology, paleoecology, paleoclimatology and paleogeography to reconstruct today's lost environmental conditions and observing the recent landscape as a layered formation of historical events using historical sources, bioarchaeological data, etc. Thus, the landscape is defined through the mutual relationship between natural processes and human activities, and this was precisely the topic of the 6th International Scientific Conference on Mediaeval Archaeology held in Zagreb on 6th of June 2019, entitled *Using landscape in the Middle Ages in the light of interdisciplinary research*, organized by the Institute of Archaeology. During the conference, 12 presentations and four poster presentations were held, and 37 scientists participated, 16 of them from Croatia and 21 from Hungary, Romania, Russia, Slovakia, Slovenia and Serbia. The aim of this conference was to observe man in his ecological, economic, cultural-religious and historical environment during the Middle and Modern Ages in the light of interdisciplinary research.

Part of the presented papers is included in this Proceedings of the scientific conference volume. The papers observe the human landscape in a variety of ways: from reconstructions of environmental and ecological conditions, spatial analyses of settlements, reconstructions of the environment according to the archaeological contexts, to the transformation of the medieval town, water supply as part of a carefully planned urban landscape, and reflections on cultural and religious landscapes.

Collecting the papers for this Proceedings volume and preparing them for printing at the time of the COVID-19 pandemic, complete lockdown, two devastating earthquakes (the one in Zagreb on Sunday, 22nd of March 2020 at 6.24 AM and the one in Petrinja on Tuesday, 29th of December 2020 at 12.19 AM) and their far-reaching consequences that forced the Institute to change its address, seemed an almost impossible task. Therefore, we are especially grateful to the authors of the papers collected in this publication, which is published in the series *Zbornik Instituta za archeologiju / Serta Instituti Archaeologici* (Vol. 18), and the Ministry of Science and Education of the Republic of Croatia for the financial support of this Proceedings volume during the global financial crisis. We would like to thank all conference participants, colleagues from the Institute of Archeology for their help with the organization and reviewers of this publication. We hope that the papers collected here will be an encouragement and inspiration to fellow archaeologists and experts from other scientific fields, as well as future generations, to observe and study different aspects of the spatial identity of a region. In this way, we would ultimately better understand the past and see from a new angle the environment in which we live today, which at its core inherits all the layers of the interrelationships between man and natural processes.

Katarina Botić, Tajana Sekelj Ivančan

MIDDLE AGES FOREST AND WOODLAND COVER IN THE DRAVA RIVER REGION, ARCHAEOLOGICAL PERSPECTIVE: TORČEC, VIRJE AND HLEBINE CASE STUDY

During several years of archaeological research on sites around Torčec, Virje and Hlebine in Podravina (Drava River region), as part of the project TransFER *Iron production along the Drava River in the Roman period and the Middle Ages: Creation and transfer of knowledge, technologies and goods* (IP-06-2016-5047) funded by the Croatian Science Foundation, a large number of samples of burnt wood was collected. Anthracological analyses of samples collected in medieval houses have shown that in the everyday life a large number of wood species have been used, not only for the construction of houses, but also for the heating and possibly making of furniture or smaller items for everyday use.

There is a documented change in the use of wood species from the second half of the 6th century to the beginning of the 14th century in the example of several sites in the vicinity of Torčec, which was confirmed on the sites around Virje and Hlebine. Although oak (*Quercus*) prevails in all periods, its use from the 10th century is reduced, when other types of wood appear. Some medieval settlements were located near the workshops for iron smelting, an activity that over time led to over clearing of oak forests and to the transformation of forest habitats. Thus, anthropogenic influences have allowed the spread of other species such as elm (*Ulmus*), maple (*Acer*), ash (*Fraxinus*), alder (*Populus*), willow (*Salix*), birch (*Betula*) and blackthorn (*Prunus spinosa*).

KEY WORDS: **DRAVA RIVER REGION, ANTHRACOLOGICAL ANALYSES, RELATIVE CHRONOLOGY, RADIOCARBON DATING, MIDDLE AGES**

INTRODUCTION

In the last few decades several mediaeval sites concentrated in the upper Drava river valley were identified and underwent archaeological excavations.[1] Five sites around Torčec were excavated between 2002 and 2008 (Prečno pole I, Blaževo pole 6, Ledine, Pod Gucak and Rudičevo) (Fig. 1) (Sekelj Ivančan 2010), two sites around Virje between 2008 and 2014 in 5 campaigns (Volarski breg and Sušine), and two sites around Hlebine between 2016 and 2018 (Velike Hlebine and Dedanovice) (Sekelj Ivančan, Karavidović 2021a). Research around Torčec was first conducted in the scope of projects *Archaeological image of medieval settlements in Drava region* (2002–2006) and *Medieval settlement of northern Croatia in the light of archaeological sources* (2007–2013) (197-1970685-0693), financed by the Ministry of Science, Education and Sport while later research around Virje and Hlebine was conducted in the scope of the project *Iron production along the Drava River in the Roman period and the Middle Ages: Creation and transfer of knowledge, technologies and goods* (TransFER, 2017–2021, IP-06-2016-5047), financed by the Croatian Science Foundation.

Both residential and work areas for iron smelting were explored and charcoal samples,

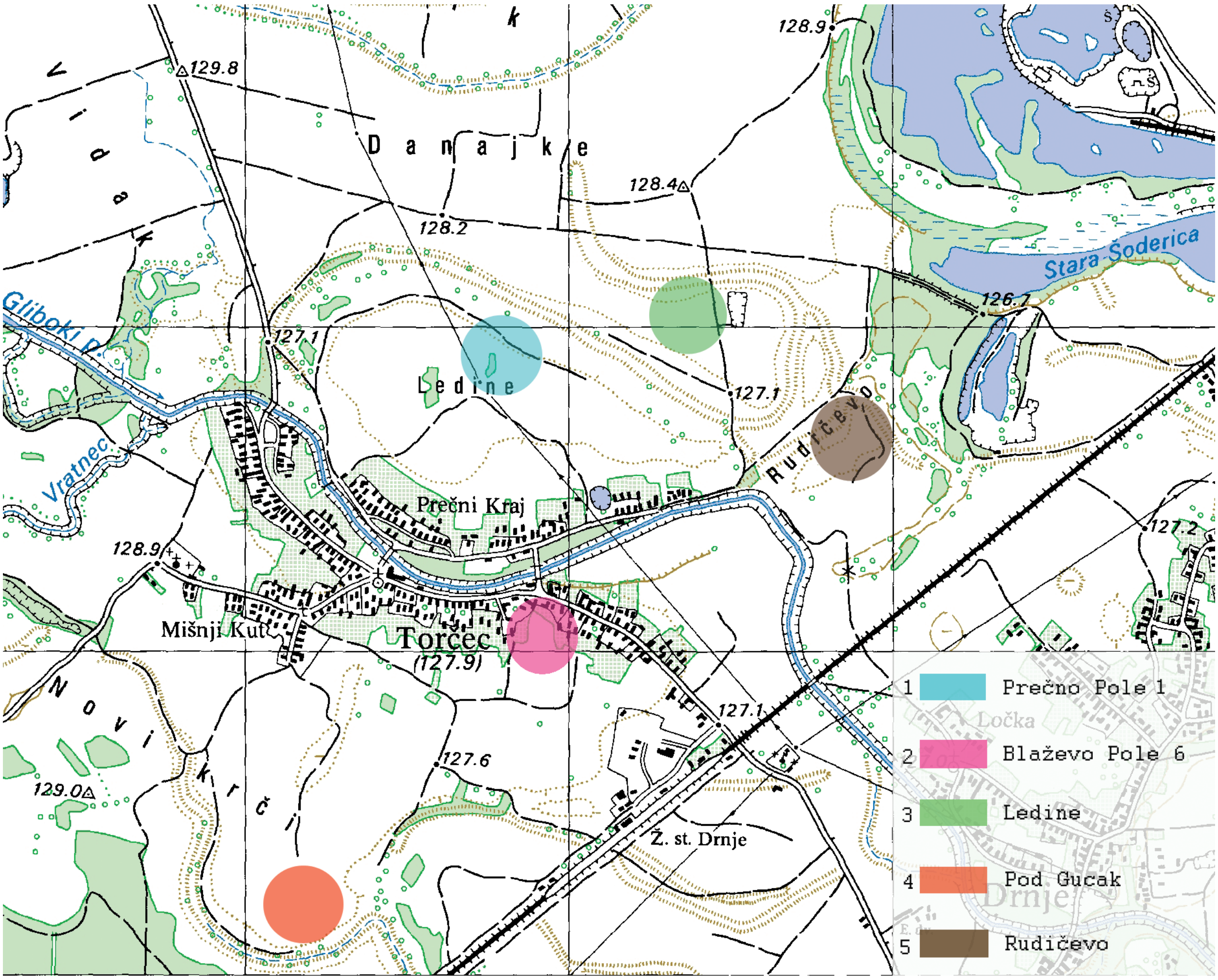

Fig. 1 — Map with the marked positions of archaeologically excavated early medieval settlements in the vicinity of Torčec: blue – Prečno pole I; purple – Blaževo pole 6; green – Ledine; orange – Pod Gucak; brown – Rudičevo (map source: State Geodesic Administration (SGA), sheet Hlebine, originally 1:25,000; after: Sekelj Ivančan 2010: 26, Fig. 3)

Sl. 1 — Karta s označenim položajima arheološki istraživanih srednjovjekovnih naselja u okolici Torčeca: plavo – Prečno pole I; rozo – Blaževo pole 6; zeleno – Ledine; narančasto – Pod Gucak; smeđe – Rudičevo (izvor karte: Državna geodetska uprava (DGU), list Hlebine, izvornik u mjerilu 1 : 25 000; preuzeto: Sekelj Ivančan 2010: 26, sl. 3)

1 — All archaeological excavations were financed by the Ministry of Culture and Media of the Republic of Croatia.

among other, were systematically collected from individual layers and fillings of archaeologically explored features. Collected samples were used for radiocarbon dating (Botić 2021) and for anthracological analyses in which wood taxa was determined (Culiberg 2010; Botić, Culiberg 2021). The aim was to determine differences in taxa used for specific contexts in residential and workshop areas, as well as for other activities, such as timber construction or production of objects for everyday use (spoons, ladles, plates, knife holders, etc.). Additionally, an attempt was made to reconstruct the availability of wood as a raw material and to understand the natural environment around the archaeological sites through different periods of their occupation and activities. Charcoal samples were also used for dating specific archaeological contexts of all explored sites and helping in creating more robust chronology of this micro region.

In this paper, for the first time, we combine data collected from all the sites for the period between the end of the 6th and the 14th century, i.e. from the Late Roman / Early Middle Ages transition period to the developed Middle Ages. Results for the Torčec micro region are discussed in detail while description of finds from Virje and Hlebine micro regions and other periods were addressed elsewhere (Botić, Culiberg 2021).

ABSOLUTE DATING OF TORČEC, VIRJE AND HLEBINE SITES

Samples and methods

For radiocarbon dating 36 charcoal samples from all above mentioned sites were selected (Tab. 1). Most of the samples were AMS dated;[2] only dates from Zagreb laboratory are conventional.[3] Torčec pottery phases (I–V) (Sekelj Ivančan 2010) were added to the radiocarbon dates in order to facilitate understanding of archaeologically based relative chronology and its connection to the absolute chronology. Both samples from the residential and workshop areas were collected and dated although on some sites, especially around Torčec, no workshop areas with traces of metallurgical activities were documented.

Dates from earlier or later occupation of these sites are not included in this study (see Sekelj Ivančan, Karavidović 2021a for other periods).

By applying the method of relative chronology based on the collected archaeological material, mainly pottery which is most often found within closed units, it is possible to temporally determine the settlement features (Sekelj Ivančan 2010; 2021). Radiocarbon dating of charcoal samples collected from the same units confirmed, with some exceptions, this established relative chronology.

