

DENDROCHRONOLOGICAL INVESTIGATION OF WOOD FROM VARAŽDIN OLD CASTLE

DENDROKRONOLOŠKA ISTRAŽIVANJA DRVA IZ STAROGA GRADA U VARAŽDINU

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SAŽETAK

Tijekom arheoloških istraživanja na Starom gradu u Varaždinu, a iskopavanja su provedena kao dio Projekta BASTION u sklopu međunarodnog INTERREG III A programa, otkriveni su dijelovi dviju drvenih konstrukcija. U sjevernom jarku bili su pronađeni ostaci mosta ili prilazne rampe, koja je vodila prema vratima srednjovjekovne četvrtaste kule, a u zapadnom unutarnjem jarku otkriveni su ostaci drvene obrambene ograde - palisade. Na osnovi raspoloživih povijesnih podataka bilo je procijenjeno da drvo pripada konstrukcijama s vremenskim rasponom nastanka od 13. do sredine 16. stoljeća. Nakon vađenja iz zemlje drvo je bilo odgovarajuće pohranjeno u podrumu muzeja u Varaždinu pa se nije osušilo niti je doživjelo oštećenja. Prema uputama Odsjeka za drvnu tehnologiju Univerziteta u Ljubljani, pripremljeni su manji uzorci koji su poslani na dendrokronološku analizu u Ljubljani. Tamo je drvo fino obrađeno te su provedeni identifikacija i dendrokronološko datiranje u skladu s važećom metodologijom (ČUFAR et al. 2006).

*Rezultati istraživanja su sljedeći: (1) uzorci iz pristupnog mosta u sjevernom jarku (sonda VII) bili su: daska (VAR1A i VAR2A) iz jelovine (*Abies alba*) dendrokronološko datirana u god. 1406., dva pilota iz hrastovine (*Quercus sp.*) datirana u 1374. (VAR12A) i 1394. (VAR13A) te mali komad drva hrasta (VAR14A) datiran u 1400. godinu. Uzorak pilota ili ostatak debla od drva pravoga kestena (*Castanea sativa*) s očuvanom korom nismo mogli datirati jer je imao premalo godova.*

Uzorci VAR5A i VAR8A iz zapadnog jarka (sonda VIII) bili su iz aksialno raskoljenih trupaca hrasta i predstavljali su dijelove drvene obrambene palisade te su bili datirani u 1415. i 1404. godinu. Datacije su bile provedene s referentnim kronologijama laboratorija u Ljubljani.

Nijedan od uzoraka nije imao sačuvanu bjeljiku niti koru te zato navedeni datumi predstavljaju godinu nastanka krajnjeg perifernoga goda, sječa stabla i postavljanje konstrukcije u svim su se slučajevima dogodili nakon navedenih datuma. Most je bio podignut nakon 1406., a palisada poslije 1415. godine. S obzirom na procijenjeni broj godova koji nedostaju, pretpostavljamo da bi obje konstrukcije mogle biti sagrađene istodobno ili pak u kratkom razmaku, poslije 1415. i prije 1445. godine. U tom je razdoblju Stari grad bio u vlasništvu grofova Celjskih. Izvori spominju da je 1446. Janko Hunjadi napao i spalio Varaždin, a utvrdu nije mogao osvojiti jer je bila dobro branjena drvenom ogradom.

Dendrokronološko datiranje i interpretacija s povijesnim izvorima pokazuju važnost interdisciplinarnih istraživanja. Datacija drvenih konstrukcija sa Staroga grada u Varaždinu je, uz datiranje nalazišta Torčec-Gradić (ČUFAR i SEKELJ-IVANČAN, u ovom broju), među prvim uspješnim aplikacijama dendrokronologije u arheologiji u Hrvatskoj s uporabom referentnih kronologija iz Slovenije.

Ključne riječi: Varaždin, Stari grad, arheološko drvo, dendrokronologija, datiranje, projekt BASTION

Key words: Varaždin, Old Castle, archaeological wood, dendrochronology, dating, BASTION project

INTRODUCTION

Renaissance Varaždin Old Castle has been the subject of historical, archival and architectural research for over a decade, because of its well preserved elements of fortification, such as the embankment, bastions and ditches (e.g. HORVAT 1993: 119,193; ILJANIĆ 1954; KRUIEK 1995: 141,240; ŽMEGAČ 2000, 28, 160 etc.). Archaeological excavations with small trenches were conducted in the 1960s and 1970s. The trenches were dug mainly near the walls close to the building, so they provided us with new knowledge about its architectural characteristics, but not with sufficient data about the archaeological layering of the complex. In the fall of 2006, archaeological research was conducted on several locations at the Varaždin fort within the framework of the biennial BASTION Project, part of the International INTERREG III A Program (see ŠIMEK, article in this issue). The Bastion Project was accepted and partly financed by the EU. The main goal of the project was to investigate two renaissance fortresses, in Maribor and in Varaždin, that were thought to have been constructed for protection against Ottoman attacks in the 16th century.