On the other hand, chronologically sensitive archaeological finds are completely absent in the explored sites related to metallurgical activities (Tab. 1: bold), which is why the application of absolute dating method is the only possibility for temporal determination (Botić 2021). Aware that some samples can yield older dates because of the so-called 'old wood effect'[4] or that some sampling methods (samples taken from slag, furnaces or other workshop facilities)[5] may sometimes result in a doubtful range of dates, especially when compared to the results obtained by applying archaeological dating methods to this type of site (Gassmann, Schäfer 2018), we created a basic Bayesian model (Fig. 2) (Botić 2021).[6] The aim was to gain more precise dating, i.e. to narrow the timeframe of site occupation within archaeologically established Torčec pottery phases.

2 —— Radiocarbon measurements were performen in three facilities: 14Chrono Centre (Queens University Belfast, Northern Ireland, UK), Beta Analytic (Miami, FL, USA), and the Leibniz Laboratory for Radiometric Dating (Christian-Albrecht-University, Kiel, Germany) (Botić 2021).

3 —— Samples Z-3167, Z-3311 and Z-3310 processed in the Rudjer Bošković Institute.

4 —— This may mostly happen with samples taken from settlement features, i.e. features not directly linked to the iron production, because branches and smaller trees may have been used in charcoal production for metallurgical purposes (Gassmann, Schäfer 2018: 320), representing excellent short-lived sample. Pollarding may have been primarily used for woodland management and to some extent coppicing, rather than total forests clearing (e.g. Crew, Mighall 2013).

5 —— Gassmann and Schäfer (2018) argue that samples taken from workshops, especially those that underwent a high temperature process, can yield older dates than what was archaeologically established. For these dates fossil carbon contamination is proposed; excess of fossil carbon can be linked to geology rich in limestone and loess (Botić 2021).

6 —— On-line OxCal v. 4.4.4 was used (©Bronk Ramsey 2021). Results in the Tab. 1 differ from previously published ones calibrated in CALIB 8.2 ^{14}C age calibration program (Botić 2021) although this program also uses IntCal20 calibration curve (Reimer et al. 2020).

Site	SU	Lab code	Radiocarbon age (BP)	1σ (68.3%) cal AD	2σ (95.4%) cal AD	Median cal AD	Torčec pottery phases
Hlebine – Dedanovice	14	CHRONO UBA-39595	BP 1378±22	646-663 (68.3%)	607-623 (6.4%) 637-673 (89.0%)	654	T. I
	33b	**CHRONO UBA-39592**	**BP 1378±27**	**643-666 (68.3%)**	**605-676 (95.4%)**	**653**	**T. I**
	31b	**CHRONO UBA-39590**	**BP 1367±28**	**645-671 (68.3%)**	**606-627 (5.8%) 636-685 (81.9%) 743-773 (7.7%)**	**658**	**T. I**
	27	CHRONO UBA-39591	BP 1363±29	645-675 (68.3%)	606-625 (4.4%) 636-689 (79.3%) 742-774 (11.8%)	660	T. I
	10	CHRONO UBA-39593	BP 1317±32	660-688 (33.2%) 742-772 (35.1%)	653-775 (95.4%)	706	T. I
Hlebine – Velike Hlebine	**037b**	**CHRONO UBA-35133**	**1417±33**	**606-628 (36.1%) 634-653 (32.2%)**	**587-664 (95.4%)**	**627**	**T. I**
	102	**CHRONO UBA-35780**	**1245±28**	**688-742 (41.9%) 788-825 (26.4%)**	**677-750 (47.0%) 757-779 (6.7%) 785-878 (41.7%)**	**760**	**T. I**
	107	**CHRONO UBA-35781**	**1380±30**	**612-617 (4.4%) 640-669 (63.9%)**	**601-680 (93.6%) 750-758 (1.8%)**	**652**	**T. I**
	119	CHRONO UBA-35782	1248±32	684-744 (44.5%) 788-825 (23.8%)	675-778 (57.4%) 785-839 (27.9%) 844-878 (10.2%)	752	T. II
	121	CHRONO UBA-35783	1245±31	686-743 (41.7%) 788-827 (26.5%)	677-750 (45.6%) 757-778 (7.1%) 785-878 (42.8%)	763	T. II
Torčec – Prečno pole I	085/2	KIA 37482	1471±19	581-607 (49.1%) 625-637 (19.2%)	569-642 (95.4%)	601	T. I
	096b	KIA 37484	1465±24	584-610 (36.6%) 617-640 (31.6%)	568-645 (95.4%)	607	T. II
	037	KIA 28648	1439±22	605-642 (68.3%)	591-652 (95.4%)	622	T. II
	104	KIA 37483	1433±34	604-646 (68.3%)	576-658 (95.4%)	622	T. II
	094	KIA 41462	1365±21	650-665 (68.3%)	641-680 (93.5%) 750-759 (1.9%)	658	T. II
	014	KIA 28646	1234±22	706-736 (24.4%) 787-828 (43.9%)	687-743 (30.2%) 772-880 (65.2%)	799	T. II
	031	KIA 37481	1206±23	785-834 (38.8%) 844-877 (29.5%)	710-715 (1.0%) 772-888 (94.4%)	829	T. IIIa
	068	KIA 32250	1172±24	776-788 (11.6%) 826-893 (55.0%) 934-937 (1.6%)	772-899 (81.2%) 920-957 (14.2%)	857	T. IIIb
	070	KIA 32249	1095±22	898-920 (26.0%) 956-992 (42.3%)	891-995 (94.8%) 1009-1012 (0.6%)	955	T. IIIb
Torčec – Blaževo pole 6	029	KIA 28647	1177±23	776-788 (11.8%) 826-890 (56.4%)	772-896 (87.0%) 924-950 (8.4%)	850	T. IIIa
Torčec – Ledine	016	Z 3167	1115±90	776-787 (3.2%) 828-1021 (65.1%)	681-746 (6.3%) 759-1049 (84.0%) 1082-1152 (5.1%)	917	T. IVa
	022	Z 3311 Z 3310	985±65 1150±65	995-1008 (5.7%) 1014-1054 (21.0%) 1076-1156 (41.5%) 777-788 (4.5%) 827-979 (63.7%)	898-920 (2.4%) 957-1216 (93.0%) 703-740 (4.6%) 771-1022 (90.8%)	1081 888	T. IVa
	024	KIA 26974	989±25	1021-1047 (36.4%) 1084-1095 (9.1%) 1102-1124 (20.7%) 1143-1146 (2.1%)	994-1007 (5.5%) 1015-1051 (39.3%) 1079-1154 (50.6%)	1083	T. IVa
Torčec – Pod Gucak	004	KIA 34852	986±20	1022-1045 (40.9%) 1085-1093 (7.9%) 1104-1121 (19.4%)	996-1004 (2.2%) 1019-1050 (42.4%) 1080-1154 (50.8%)	1084	T. IVb
	037	KIA 34853	899±20	1052-1078 (24.6%) 1155-1180 (28.8%) 1190-1206 (14.8%)	1046-1085 (30.3%) 1096-1103 (1.2%) 1125-1218 (64.0%)	1161	T. IVb

Site	SU	Lab code	Radiocarbon age (BP)	1σ (68.3%) cal AD	2σ (95.4%) cal AD	Median cal AD	Torčec pottery phases
Torčec – Rudičevo	003	KIA 32251	979±22	1025-1047 (29.1%) 1084-1095 (11.6%) 1102-1124 (24.3%) 1143-1147 (3.3%)	1021-1053 (33.3%) 1077-1155 (62.1%)	1093	T. Va
	026	KIA 32254	779±21	1229-1245 (28.7%) 1256-1274 (39.5%)	1225-1276 (95.4%)	1253	T. Vb
	012	KIA 32252	699±25	1277-1299 (68.3%)	1271-1306 (77.4%) 1364-1384 (18.0%)	1291	T. Vb
	014	KIA 32253	667±31	1285-1306 (34.9%) 1364-1385 (33.4%)	1277-1325 (51.5%) 1354-1394 (44.0%)	1319	T. Vb
Virje – Volarski breg	**008c**	**KIA 36425**	**1236±25**	**705-738 (26.8%)** **787-828 (38.0%)** **861-867 (3.5%)**	**683-744 (34.6%)** **771-881 (60.9%)**	**795**	**T. IIIa**
	018	**KIA 36424**	**1169±26**	**776-788 (10.2%)** **828-893 (50.7%)** **930-942 (7.4%)**	**772-900 (74.9%)** **917-973 (20.5%)**	**863**	**T. IIIa**
Virje – Sušine	436	CHRONO UBA-27793	1307±27	665-689 (27.4%) 697-701 (3.7%) 742-772 (37.2%)	658-775 (95.4%)	719	T. II
	310	CHRONO UBA-27791	1254±28	683-744 (51.5%) 762-766 (2.0%) 791-820 (14.7%)	672-779 (68.6%) 786-833 (21.7%) 851-876 (5.2%)	736	T. II
	290	CHRONO UBA-35132	1239±33	690-696 (2.9%) 702-741 (28.1%) 787-829 (30.6%) 858-871 (6.7%)	678-749 (38.1%) 758-882 (57.4%)	789	T. IIIa
	320	CHRONO UBA-27790	1216±23	786-833 (46.4%) 849-876 (21.9%)	706-735 (7.1%) 772-885 (88.4%)	819	T. IVa

Tab. 1 — Radiocarbon dates, samples from metallurgical activity contexts are in bold (Sekelj Ivančan 2010: 75; Botić 2021: 93–94, Tab. 1)

Tab. 1 — Radiokarbonski datumi, uzorci iz konteksta metalurških aktivnosti označeni su bold (Sekelj Ivančan 2010: 75; Botić 2021: 93–94, Tab. 1)

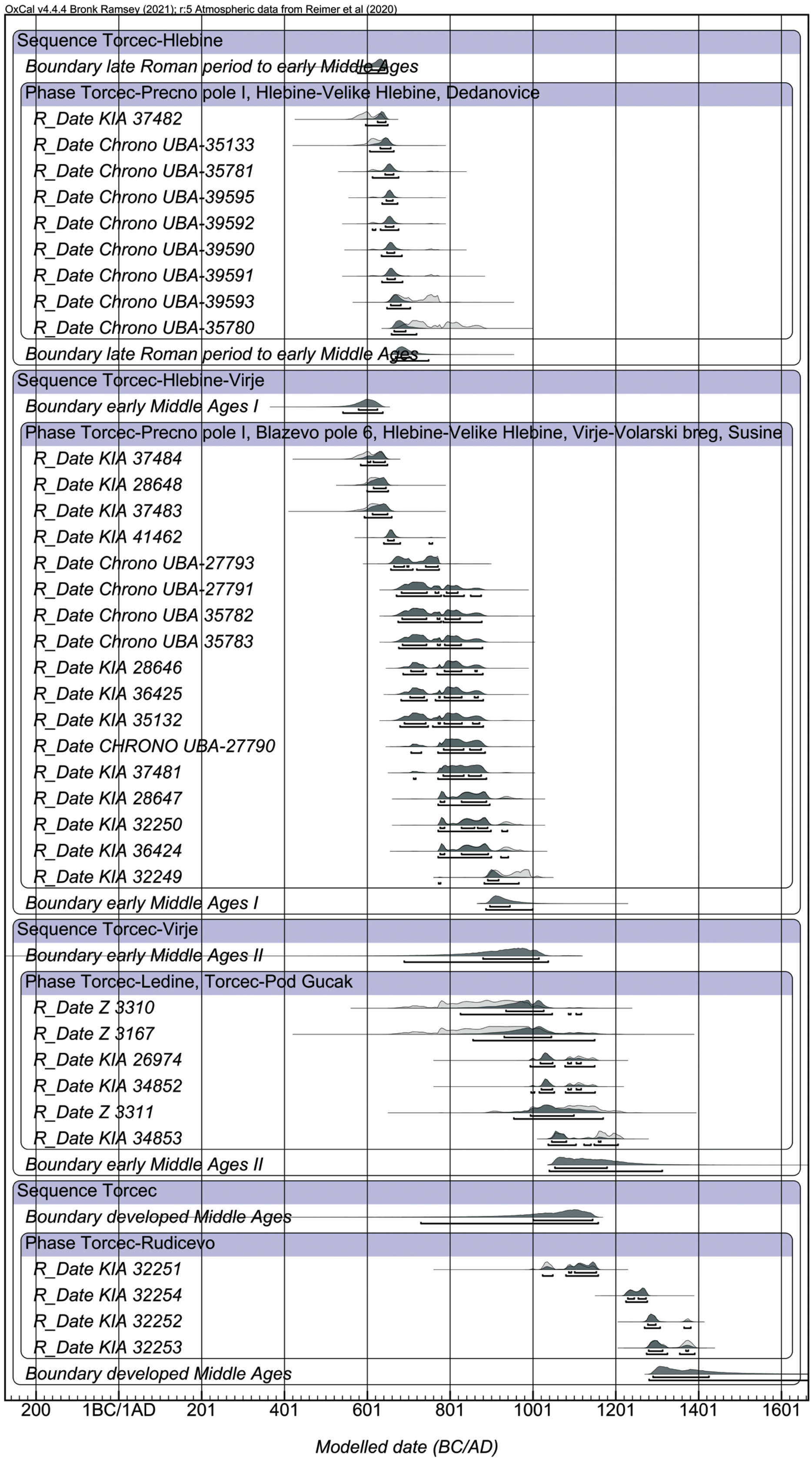

Fig. 2 — A Bayesian model of radiocarbon dates (OxCal v. 4.4.4, ©Bronk Ramsey 2021; r:5 Atmospheric data from Reimer et al. 2020; made by: K. Botić)

Sl. 2 — Bayesian model radiokarbonskih datuma (OxCal v. 4.4.4, ©Bronk Ramsey 2021; r:5 Atmosferski podaci prema Reimer et al. 2020; izradila: K. Botić)

Results and discussion

A Bayesian model (©Bronk Ramsey 2009) based on archaeologically obtained data was created to establish narrower timeframes for specific sites under study (Fig. 2). The primary goal was to investigate the extent of (dis)continuity on a larger sample of temporally and functionally related site types (settlement and iron production workshop). Based on the acquired data from excavated sites, four sequences were determined: transition period between Late Roman and Early Middle Ages, Early Middle Ages I, Early Middle Ages II and developed Middle Ages periods. According to the relative chronology, these sequences were dated to:

– Late Roman/Early Middle Ages, Torčec I phase, the end of the 6th to the mid- 7th century

– Early Middle Ages I, Torčec phases II–III, mid- 7th and the 9th century

– Early Middle Ages II, Torčec phase IV, 10th to the 12th century

– developed Middle Ages, Torčec phase V, 13th to the 14th century.

For the first sequence four dates were available, for the second 16 dates, for the third six and for the fourth four dates. Within sequence, dates were modelled in phases, with each phase representing a group of sites on which specific pottery was found within Torčec phases system (Sekelj Ivančan 2010). Only the second sequence corresponds to two combined Torčec phases (II and III). Dates from both settlement and workshop contexts were modelled together. The model created is in general in accordance with the archaeological information, although there are several instances in which radiocarbon dates suggest older phase while in relative chronological model these contexts belong to the younger phase (KIA 37484, KIA 28648, KIA 37483 and KIA 41462 – Fig. 2; Tab. 1). This is the case with Torčec – Prečno pole I site. In another instance, younger date from Helbine – Velike Hlebine site and from the workshop context is attributed to the older phase (Chrono UBA-35780 – Fig. 2; Tab. 1). The third instance of poor agreement is the date from Torčec – Rudičevo site (KIA 32251 – Fig. 2; Tab. 1) for which the sample was collected from a pit fill under the alluvial layer and was most probably re-deposited with the sediment brought by the fluvial activity (Fig. 1: 5 brown) (Sekelj Ivančan 2010: 69).

Torčec micro region – relative chronological problems and radiocarbon dates

In the vicinity of Torčec in the western Drava River region (upper Podravina), five sites (Prečno pole I, Blaževo pole 6, Ledine, Pod Gucak, Rudičevo) were archaeologically investigated over several years (2002–2008) (Fig. 1). These sites represent a smaller spatial micro-unit with continuity of settlement from the 6th to the 14th century as documented by the archaeological excavations (Sekelj Ivančan 2010). The analysis of all archaeological finds yielded significant data on the settlement features (77 buildings / features), as well as significant differences in morphological and technological characteristics of the collected pottery. This enabled creation of pottery groups (so-called ceramic groups 1–5), which were defined, on the one hand, on similarities, and on the other, on differences or the absences of specific features, ceramic forms of whole vessels, or their parts, ways and motifs of decoration, as well as in manufacturing techniques. Such a way of grouping ceramic material made it possible to recognize contemporaneous structures and / or features and their relative chronological relationships. The results of typo-chronological analysis of the ceramic material were compared with analogous examples from other sites in the Drava River valley and the wider region, supplemented by the analysis of accompanying metal and other finds.

Next, charcoal samples were selected for radiocarbon analysis from structures with the most pronounced characteristics of an individual ceramic group. The obtained results made it possible to date the relative chronological relationships recognized in the archaeological material, and identify the specific settlement phases in that area (phases Torčec I–V) that correspond to specific ceramic groups (1–5). These settlement phases are, therefore, clearly contemporaneous with historical events in the area, although there are some deviations (Sekelj Ivančan 2010). Settlement phases were dated as follows:

Phase Torčec I – the 2nd half of the 6th c. / beginning of the 7th c. (Prečno pole I – 2 features)

Phase Torčec II – the 1st half / mid- 7th c. to the 2nd half of the 8th c. (Prečno pole I – 9 features)

Phase Torčec III a – the end of the 8th c. to the mid- / 2nd half of the 9th c. (Prečno pole I – 6 features; Blaževo pole 6 – 1 feature)

Phase Torčec III b – the end of the 9th c. to the mid- / 2nd half of the 10th c. (Prečno pole I – 4 features)

Phase Torčec IV a – the 2nd half of the 10th c. to the 2nd half of the 11th c. (Prečno pole I – 3 features, Ledine – 13 features)

Phase Torčec IV b – the 2nd half of the 11th c. and the 12th c. (Pod Gucak – 10 features)

Phase Torčec V a – the 12th c. and the beginning of the 13th c. (Prečno pole I – 3 features; Rudičevo – 1 feature)

Phase Torčec V b – the 2nd half of the 13th c. and the beginning of the 14th c. (Prečno pole I – 2 features; Rudičevo – 7 features).

Several phases were divided into sub-phases because the analysis of pottery revealed some change in details, although ceramic vessels of the same or similar characteristics appear in the wide time frame. Such phenomena were not observed in the Phase Torčec II, although the radiocarbon dates of the group of features in the probe S-6 (feature SU 094 with two fillings SU 096b and 104) and in the probe S-1 (fill of the feature SU 037) were closer to the dates obtained for ceramic group 1, i.e. Phase Torčec I. Further, ceramic details clearly indicated that these features could be related to the Phase Torčec II settlement of Prečno pole I. Maybe it may have been necessary to divide this phase into older (a) (closer to the Phase Torčec I) and younger (b) (8th c.) sub-phases but pottery finds did not support this conclusion. Therefore, it is possible that we are dealing with the 'old wood effect', especially with regard to the occupation of the Prečno pole I in the Phase Torčec I. This is further supported by the finds of the only two structures of the Phase Torčec I in the immediate vicinity of the abovementioned complexes, dated to the (older) phase of Torčec II.

Two discrepancies in the Bayesian model

In the archaeological context, two problematic dates come from the top fill of the pit with the burned bottom from Hlebine – Velike Hlebine (Tab. 1: SU 102, Chrono UBA-35780) and the top layer from the site Torčec – Rudičevo (Tab. 1: SU 003, KIA 32251). Both of the dates obtained by radiocarbon analysis of charcoal are interpreted as a result of the frequent floods to which these sites were exposed in the Early Middle Ages or later, whereby a few fragments of pottery and a piece of charcoal could have been deposited in the pit fill and the top layer at a later time (Sekelj Ivančan, Karavidović 2021b). However, radiocarbon date from Hlebine – Velike Hlebine site has good agreement within the Bayesian model (Fig. 2).

It should be noted that most of the dates from the Early Middle Ages I phase (Torčec II–III phase), except the ones from Prečno pole I already mentioned, fall into the plateau of the calibration curve and the same is the case with the Early Middle Ages II phase (Torčec IV phase).[7] Although the model presented here agrees with the archaeological phases of all the mentioned sites, further data processing and creation of an age-depth model (Blaauw 2010; Blaauw, Christen 2011) is needed to clarify the poor agreement of dates and their span.

ANTHRACOLOGICAL ANALYSIS OF SAMPLES FROM TORČEC, VIRJE AND HLEBINE SITES

Materials and methods

In total, 193 charcoal samples were collected: Torčec – Prečno pole I 50 samples, Torčec – Blaževo pole 6 2 samples, Torčec – Ledine 16 samples, Torčec – Pod Gucak 33 samples, Torčec – Rudičevo 11 samples, Virje – Volarski breg 19 samples, Virje – Sušine 21 samples, Hlebine – Velike Hlebine 20 samples, and Hlebine – Dedanovice 17 samples (Culiberg 2010; Botić, Culiberg 2021). Several samples contained no charcoal, or contained pieces that were too fragmented,[8] and some were used entirely for radiocarbon dating.[9] From the samples available, 3668 charcoal fragments were analysed.[10] A simplified microscopic method was used in which samples were observed under reflective light and with several different magnifications in three different cross sections: transverse, radial and tangential (Culiberg 2010: 389). The size and preservation levels of the charcoal fragments varied. In some cases, constant change in sediment humidity resulted in the more or less damaged anatomical structure of the charcoal fragments, or the charcoal was impregnated with sediment which prevented identification

7 —— Including Zagreb radiocarbon dates, although their span is altogether problematic.

8 —— Torčec – Pod Gucak SU 37, samples 53 and 77 (Culiberg 2010: 396, Tab. 4); Virje – Sušine SU 315, sample 137 (Botić, Culiberg 2021: Tab. 2).

9 —— Virje – Sušine SU 320, sample 145 (Botić, Culiberg 2021: Tab. 2); Hlebine – Velike Hlebine SU 201, sample 55 (Botić, Culiberg 2021: Tab. 4).

10 —— Samples from all Torčec sites were previously published in Slovenian (Culiberg 2010).

(Culiberg 2010: 389; Sekelj Ivančan et al. 2019: 52). In other cases, larger fragments of charred wood were fragmented during the extraction[11] or transport; they were treated as a single fragment. Measurements of growth-ring curvatures were not done and consequently diameter estimate methods[12] were not used (Botić, Culiberg 2021).

Identification was made to the level of genus, with the exception of *Prunus*, where two species were determined; both published identification keys (Greguss 1954; Grosser 1977; Schweingruber 1978) and personal collection of recent charred wood was used (Culiberg 2010: 389).

Paleontological statistics package (PAST) 4.06 software (Hammer et al. 2001) was used for the statistical analysis.

Results

Quantitative analysis

For the purposes of quantitative analysis, the same relative chronological model was used, based on archaeological data, as in the case of residential features (Sekelj Ivančan 2010; 2021), workshop features (Sekelj Ivančan, Karavidović 2021b), and radiocarbon-based Bayesian model (Fig. 2). Results from the residential areas and those from the workshop areas are presented in Figs. 3–4. The overall percentages of samples from the residential and workshop areas of all the sites, and all chronological phases, are presented in Fig. 5.

Bias regarding the number of available charcoal fragments form different contexts and in different chronological phases can be seen on Fig. 4.

Transition period between Late Roman and Early Middle Ages (Torčec I phase, the end of the 6th to the mid- 7th century)

Occupation from this transition period is present at Torčec – Prečno pole I and Hlebine – Dedanovice residential areas as well as at Hlebine – Dedanovice and Hlebine – Velike Hlebine workshop areas. From Torčec – Prečno pole I residential area 46 fragments were analysed from two features (Culiberg 2010: 393, Tab. 1). Two taxa were determined: *Quercus* (91.3%) and *Carpinus* (6.5%) while one fragment could not be determined (2.2%).

From Hlebine – Dedanovice residential area 67 fragments were analysed from five features (Botić, Culiberg 2021: Tab. 4). Four taxa were determined: *Quercus* (47.76%), *Fraxinus* (1.49%), *Carpinus* (31.35%), and *Alnus* (19.40%).