Well preserved parts of wooden constructions were discovered during the archaeological excavations in the northern and western moats. Wooden pillars, three beams around 2 m long and a few smaller elements such as boards and ledges were found at the bottom of the northern moat. All parts were found in the moat in front of the entrance to the medieval northern tower. On the basis of the characteristics of the wooden elements and their positions in the layers, we concluded that they were the remains of a bridge or an access ramp - which led to the entrance gate of the square medieval tower.

A 135 m long wooden construction was discovered in the second excavated location, in the western inner moat. It was buried in the alluvial layer of Drava river gravel below the bottom of the moat. Although, the upper part of the construction was missing, presumably because it was

Varaždin Stari grad Sonda VII



Figure 1.: Wooden board from trench VII with indication of how the sample for analysis should be taken.
Slika 1.: Drvena daska iz sonde VII i opis uzimanja uzorka za analize

destroyed during renaissance reconstruction of the castle, it was still possible to deduce its function. The parts found were probably the remains of wooden defence palisades. A wide range of dating of the discovered findings was proposed. According to historical information about the object and the stratigraphic location of the finds, it was assumed that the wooden configuration was built after the 13th century (time of the oldest building phase of the castle) and before the 16th century (time of major adaptation of the building). In October and November 2006, samples of wood were taken at both locations. They were sent to the Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana for analysis to determine the wood species and the age of the wood. Exact dendrochronological dating of the wooden defence elements would be very important for establishing the building phases of Varaždin Old Castle.

MATERIALS AND METHODS

From the northern ditch (trenches VII + A + B), samples were taken of different wooden elements of the same wooden construction, as assumed from where the wooden parts were found. Only sample VAR9A did not appear to belong to the construction. All parts were located in the dark layer of mud at the bottom of a ditch and in the gravel layer, at the transition from the ditch towards the bulwark.

Well-preserved samples with a sufficient number of tree-rings for dendrochronological analysis were selected for analysis. Two samples (VAR1A, VAR2A) originated from a board (Fig. 1, Fig. 2) which was a part of the construction. Other two samples were wooden pillars (VAR12A, VAR13A), which had been pounded into gravel and were found at their original location. One sample (VAR14A) was a part of a small wooden artefact.

Two samples (VAR5A, VAR8A) were chosen from the western moat (trench VIII B). They were taken from axially split beams, from the alluvial gravel (below the bottom of the trench). The beams were 1.5 to 4.5 m long and were the remains of a defence palisade, presumably older than the ditch and the clay defensive embankment.

During the scraping of a large piece of wood (VAR9A) in trench VII A, well-preserved bark was found. Since it did not seem to be processed (by wood working tools) the archaeologists assumed that it did not belong to any of the wooden constructions. Nevertheless, they took a sample of the trunk to determine the wood species and the date that the tree was felled.

The context of the finds indicated that the wooden elements from the northern moat (except sample VAR9A) belonged to the same construction - the bridge or access ramp, and that all samples from the western trench belonged to palisades.

After excavation, the wooden elements were kept in the cool, wet basement storeroom of the museum. In order to prevent desiccation and damage, they were wrapped in »geotextile«, which was remoistened every 3 to 4 days by sprinkling with water. Permanent control of the relative humidity in the room and wetting the geotextile helped ensure that the samples retained their moisture, volume and form and that they remained undamaged.

Since the excavated samples were too big for transport and analysis, they were photographed with identification labels. The photos helped the Department of Wood Science and Technology in Ljubljana to give instructions on where and how smaller samples for analysis should be taken (Fig. 1). These smaller samples were sent to Ljubljana, where they were cut to final size and their cross-sections were smoothed (Fig. 2).

We identified the wood species, counted the number of tree-rings and measured their widths to the nearest 0.01 mm using a LINTAB measuring table and TSAP/X and TSAPWIN programmes. The obtained tree-ring series were dated with reference chronologies of the laboratory in Ljubljana. Dendrochronological procedures and interpretation of the results are described elsewhere (e.g. ČUFAR and LOZAR ŠTAMCAR 2004, ČUFAR et al. 2006).

RESULTS AND DISCUSSION

The description of the samples, the results of wood identification and dendrochronological dating are presented in Table 1. Samples from the northern moat (trench VII) belonging to the bridge or access ramp construction were identified and dated as follows. The board (VAR1A and VAR2A) was made of silver fir (*Abies alba*). Its last preserved ring was dated 1406. The oak (*Quercus* sp.) beams from the same construction were dated 1374 (VAR12A) and 1394 (VAR13A). The small wooden artefact (VAR14A) surprisingly also had enough rings for dendrochronology and was dated 1400 (Fig. 2, Fig. 3, Tab. 1).

The unprocessed pole with bark (VAR9A) was made of sweet chestnut (*Castanea sativa*) wood. It contained only 22 tree-rings, which is not enough for dendrochronological dating.



Figure 2.: Samples prepared for wood identification and dendrochronological analysis.

Slika 2.: Uzorci pripremljeni za identifikaciju drva i dendrokronološke analize

Samples VAR5A and VAR8A from the axially split oak beams of the remains of the palisade in the western moat (trench VIII B) were dated 1415 and 1404 (Fig. 2, Fig. 3, Tab. 1).