From the Dedanovice workshop area 272 fragments were analysed from four features (Botić, Culiberg 2021: Tab. 4). Five taxa were determined: *Quercus* (61.40%), *Fraxinus* (17.65%), *Carpinus* (14.70%), *Alnus* (5.15%), and *Salix* (1.10%).

From the Hlebine – Velike Hlebine workshop area 60 fragments were analysed from ten features (Botić, Culiberg 2021: Tab. 3). Five taxa were determined: *Quercus* (81.66%), *Ulmus* (3.33), *Acer* (1.67), *Carpinus* (11.67%), and *Juglans* (1.67%).

Early Middle Ages (Torčec phase II, mid- 7th to the second half of the 8th century)

Occupation during this period was documented at Torčec – Prečno pole I, Hlebine – Velike Hlebine residential areas and Virje – Sušine both residential and workshop areas. From Torčec – Prečno pole I residential area 395 fragments were analysed from nine features (Culiberg 2010: 393, Tab. 1). Six taxa were determined: *Quercus* (57.7%), *Ulmus* (2.3%), *Fagus* (8.9%), *Fraxinus* (1.5%), *Carpinus* (24%), and *Acer* (2.3%). Nine fragments could not be determined (2.3%).

From Hlebine – Velike Hlebine residential area 61 fragments were analysed from four features (Botić, Culiberg 2021: Tab. 3). Seven taxa were determined: *Quercus* (18.03%), *Fraxinus* (3.28%), *Ulmus* (27.87%), *Acer* (4.92%), *Carpinus* (21.31%), *Populus* (1.64%), and *Salix* (14.75%). Five fragments could not be determined (8.2%).

From the Virje – Sušine workshop area only one fragment of *Quercus* was determined (Botić, Culiberg 2021: Tab. 2), whereas from the residential area of the same period 53 fragments were analysed from three features (Botić, Culiberg 2021: Tab. 2). Five taxa were determined: *Quercus* (52.83%), *Fraxinus* (37.73%), *Acer* (5.66%), *Carpinus* (1.89%), and *Betula* (1.89%).

Early Middle Ages (Torčec phase IIIa–b, the end of the 8th to the second half of the 10th century)

Occupation during the Torčec IIIa phase was documented at Torčec – Prečno pole I and Torčec – Blaževo pole 6 residential areas and Virje – Volarski breg both residential and workshop areas. From Torčec – Prečno pole I residential area

11 — Sampling was done by manual recovery during excavation (for various sampling methods and their suitability, see Kabukcu, Chabal 2020).

12 — See e.g. Kabukcu 2018: 142, Fig. 2; Marguerie, Hunot 2007: 1421.

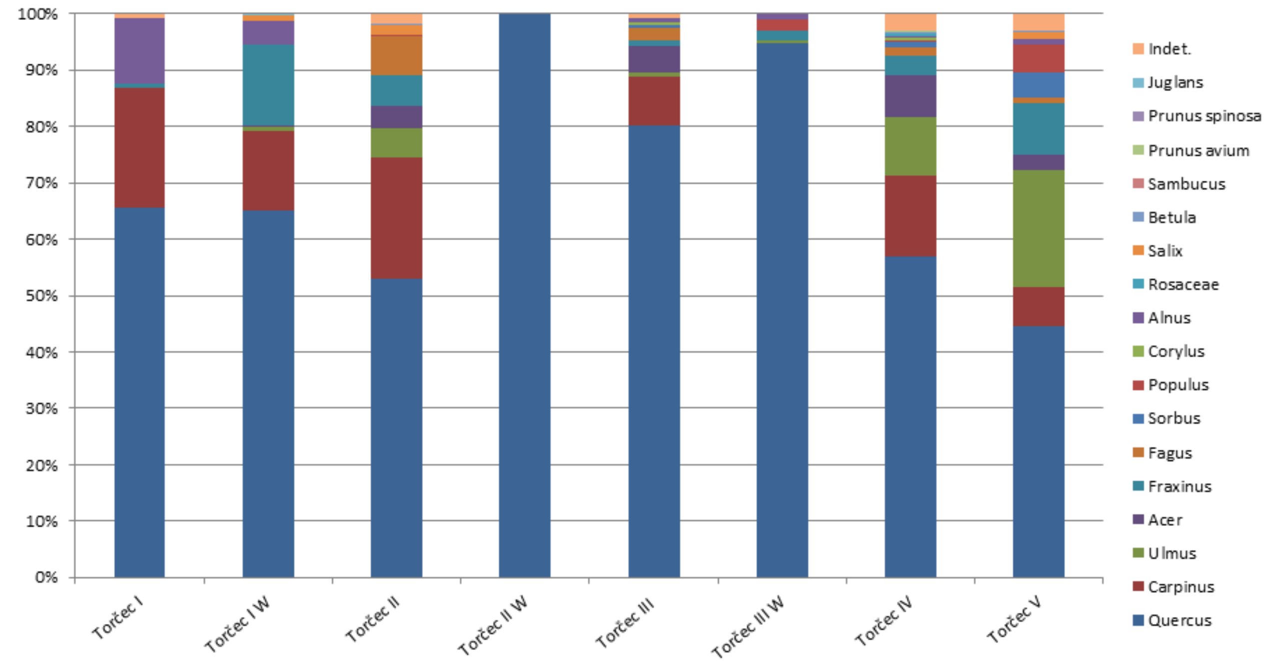

Fig. 3a — Results of anthracological analysis for residential and workshop areas – percentage of individual wood taxa in the samples from all sites sorted into Torčec pottery groups / chronological phases according to Sekelj Ivančan 2010; W = workshop area (made by: K. Botić)

Sl. 3a — Rezultati antrakoloških analiza za naseobinske i radioničke prostore – postotak pojedinačnih svojti drva u uzorcima sa svih nalazišta razvrstan u Torčec keramičke grupe / kronološke faze prema Sekelj Ivančan 2010; W = radionički dio (izradila: K. Botić)

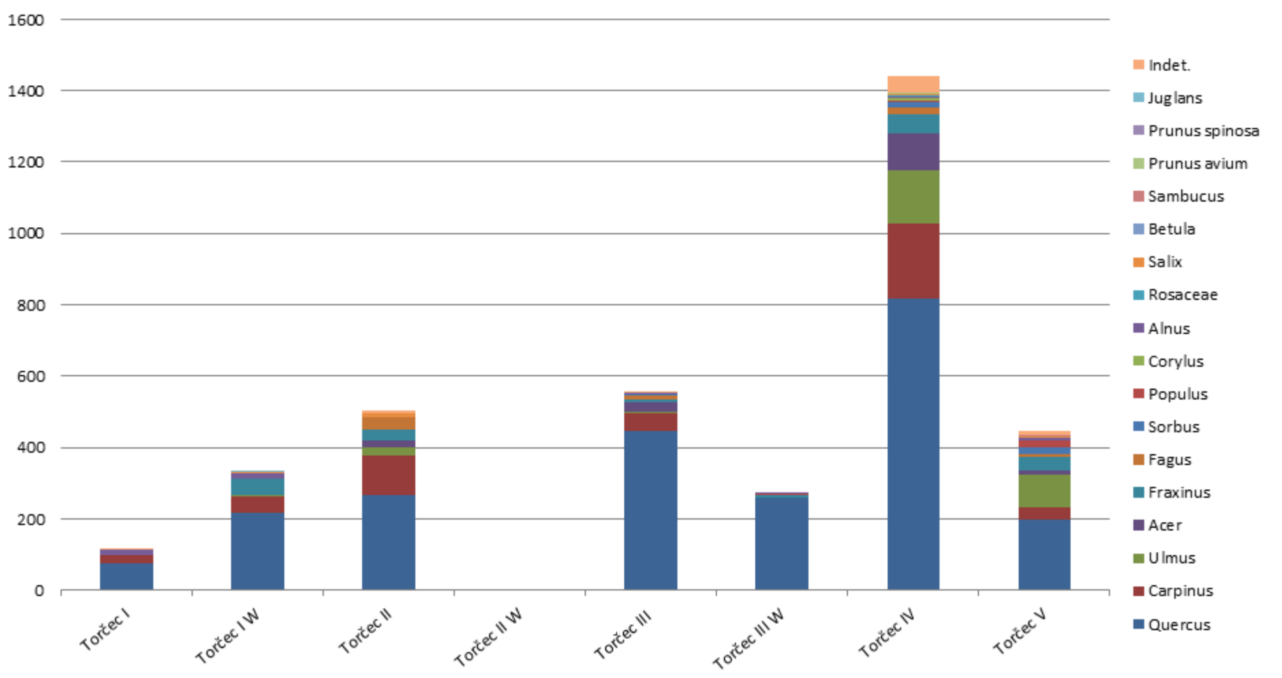

Fig. 3b — Results of anthracological analysis for residential and workshop areas – number of individual wood taxa in the samples from all sites sorted into Torčec pottery groups / chronological phases according to Sekelj Ivančan 2010; W = workshop area (made by: K. Botić)

Sl. 3b — Rezultati antrakoloških analiza za naseobinske i radioničke prostore – broj pojedinačnih svojti drva u uzorcima sa svih nalazišta razvrstan u Torčec keramičke grupe / kronološke faze prema Sekelj Ivančan 2010; W = radionički dio (izradila: K. Botić)

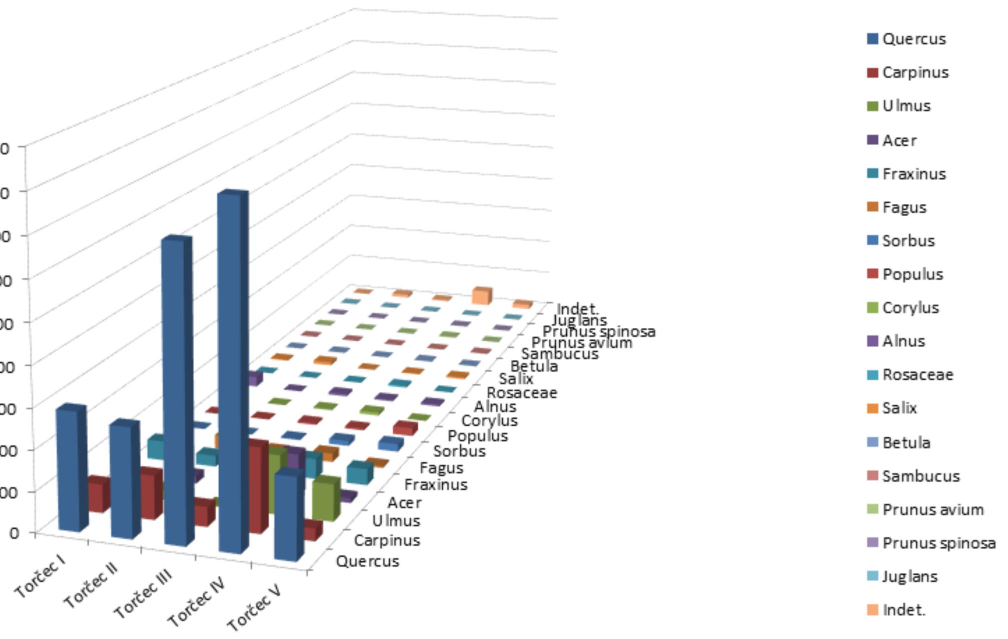

Fig. 4b — Results of anthracological analysis for residential and workshop areas – number of individual wood taxa in the samples from all sites sorted into Torčec pottery groups / chronological phases according to Sekelj Ivančan 2010; W = workshop area (made by: K. Botić)

Sl. 4b — Rezultati antrakoloških analiza za naseobinske i radioničke prostore – broj pojedinačnih svojti drva u uzorcima sa svih nalazišta razvrstan u Torčec keramičke grupe / kronološke faze prema Sekelj Ivančan 2010; W = radionički dio (izradila: K. Botić)

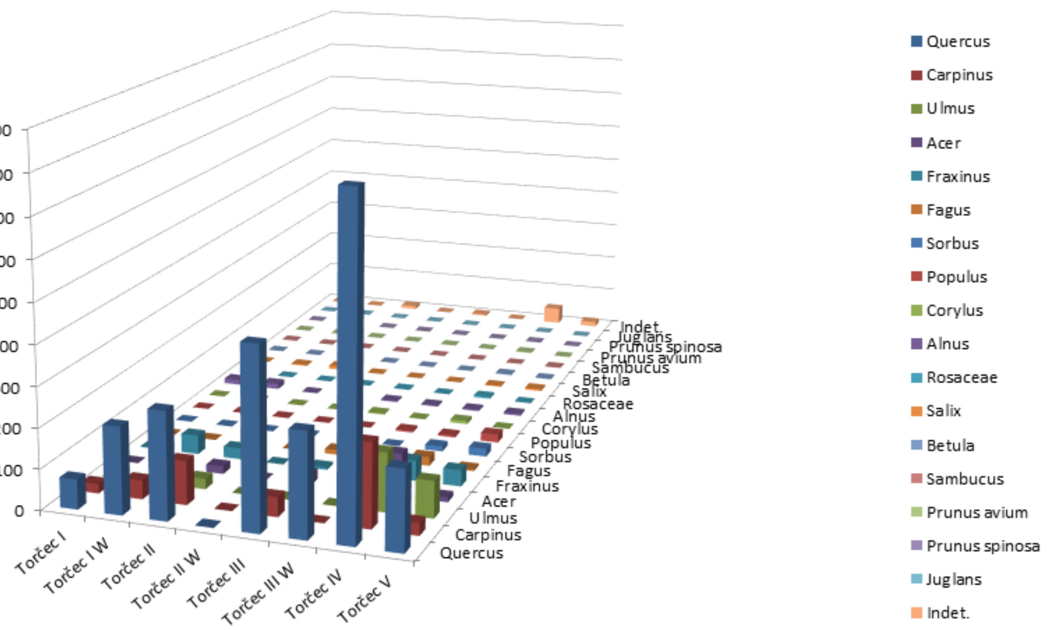

Fig. 4a — Results of anthracological analysis – number of individual wood taxa in the samples from all sites, from both settlement and workshop contexts, sorted into Torčec pottery groups / chronological phases according to Sekelj Ivančan 2010 (made by: K. Botić)

Sl. 4a — Rezultati antrakoloških analiza – broj pojedinačnih svojti drveta u uzorcima sa svih nalazišta, iz konteksta naselja i radionica zajedno, razvrstan u Torčec keramičke grupe / kronološke faze prema Sekelj Ivančan 2010 (izradila: K. Botić)

137 fragments were analysed from four features (Culiberg 2010: 393, Tab. 1). Five taxa were determined: *Quercus* (77.3%), *Ulmus* (0.7%), *Fagus* (3.7%), *Carpinus* (11.7%), *Acer* (3.7%) while four fragments could not be determined (2.9%).

From Torčec – Blaževo pole 6 residential area 71 fragments were analysed from one feature (Culiberg 2010: 394, Tab. 2). Six taxa were determined: *Quercus* (46.5%), *Fagus* (2.8%), *Fraxinus* (4.2%), *Carpinus* (40.9%), *Acer* (1.4%), and *Corylus* (4.2%).

From Virje – Volarski breg residential area 29 fragments were analysed from two features (Botić, Culiberg 2021: Tab. 1). Two taxa were determined: *Quercus* (89.7%) and *Alnus* (10.3%). From the workshop area of the same site 273 fragments were analysed from 15 features (Botić, Culiberg 2021: Tab. 1). Five taxa were determined: *Quercus* (94.9%), *Fraxinus* (1.8%), *Ulmus* (0.4%), *Alnus* (1.1%), and *Populus* (1.8%).

In the next Torčec IIIb phase only the occupation at Torčec – Prečno pole I residential area was documented and 322 fragments were analysed from three features (Culiberg 2010: 393, Tab. 1). Eight taxa were determined: *Quercus* (87.9%), *Ulmus* (0.6%), *Fagus* (1.6%), *Fraxinus* (0.9%), *Carpinus* (1.3%), *Acer* (6.5%), *Sorbus* (0.9%), and *Rosaceae* (0.3%).

Early Middle Ages (Torčec phase IVa–b, second half of the 10th to the 12th century)

In the Torčec IVa phase occupation of residential areas was documented at Torčec – Prečno pole I, Torčec – Ledine, Virje – Sušine and Hlebine – Velike Hlebine sites. From Torčec – Prečno pole I 83 fragments were analysed from three features (Culiberg 2010: 393, Tab. 1) and six taxa were determined: *Quercus* (80.7%), *Ulmus* (8.5%), *Carpinus* (3.6%), *Acer* (2.4%), *Sorbus* (3.6%), and *Rosaceae* (1.2%).

From Torčec – Ledine 384 fragments were analysed from nine features (Culiberg 2010: 395, Tab. 3) and 11 taxa were determined: *Quercus* (37.8%), *Ulmus* (12%), *Fagus* (1.3%), *Fraxinus* (10.4%), *Carpinus* (16.7%), *Acer* (14.1%), *Alnus* (0.8%), *Sorbus* (0.2%), *Populus* (1%), *Corylus* (2.1%), and *Rosaceae* (1%). Ten fragments could not be determined (2.6%).

From Virje – Sušine 45 fragments were analysed from four features and six taxa were determined: *Quercus* (57.8%), *Fraxinus* (8.9%), *Ulmus* (2.2%), *Acer* (11.1%), *Fagus* (6.7%), and *Carpinus* (8.9%). One species was also determined: *Prunus avium* (4.4%).

From Hlebine – Velike Hlebine 28 fragments were analysed from two features (Botić, Culiberg 2021: Tab. 3) and three taxa were determined: *Quercus* (39.3%), *Acer* (28.6%), and *Carpinus* (32.1%).

In the next Torčec IVb phase occupation of residential areas at Torčec – Pod Gucak and Virje – Sušine sites was documented. From Torčec – Pod Gucak 877 fragments were analysed from eight features (Culiberg 2010: 396, Tab. 4). Ten taxa were determined: *Quercus* (64.6%), *Ulmus* (10.3%), *Fagus* (1.6%), *Fraxinus* (0.2%), *Carpinus* (14%), *Acer* (4%), *Alnus* (0.1%), *Sorbus* (1%), *Populus* (0.1%), and *Betula* (0.2%) while 34 fragments could not be determined (3.9%).

From Virje – Sušine 23 fragments were analysed and six taxa were determined: *Quercus* (17.4%), *Fraxinus* (21.7%), *Ulmus* (13%), *Acer* (8.7%), *Carpinus* (26.1%), and *Salix* (8.7%). One species was also determined: *Prunus spinosa* (4.4%).

Developed Middle Ages (Torčec phase Va–b, the end of the 12th to the beginning of the 14th century)

This last Torčec V phase was only documented on two sites: Torčec – Prečno pole I and Torčec – Rudičevo. On both sites only residential areas were documented in both sub-phases (Torčec Va and Vb). In Torčec Va phase from Torčec – Prečno pole I 84 fragments were analysed (Culiberg 2010: 393, Tab. 1) from two features and ten taxa were determined: *Quercus* (30.9%), *Ulmus* (7.1%), *Fagus* (2.4%), *Fraxinus* (20.2%), *Carpinus* (17.9%), *Acer* (2.4%), *Alnus* (2.4%), *Sorbus* (2.4%), *Populus* (4.8%), and *Salix* (5.9%). Three fragments could not be determined (3.6%). In the same sub-phase from Torčec – Rudičevo 88 fragments were analysed (Culiberg 2010: 397, Tab. 5) from one feature and ten taxa were determined: *Quercus* (18.2%), *Ulmus* (38.7%), *Fagus* (3.4%), *Fraxinus* (4.6%), *Carpinus* (7.9%), *Acer* (7.9%), *Alnus* (1.1%), *Sorbus* (11.4%), *Populus* (2.3%), and *Betula* (1.1%). Three fragments could not be determined (3.4%).

In Torčec Vb phase from Torčec – Prečno pole I 27 fragments were analysed (Culiberg 2010: 393, Tab. 1) from two features and four taxa were determined: *Quercus* (81.5%), *Sorbus* (3.7%), *Populus* (11.1%), and Sambucus (3.7%).

From Torčec – Rudičevo 247 fragments were analysed (Culiberg 2010: 397, Tab. 5) from four features and eight taxa were determined: *Quercus* (54.7%), *Ulmus* (21.1%), *Fraxinus* (8.1%), *Carpinus* (3.6%), *Acer* (1.2%), *Alnus* (0.8%), *Sorbus* (2.8%), and *Populus* (4.9%). Seven fragments could not be determined (2.8%).

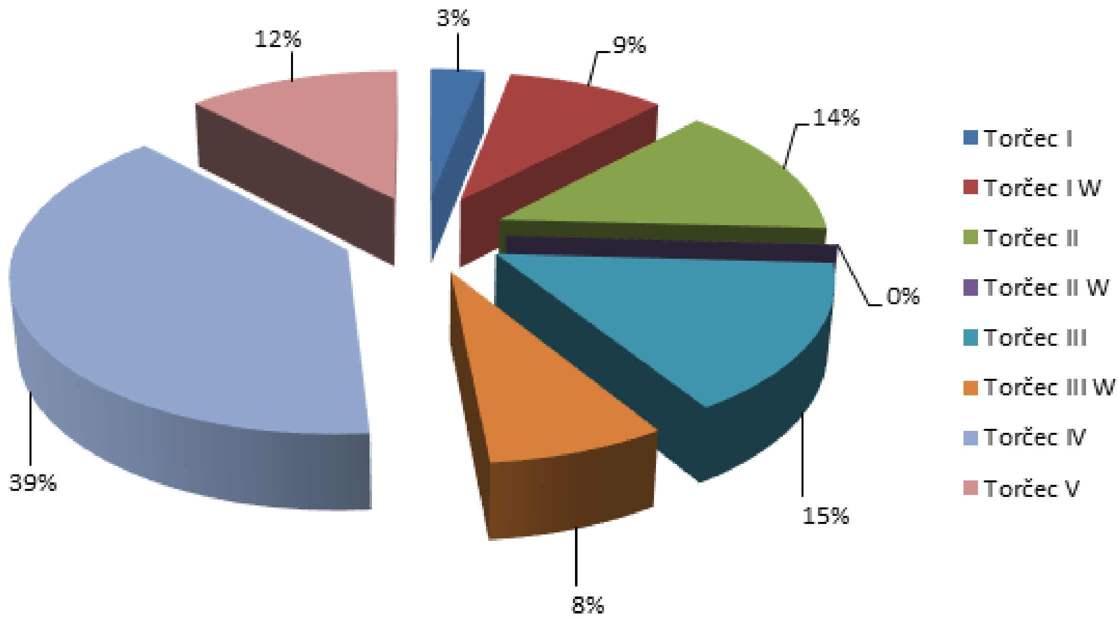

Fig. 5 — Percentage of wood taxa analysed from residential and workshop areas of all sites and all Torčec pottery groups / chronological phases. Samples are not equally distributed among the phases and activities performed (made by: K. Botić)
Sl. 5 — Postotak svojti drveta iz naseobinskih i radioničkih dijelova svih nalazišta i svih Torčec keramičkih grupa / kronoloških faza. Uzorci nisu podjednako raspoređeni prema fazama i aktivnostima (izradila: K. Botić)

Statistical analysis

For the purposes of statistical analysis, the anthracological dataset was organized by relative chronological phases of the sites and by the activities performed there against the taxa determined (Tab. 2a–b). Two methods were used to verify the results of the already described quantitative analyses.[13]

Principal components analysis (PCA)
This analysis, although possibly not very suited for environmental data, provided good results, especially if the two principal components represent *Quercus* (PC1) and *Carpinus* (PC2) taxa values (Fig. 6).[14] Grouping of residential and workshop areas independently of the phase is visible, and it is in negative correlation with several dispersed exceptions: residential areas of Torčec sites (Prečno pole I – phase II, Ledine – phase IVa and Pod Gucak – phase IVb) contain a higher number of *Carpinus* samples in the overall charcoal sample while two sites from the phase III (Torčec – Prečno pole I residential area and Virje – Volarski breg workshop area) clearly show predominance of *Quercus* in the overall charcoal sample. Hlebine – Velike Hlebine workshop area contained only one fragment of *Quercus* and is biased regarding the *Quercus / Fraxinus* ratio.

Detrended correspondence analysis (DCA)
This analysis is specialized for use with environmental data, and, in our case it confirms previously obtained results.[15] Taxa organized in columns were used in this analysis, although the reverse is suggested (Hammer et al. 2001: 4). In Fig. 7 all the sites, independently of the context and chronological phase, group in the 95% value between *Quercus* and *Carpinus* taxa, except Torčec – Rudičevo (phase Torčec Va) at which *Ulmus* is predominant in the sample (Tab. 2a).

13 — For the relevant information about statistical analyses in archaeology, see Drennan 2009; for PAST software, see Hammer et al. 2001.
14 — The percentages of variances accounted for by the first two components (94,027% and 3,1583%) justify the use of PCA analysis.
15 — Eigenvalues for the first two Axis are 0.2091 and 0.08264, which again justifies the analysis.

Sites and phases	*Quercus*	*Carpinus*	*Ulmus*	*Acer*	*Fraxinus*	*Fagus*	*Sorbus*	*Populus*	*Corylus*	*Alnus*	*Rosaceae*	*Salix*	*Betula*	*Sambucus*	*Prunus avium*	*Prunus spinosa*	*Juglans*	*Indet.*	Σ
T-PP T. I	42	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	46
H-D T. I	32	21	0	0	1	0	0	0	0	13	0	0	0	0	0	0	0	0	67
H-D T. I W	167	40	0	0	48	0	0	0	0	14	0	3	0	0	0	0	0	0	272
H-VH T. I W	49	7	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	60
T-PP T. II	228	95	9	13	6	35	0	0	0	0	0	0	0	0	0	0	0	9	395
V-S T. II	28	1	0	3	20	0	0	0	0	0	0	0	1	0	0	0	0	0	53
H-VH T. II	11	13	17	3	2	0	0	1	0	0	0	9	0	0	0	0	0	0	56
V-S T. II W	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T-PP T. IIIa	106	16	1	5	0	5	0	0	0	0	0	0	0	0	0	0	0	4	137
T-BP T. IIIa	33	29	0	1	3	2	0	0	3	0	0	0	0	0	0	0	0	0	71
T-PP T. IIIb	283	4	2	21	3	5	3	0	0	0	1	0	0	0	0	0	0	0	322
V-VB T. IIIa	26	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	29
V-VB T. IIIa W	259	0	1	0	5	0	0	5	0	3	0	0	0	0	0	0	0	0	273
T-PP T. IVa	67	3	7	2	0	0	3	0	0	0	1	0	0	0	0	0	0	0	83
T-LD T. IVa	145	64	46	54	40	5	1	4	8	3	4	0	0	0	0	0	0	10	384
T-PG T. IVb	566	123	90	35	2	14	9	1	0	1	0	0	2	0	0	0	0	34	877
V-S T. IVa	26	4	1	5	4	3	0	0	0	0	0	0	0	0	2	0	0	0	45
V-S T. IVb	4	6	3	2	5	0	0	0	0	0	0	2	0	0	0	1	0	0	23
H-VH T. IVa	11	9	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
T-PP T. Va	26	15	6	2	17	2	2	4	0	2	0	5	0	0	0	0	0	3	84
T-RD T. Va	16	7	34	7	4	3	10	2	0	1	0	0	1	0	0	0	0	3	88
T-PP T. Vb	22	0	0	0	0	0	1	3	0	0	0	0	0	1	0	0	0	0	27
T-RD T. Vb	135	9	52	3	20	0	7	12	0	2	0	0	0	0	0	0	0	7	247
Σ	2283	469	271	165	180	74	36	32	11	42	6	19	4	1	2	1	1	71	3668

Tab. 2a — Anthracological dataset used in statistical analysis. Samples are organized by the individual chronological phases of the sites and by the activities performed there: Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D); W = workshop area (made by: K. Botić)

Tab. 2a — Antrakološki skup podataka korišten u statističkoj analizi. Uzorci su organizirani prema pojedinačnim kronološkim fazama nalazišta i prema aktivnostima koje su se na njima odvijale: Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D); W = radionički dio (izradila: K. Botić)

Sites and phases	*Quercus*	*Carpinus*	*Ulmus*	*Acer*	*Fraxinus*	*Fagus*	*Sorbus*	*Populus*	*Corylus*	*Alnus*	*Rosaceae*	*Salix*	*Betula*	*Sambucus*	*Prunus avium*	*Prunus spinosa*	*Juglans*	Indet.
Torčec I	74	24	0	0	1	0	0	0	0	13	0	0	0	0	0	0	0	1
Torčec I W	216	47	2	1	48	0	0	0	0	14	0	3	0	0	0	0	1	0
Torčec II	267	109	26	19	28	35	0	1	0	0	0	9	1	0	0	0	0	9
Torčec II W	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Torčec III	448	49	3	27	6	12	3	0	3	3	1	0	0	0	0	0	0	4
Torčec III W	259	0	1	0	5	0	0	5	0	3	0	0	0	0	0	0	0	0
Torčec IV	819	209	147	106	51	22	13	5	8	4	5	2	2	0	2	1	0	44
Torčec V	199	31	92	12	41	5	20	21	0	5	0	5	1	1	0	0	0	13

Tab. 2b — Final anthracological dataset used for statistical analysis. Bulk data is sorted into Torčec pottery groups / chronological phases independently of the sites; W = workshop area (made by: K. Botić)

Tab. 2b — Završni antrakološki skup podataka korišten u statističkoj analizi. Skupni podaci razvrstani su u Torčec keramičke grupe / kronološke faze neovisno o nalazištima; W = radionički dio (izradila: K. Botić)

The dispersal of wood taxa corresponds to the results obtained by quantitative analysis, i.e. it indicates a less uniform taxa count in the overall site contexts.

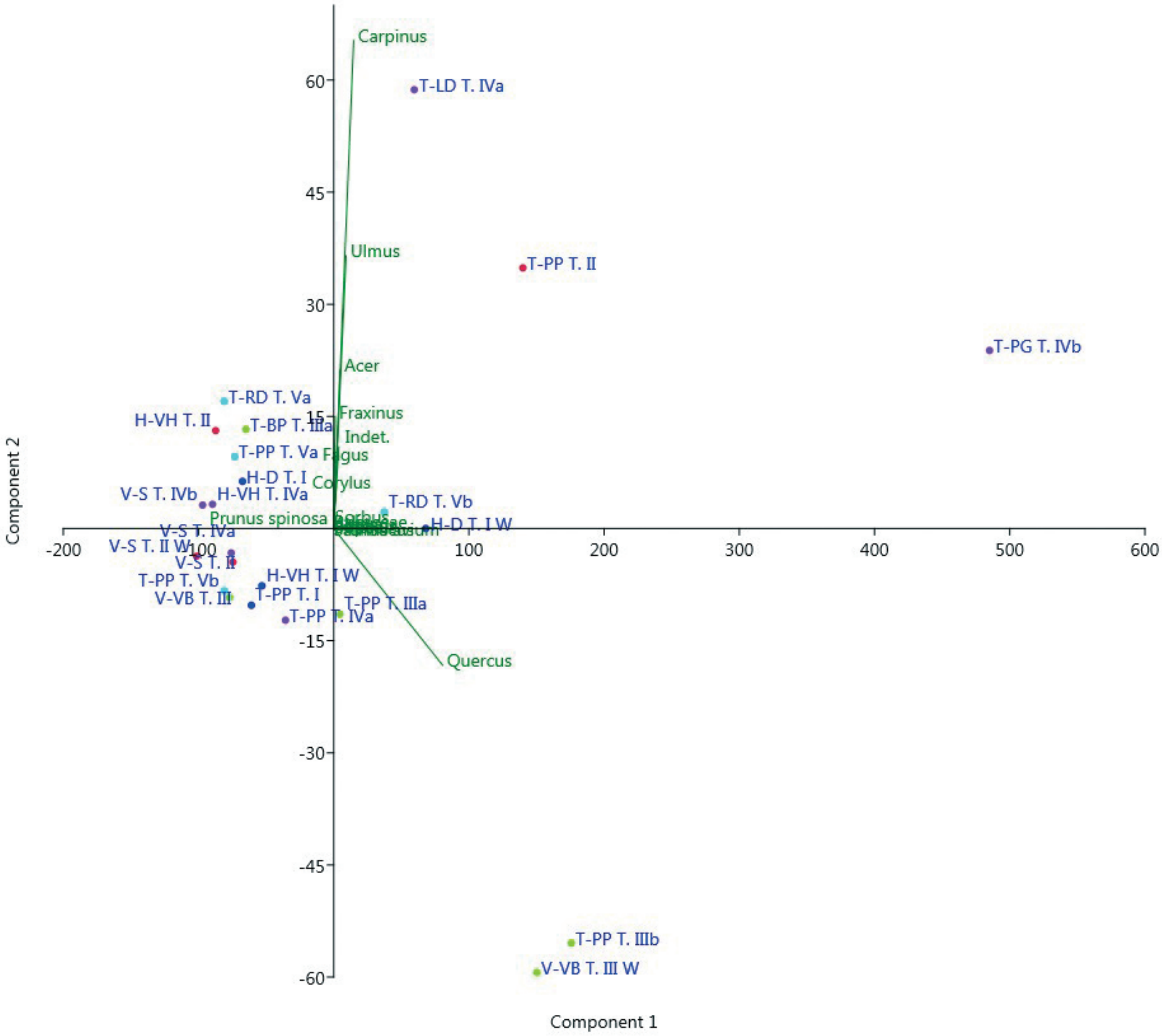

Fig. 6 — Principal component analysis (PCA) scatter plot. The two principal components are *Quercus* and *Carpinus*. Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D); W = workshop areas (squares); chronological phases Torčec I (blue circle), II (red circle), IIIa and IIIb (light green circle), IVa and IVb (purple circle), Va and Vb (light blue circle) (made by: K. Botić)

Sl. 6 — Dijagram raspršenosti Analize glavnih komponenata (PCA). Dvije glavne komponente su *Quercus* i *Carpinus*. Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D); W = radionički dio (kvadrati); kronološke faze Torčec I (plavi krug), II (crveni krug), IIIa and IIIb (svijetlo zeleni krug), IVa and IVb (ljubičasti krug), Va and Vb (svijetlo plavi krug) (izradila: K. Botić)

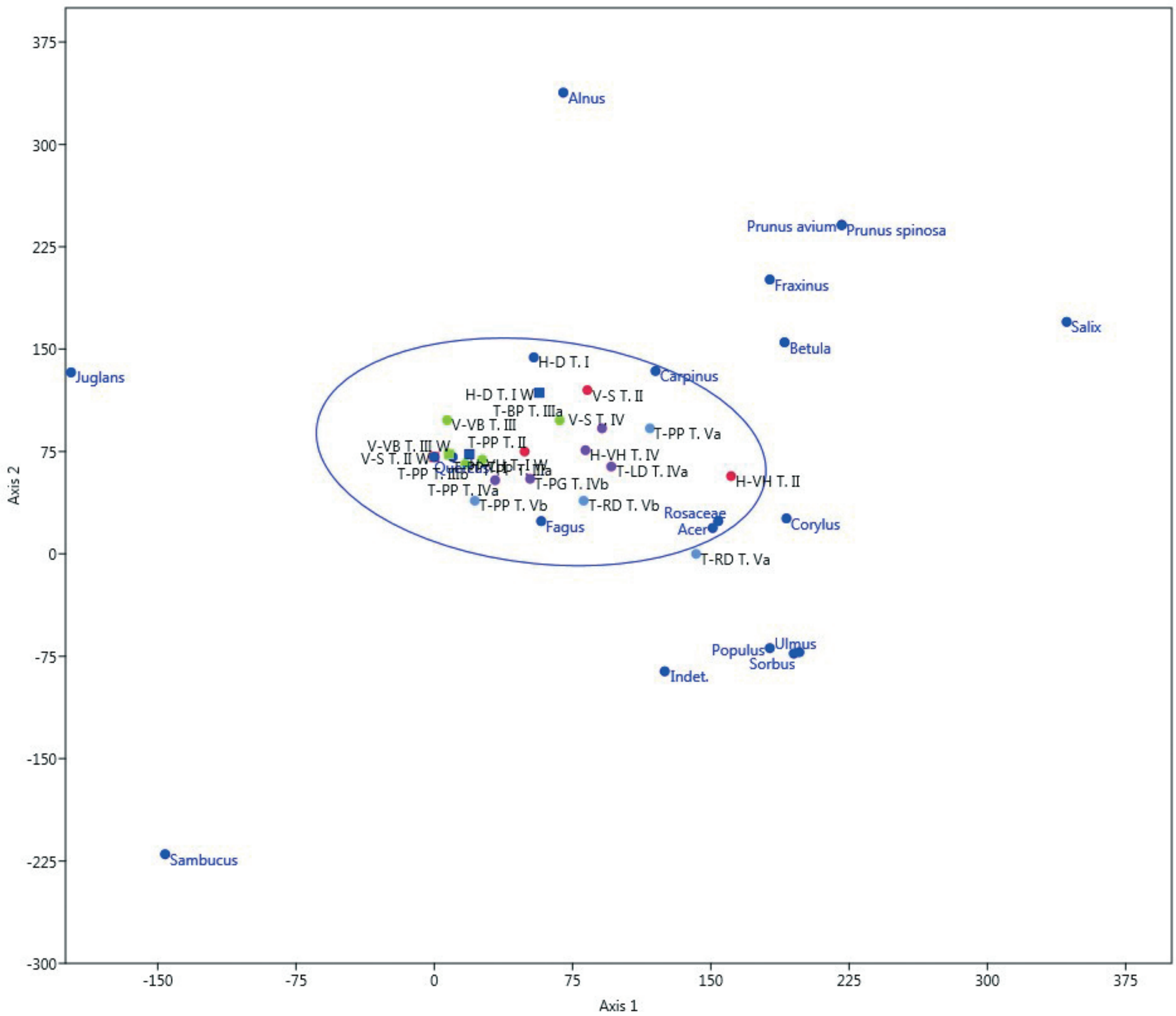

Fig. 7 — Detrended correspondence analysis (DCA) results. Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D); W = workshop areas (squares); chronological phases Torčec I (blue circle), II (red circle), IIIa and IIIb (light green circle), IVa and IVb (purple circle), Va and Vb (light blue circle) (made by: K. Botić)

Sl. 7 — Rezultati Detrendirane analiza korespondencije (DCA). Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D); W = radionički dio (kvadrati); kronološke faze Torčec I (plavi krug), II (crveni krug), IIIa and IIIb (svijetlo zeleni krug), IVa and IVb (ljubičasti krug), Va and Vb (svijetlo plavi krug) (izradila: K. Botić)

Discussion

The results of the quantitative analysis show predominant use of oak (*Quercus*), 59% of all the samples in the residential areas (all the sites, all Torčec phases), followed by hornbeam (*Carpinus*) with almost 13.8% and elm (*Ulmus*) with 8.8%, with the presence of 13 more taxa (≤ 7%) (Fig. 3). In the workshop areas, the predominance of oak (*Quercus*) is more pronounced (78.6% of all samples), followed by ash (*Fraxinus*) with 8.7% and hornbeam (*Carpinus*) with 7.7%, with the presence of six more taxa (≤ 7%) (Fig. 3). The lower calorific values (LCV) of all these taxa is very similar when burnt at 12% moisture content, between 4000 and 5000 kcal/kg (Kabukcu, Chabal 2020: 20, Fig. 7; Botić, Culiberg

2021).[16] Their abundance around the sites must have been a reason for their predominance in use. However, the ratio of identified taxa varies over time and within the contexts of individual sites (Fig. 3–4). The bias in the available samples can partially explain some ratio issues in both contexts of the sites, residential and workshop. Strong example for bias in the residential area is Virje – Volarski breg (Torčec IIIa) (Tab. 2a), whereas for the workshop areas these are Hlebine – Velike Hlebine (Torčec I) and Virje – Sušine (Torčec II) (Tab. 2a). Overall, the charcoal fragment count for the residential areas is lower than 600, with the exception of Torčec IV phase (Fig. 3b), whereas in the workshop areas most contain around 300 identified charcoal fragments (Fig. 3b) with the exception of Torčec II phase represented by a single charcoal fragment from Virje – Sušine site. The bias is probably the result of the sampling strategy used during the small-scale excavations. Predominance of oak in the remains of all activities in and around the workshops is to be expected, as all the sites are situated in the temperate continental zone dominated by deciduous broadleaved or mixed forest (de Rigo et al. 2016: 24), mostly oak-ash-elm or hornbeam-oak (Kevey 2019: 302; Botić, Culiberg 2021). A very narrow strip of land around the river course exhibits some temperate steppe conditions, located as it is at the southern border of the Carpathian Basin, with mid-high steppe conditions, i.e. relatively low rainfall, high evaporation, and vegetation dominated by grass and low shrubs (de Rigo et al. 2016: 24, 27; Botić, Culiberg 2021). Remains of a sandy desert like conditions can still be seen at so-called Đurđevac sands (Đurđevački pijesci) special reserve in the Natura 2000 ecological network[17] located about 10 km southeast of Virje. Lowland wet environments, clayey and alluvial soils with shallow groundwater table in the parts of the Drava river valley are good prerequisites for bog iron formation (Kaczorek, Sommer 2003; Raimandou, Wells 2014; Brenko et al. 2021) which, together with the good wood supply, enabled the iron production on the four positions around Virje and Hlebine over extensive periods of time (Botić, Culiberg 2021).

Wood taxa determined at all nine sites and in most of the relative chronological segments indicates vegetation extending from waterlogged habitats to the higher floodplain terrain (Kevey 2019: 317, Fig. 18.8). This is a natural environment for narrow-leafed ash (*Fraxinus angustifolia*) and black alder (*Alnus glutinosa*) on a peaty silt or pedunculated oak (*Quercus robur*), narrow-leafed ash (*Fraxinus angustifolia*), white elm (*Ulmus laevis*) and common hornbeam (*Carpinus betulus*) on a sandy elevated ground (Botić, Culiberg 2021). There are some exceptions. Virje – Volarski breg (Torčec IIIa phase) workshop area and Hlebine – Velike Hlebine (Torčec II phase), Torčec – Ledine (Torčec IVa phase), Torčec – Pod Gucak (Torčec IVb phase), Torčec – Prečno pole I and Torčec – Rudičevo (both Torčec Va and Vb phases) residential areas contain fragments of poplar (*Populus*)[18] which prefers higher sandy floodplain terrain near the rapid current with enough natural light (Caudullo, de Rigo 2016b: 134; Kevey 2019: 305, Fig. 18.5; Botić, Culiberg 2021) while the rest of the taxa are identical to those around waterlogged habitats. More abundant poplar charcoal fragments come from the sites around Torčec, which can be expected because this area is close to the Drava River current and prone to flooding (Fig. 1), especially from Torčec – Prečno pole I and Rudičevo residential areas (Tab. 2). The oak / poplar ratio changes between the IV and V phases, with oak being less predominant in the later phase. However, this is also linked to the spatial distribution of the sites, with Torčec – Ledine and Pod Gucak sites (phase IV) situated on somewhat different terrain, and with a bias in quantity of available charcoal samples.[19] For Virje – Volarski breg workshop area and Hlebine – Velike Hlebine residential area only six charcoal fragments of poplar were determined,[20] which are not enough for a conclusion about wood management on these two sites. However, presence of poplar may indicate change in availability of wood around the sites, chance collection of smaller branches[21] or change of the Drava River currents around the sites during the Torčec II and Torčec IIIa phases (Early Middle Ages I – Tab. 1; Fig. 2).

16 —— The difference is in the density of wood: an oak log of the same size as an alder log will produce three times more heat, as it is three times heavier, but if 1 kg of both is burned, no difference in their respective energy returns will be perceptible (Kabukcu, Chabal 2020: 21).

17 —— More details at: Natura 2000 Network Viewer (https://natura2000.eea.europa.eu/#).

18 —— Charcoal fragments most probably belong to the white poplar (*Populus alba*) although this could not be confirmed during the primary microscopic analysis. The same goes for all the evaluated taxa for which genus but not species could be determined except for the wild cherry (*Prunus avium*) and the blackthorn (*Prunus spinosa*).

19 —— Torčec – Blaževo pole 6 is represented only by 71 charcoal fragments, far less than the other Torčec sites.

20 —— One from Hlebine – Velike Hlebine and five from Virje – Volarski breg.

21 —— In natural succession, oak-ash-elm forests develop from either poplar groves or alder groves over long periods (Kevey 2019: 318). If a change in natural environment occurred, it must had started in the previous period (Late Roman period / Early Middle Ages) in order to produce transition vegetation zone between poplar and oak-ash-elm forests during the Early Middle Ages I period.

Presence of maple (*Acer*) charcoal fragments is also interesting. Out of 165 fragments from all nine sites only one was found in the workshop area of the Hlebine – Velike Hlebine site in the Torčec I phase context. The rest of the fragments come from residential areas of all chronological phases (Tab. 2). Species of maple could not be determined but in general maple avoids waterlogged areas, although does not tolerate drought, and can be found on clay soils (*Acer campestre*) (Zecchin et al. 2016: 52) or on fertile moist soils at the base of hills (*Acer plantanoides*) (Caudullo, de Rigo 2016a: 53; Botić, Culiberg 2021). Abundance of maple in the residential areas of the Torčec sites would suggest it was most probably transported from a certain distance and not only used as firewood.

Two more taxa appear only among the charcoal samples of the residential areas of Virje – Sušine (Torčec II and IVa phases), Torčec – Prečno pole I (Torčec II, IIIa, IIIb and Va phases), Torčec – Blaževo pole 6 (Torčec IIIa phase), Torčec – Ledine (Torčec IVa phase), Torčec – Pod Gucak (Torčec IVb phase) and Torčec – Rudičevo (Torčec Va phase), which cannot be found in waterlogged areas: beech (*Fagus*) and birch (*Betula*) (Tab. 2). Beech (*Fagus sylvatica*) prefers hill sides with soft soils and avoids waterlogged areas with compacted soils (Houston Durrand et al. 2016a: 94). Downy birch (*Betula pubescens*) is also drought sensitive although it tolerates damper soils and poorly drained heaths while silver birch (*Betula pendula*) grows best on fairly fertile well-drained soils (Beck et al. 2016: 70). Presence of these two taxa in the residential areas at Torčec sites is, again, very interesting.

In the residential area of the Virje – Sušine site (Torčec IVa and IVb phases) two species were also identified: wild cherry (*Prunus avium*) and the blackthorn (*Prunus spinosa*) (Tab. 3).[22] Although charcoal fragment count is very low, their presence is not surprising as fruits of both species are used for food. Blackthorn (*Prunus spinosa*) is a shrub that grows at the edges of oak and beech forests or on river banks with willows and poplars, i.e. between woodland and grassland communities, often at the borders of the agricultural fields (Popescu, Caudullo 2016: 145; Botić, Culiberg 2021). Wild cherry (*Prunus avium*) is a medium sized tree that prefers deep fertile soils but does not tolerate heavy clays, waterlogged or poorly drained areas and it is drought sensitive (Welk et al. 2016: 140). Ripe fruits of these two species occur in different seasons: wild cherry from late spring until summer (Welk et al. 2016: 140) while blackthorn fruits ripen in late summer and autumn and can persist on the plant throughout winter (Popescu, Caudullo 2016: 145; Botić, Culiberg 2021).

The Principle of Least Effort may possibly apply to the choice of wood taxa used for charcoal production needed as a fuel for the iron production or as firewood in the residential areas – all wood was indistinctly collected in proportions which occurred in the environment around the sites (Théry-Parisot et al. 2010: 144; Botić, Culiberg 2021). This may apply to the majority of identified taxa with the exceptions mentioned before: maple, birch, beech and possibly wild cherry (*Acer*, *Betula*, *Fagus, Prunus avium*).

Variety of taxa identified in the residential areas of the sites may also indicate other usage of wood besides fuel, such as construction timber (oak and ash). Oak (*Quercus*) acorns can be used for livestock food, bark for tanning leather, storing liquids (wines and spirits) etc. (Eaton et al. 2016: 161; Botić, Culiberg 2021). Ash leaves can also be used for cattle fodder while sap of manna ash (*Fraxinus ornus*) can be extracted by incising the bark, dried and used in form of edible flakes which have mild laxative and diuretic properties (Caudullo, Houston Durrant 2016: 97; Botić, Culiberg 2021). Maple (*Acer* cf. *pseudoplatanus*), not native to the immediate surroundings of the sites but can be found in the hilly region to the south-west, could have also been used for food: ethnographic sources mention drink made of fresh tree sap, buds eaten raw by shepherds and leaves used in the process of baking bread both to prevent sticking and to give a special flavour (Pasta et al. 2016: 57; Botić, Culiberg 2021).[23] White willow (*Salix alba*), present mostly in the residential areas (Tab. 2),[24] could have been used for its medicinal property (salycin) or for manufacturing of wooden kitchen utensils, bows, wicker baskets etc. (Houston Durrant et al. 2016b: 168; Botić, Culiberg 2021). Hornbeam (*Carpinus*) can also be used for making small wear resistant items, such as tool handles, mill wheels, agricultural tools, wooden rivets etc. (Sikkema et al. 2016: 75; Botić,

22 —— Two fragments of wild cherry (*Prunus avium*) and one fragment of blackthorn (*Prunus spinosa*).

23 —— Ash leaves are still used for wrapping a local cheese in northern Spain (Pasta et al. 2016: 57).

24 —— Hlebine – Dedanovice (Torčec I phase) workshop area, Hlebine – Velike Hlebine (Torčec II phase), Virje – Sušine (Torčec IVb phase) and Torčec – Prečno pole I (Torčec Va phase) residential areas.

Culiberg 2021). Beech (*Fagus*), with about 250 known usages today, is not very present in the overall charcoal sample and only in the residential areas, as mentioned before. Beech wood can also be used for production of cooking utensils such as bowls, wooden spoons, platters etc. (Houston Durrant et al. 2016a: 94; Botić, Culiberg 2021). Several wood taxa can be used for furniture making (oak, maple, beech, wild cherry) or even for musical instruments (maple, beech, wild cherry) and some for vessels (oak, willow, elm) (Botić, Culiberg 2021). However, true use of these taxa cannot be reconstructed based on such a small charcoal sample scattered over variety of residential contexts and time periods at sites around Torčec, Virje and Hlebine.

Questions of wood alteration during the charcoal production, taphonomic processes, sampling methods, moisture content, size of used wood as indicator of wood management etc. have not been addressed *in extenso* here due to the small sample and mostly bad preservation of charcoal fragments.[25]

CONCLUSION

Radiocarbon dates and Bayesian model show great accordance with the archaeologically based data with some exceptions that are most probably a result of modelling strategy used, which should be addressed in detail in the future. Contemporaneity of Torčec – Prečno pole I site and the sites around Hlebine and Virje, from the transition Late Roman / Early Middle Ages period (Torčec I phase), is attested just after the AD 600 and it continues in the Middle Ages I period (Torčec II and III phases) ending in the 2nd half of the 10th century.[26] Sites around Torčec[27] continue in the Middle Ages II (Torčec IV phase), from the 2nd half of the 10th century to the end of the 12th century, and in the developed Middle Ages period (Torčec V), from the 12th to the beginning of the 14th century.

Anthracological analysis conducted on the remains of charcoal from workshop and residential areas extracted during the small scale excavations at five sites around Torčec and four sites around Virje and Hlebine gave an insight into the habits and activities performed there. Predominance of oak (*Quercus*) in the context of workshop areas from all four sites (Tab. 3b) and in all relative chronological periods is consistent with the availability of this taxon around the sites. At the same time, in the residential areas (Tab. 3a) three main taxa identified were oak (*Quercus*), ash (*Fraxinus*) and elm (*Ulmus*). In total, nine taxa were identified from the workshop area contexts while residential area contexts yielded 16 different taxa. Statistical analyses applied confirmed the results obtained by the quantitative analysis. Wood taxa determined at all sites and in most of the relative chronological segments indicates vegetation extending from waterlogged habitats to the higher floodplain terrain. Abundance of taxa collected for residential use may possibly be explained by the Principle of Least Effort, i.e. all available wood was collected in proportions they occurred in the environment around the sites but with some exceptions such as maple, birch, beech and possibly wild cherry (*Acer*, *Betula*, *Fagus, Prunus avium*) which do not grow in waterlogged areas and which could have had other use besides fuel.

There is a documented change in the use of wood species from the 6th century to the beginning of the 14th century. Although oak (*Quercus*) prevails in all periods, its use from the 10th century is reduced, when other types of wood appear. Some medieval settlements were located near the workshops for iron smelting, an activity that over time led to over clearing of oak forests and to the transformation of forest habitats. Anthropogenic influences have allowed the spread of other species such as elm (*Ulmus*), maple (*Acer*), ash (*Fraxinus*), alder (*Populus*), willow (*Salix*), birch (*Betula*), and blackthorn (*Prunus spinosa*) or some of these species were transported to the settlements from elevated regions in relatively vicinity.

25 —— Please consult: Théry-Parisot et al. (2010); Crew, Mighall (2013); Kabukcu, Chabal (2020) etc. with references.

26 —— Sites around Virje and Hlebine continue into the next period (Middle Ages II), according to the archaeological finds, but there are no available radiocarbon dates to fill in the gap in the Bayesian model.

27 —— Torčec – Ledine, Torčec – Pod Gucak and Torčec – Rudičevo.

Sites and phases	*Quercus*	*Carpinus*	*Ulmus*	*Acer*	*Fraxinus*	*Fagus*	*Sorbus*	*Populus*	*Corylus*	*Alnus*	*Rosaceae*	*Salix*	*Betula*	*Sambucus*	*Prunus avium*	*Prunus spinosa*	*Juglans*	Indet.	Σ
T-PP T. I	42	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	46
H-D T. I	32	21	0	0	1	0	0	0	0	13	0	0	0	0	0	0	0	0	67
T-PP T. II	228	95	9	13	6	35	0	0	0	0	0	0	0	0	0	0	0	9	395
V-S T. II	28	1	0	3	20	0	0	0	0	0	0	0	1	0	0	0	0	0	53
H-VH T. II	11	13	17	3	2	0	0	1	0	0	0	9	0	0	0	0	0	0	56
T-PP T. IIIa	106	16	1	5	0	5	0	0	0	0	0	0	0	0	0	0	0	4	137
T-BP T. IIIa	33	29	0	1	3	2	0	0	3	0	0	0	0	0	0	0	0	0	71
T-PP T. IIIb	283	4	2	21	3	5	3	0	0	0	1	0	0	0	0	0	0	0	322
V-VB T. IIIa	26	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	29
T-PP T. IVa	67	3	7	2	0	0	3	0	0	0	1	0	0	0	0	0	0	0	83
T-LD T. IVa	145	64	46	54	40	5	1	4	8	3	4	0	0	0	0	0	0	10	384
T-PG T. IVb	566	123	90	35	2	14	9	1	0	1	0	0	2	0	0	0	0	34	877
V-S T. IVa	26	4	1	5	4	3	0	0	0	0	0	0	0	0	2	0	0	0	45
V-S T. IVb	4	6	3	2	5	0	0	0	0	0	0	2	0	0	0	1	0	0	23
H-VH T. IVa	11	9	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
T-PP T. Va	26	15	6	2	17	2	2	4	0	2	0	5	0	0	0	0	0	3	84
T-RD T. Va	16	7	34	7	4	3	10	2	0	1	0	0	1	0	0	0	0	3	88
T-PP T. Vb	22	0	0	0	0	0	1	3	0	0	0	0	0	1	0	0	0	0	27
T-RD T. Vb	135	9	52	3	20	0	7	12	0	2	0	0	0	0	0	0	0	7	247
Σ	1807	422	268	164	127	74	36	27	11	25	6	16	4	1	2	1	0	71	3062
%	59	13.8	8.8	5.4	4.2	2.4	1.2	0.9	0.4	0.8	0.2	0.5	0.1	0	0	0	0	2.3	100

Tab. 3a — Anthracological dataset used in statistical analysis. Samples are organized by the individual chronological phases of the residential areas of the sites: Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D) (made by: K. Botić)

Tab. 3a — Antrakološki skup podataka korišten u statističkoj analizi. Uzorci su organizirani prema pojedinačnim kronološkim fazama rezidencijalnih dijelova nalazišta: Torčec – Prečno pole I (T-PP), Torčec – Blaževo pole 6 (T-BP), Torčec – Ledine (T-LD), Torčec – Pod Gucak (T-PG), Torčec – Rudičevo (T-RD), Virje – Volarski breg (V-VB), Virje – Sušine (V-S), Hlebine – Velike Hlebine (H-VH), Hlebine – Dedanovice (H-D) (izradila: K. Botić)

Sites and phases	*Quercus*	*Carpinus*	*Ulmus*	*Acer*	*Fraxinus*	*Fagus*	*Sorbus*	*Populus*	*Corylus*	*Alnus*	*Rosaceae*	*Salix*	*Betula*	*Sambucus*	*Prunus avium*	*Prunus spinosa*	*Juglans*	Indet.	Σ
H-D T. I W	167	40	0	0	48	0	0	0	0	14	0	3	0	0	0	0	0	0	272
H-VH T. I W	49	7	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	60
V-S T. II W	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
V-VB T. IIIa W	259	0	1	0	5	0	0	5	0	3	0	0	0	0	0	0	0	0	273
Σ	476	47	3	1	53	0	0	5	0	17	0	3	0	0	0	0	1	0	606
%	78.6	7.7	0.5	0.2	8.7	0	0	0.8	0	2.8	0	0.5	0	0	0	0	0.2	0	100

Tab. 3b — Anthracological dataset used in statistical analysis. Samples are organized by the individual chronological phases of the workshop areas of the sites: Hlebine – Dedanovice (H-D), Hlebine – Velike Hlebine (H-VH), Virje – Sušine (V-S), Virje – Volarski breg (V-VB); W = workshop area (made by: K. Botić)

Tab. 3b — Antrakološki skup podataka korišten u statističkoj analizi. Uzorci su organizirani prema pojedinačnim kronološkim fazama radioničkih dijelova nalazišta: Hlebine – Dedanovice (H-D), Hlebine – Velike Hlebine (H-VH), Virje – Sušine (V-S), Virje – Volarski breg (V-VB); W = radionički dio (izradila: K. Botić)

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SAŽETAK

Srednjovjekovna šuma i šumski pokrov u Podravini, arheološka perspektiva: studija slučaja Torčec, Virje i Hlebine

KLJUČNE RIJEČI: **PODRAVINA, ANTRAKOLOŠKE ANALIZE, RELATIVNA KRONOLOGIJA, RADIOKARBONSKO DATIRANJE, SREDNJI VIJEK**

Tijekom višegodišnjih arheoloških istraživanja na nalazištima u okolici Torčeca, Virja i Hlebina u Podravini, u sklopu projekta TransFER *Proizvodnja željeza uz rijeku Dravu u rimskom razdoblju i srednjem vijeku: Stvaranje i prijenos znanja, tehnologija i robe* (IP-06-2016-5047) financiranog od strane Hrvatske zaklade za znanost, prikupljen je veliki broj uzoraka spaljenog drva. Antrakološke analize uzoraka prikupljenih u srednjovjekovnim kućama pokazale su da se u svakodnevnom životu koristio veliki broj vrsta drveta, ne samo za izgradnju kuća, već i za grijanje i eventualno izradu namještaja ili manjih predmeta za svakodnevnu uporabu. Dokumentirana je promjena u korištenju vrsta drveta od druge polovine 6. do početka 14. stoljeća na primjeru nekoliko nalazišta u okolici Torčeca, što je potvrđeno na nalazištima oko Virja i u Hlebinama. Iako hrast (*Quercus*) prevladava u svim razdobljima, njegova se upotreba od 10. stoljeća smanjuje, kada se u upotrebi pojavljuju druge vrste drveta. Neka srednjovjekovna naselja nalazila su se u blizini radionica za taljenje željeza, što je s vremenom dovelo do pretjeranog krčenja hrastovih šuma i do transformacije šumskih staništa. Tako su antropogeni utjecaji dopustili širenje drugih vrsta, kao što su brijest (*Ulmus*), javor (*Acer*), jasen (*Fraxinus*), joha (*Populus*), vrba (*Salix*), breza (*Betula*) i trnina (*Prunus spinosa*).