The dating of silver fir was done with the Slovenian silver fir chronology, version 2006 (LEVANIČ and ČUFAR 1997, ČUFAR et al. 2006) and verified by the silver fir chronology of the Hohenheim laboratory, Germany (BECKER and GIERTZ-SIEBENLIST 1970, FRIEDRICH pers. comm.). The best matching parameters were $GLK=71^{***}$ and $t_{BP}=4.9$.

The oak samples could be well synchronized and the dating was done with the Slovenian oak chronology version 2007 (ČUFAR et al. 2006b) and verified with the eastern Austria oak chronology (WIMMER et al. 1998, GEIHOFFER et al. 2005). The best matching parameters were $GLK=63^{**}$ and $t_{BP}=4.2$.

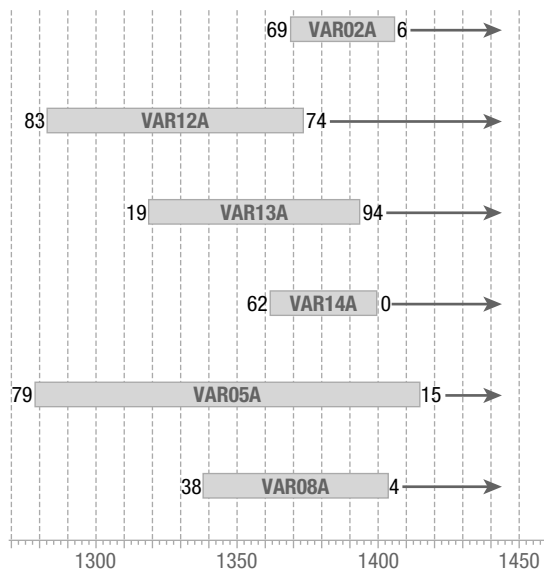


Figure 3. Dating of the last rings of all samples and estimation of felling dates of trees and time when the constructions were built.

Slika 3. Datumi zadnjih godina svih uzoraka i procjene datuma sječe stabala te vremena kada su podignute konstrukcije

Table 1. Description of samples, wood identification, and dendrochronological dating. None of the dated samples contained sapwood or the last tree-ring below the bark, so tree felling and erection of the constructions took place after the given years.

Tabela 1. Podaci o uzorcima i rezultati identifikacije drva i datiranja. Nijedan datirani uzorak nije imao bjeljiku niti zadnji god ispod kore. Sječa stabala i podizanje konstrukcija u svim su slučajevima nastupili nakon datuma zadnjeg goda prikazanog u preglednici.

No. Br.	Code Šifra	Trench Sonda	Description Opis	Wood Species Vrsta drva	Dating of the last ring Datacija zadnjeg goda	Note Primjedba
1 2	VAR1A VAR2A	Trench VII Sonda VII	Part of a bridge Ostatak objekta-most	Abies alba	1402 1406	Parts of the same board Uzorci iz iste daske
12	VAR12A	Trench VII B Sonda VII B	Part of a bridge Ostatak objekta-most	Quercus sp.	1374	
13	VAR13A	Trench VII B Sonda VII B	Part of a bridge Ostatak objekta-most	Quercus sp.	1394	
14	VAR14A	Trench VII B Sonda VII B	Smaller wooden artefact Manji drveni objekt	Quercus sp.	1400	
9	VAR9A	Trench VII A Sonda VII A	Unprocessed sample with bark Neobrađeni uzorak s korom	Castanea sativa	Undated Nedatiran	Too few tree-rings Premalo godina
5	VAR5A	Trench VIII B Sonda VIII B	Part of palisade Ostatak obrambenog zida-palisade	Quercus sp.	1415	
8	VAR8A	Trench VIII B Sonda VIII B	Part of palisade Ostatak obrambenog zida-palisade	Quercus sp.	1404	

- *Abies alba* - silver fir, jela
- *Castanea sativa* - sweet chestnut, pravi kesten
- *Quercus sp.* - oak, hrast

DISCUSSION - INTERPRETATION OF THE DATING

In interpreting the dates given in Table 1, it should be taken in account that dendrochronology provides the calendar years of tree ring formation. The year of the outermost ring on the sample is the most important for interpretation. If this ring is the last one below the bark, it tells the time when the tree was felled (Fig. 4.). None of our dated samples contained visible sapwood (outermost part of oak trunks that can be clearly differentiated from darker heartwood, Fig. 4) or the last ring below the bark (Fig. 2). At least several rings had been removed on all samples during wood processing or they were simply not preserved. The felling dates of the trees and erection of the constructions therefore occurred after the dates given in Table 1. On the basis of the given dates, the bridge or access ramp can be assumed to have been built after 1406 and the palisade was built after 1415. It is likely that the bridge and the palisade were built at the same time after 1415 and not later than 1445.

Historical interpretation of dendrochronological dating to the period between 1415 and 1445 is connected to the history of the Counts of Celje. They were the owners of the Varaždin fort at that time. In 1397, King Sigmund of Luxemburg awarded Varaždin castrum to Herman of Celje. It is almost certain that the Counts of Celje carried out reconstruction of the medieval object (ILIJANIĆ-KAPUSTIĆ 1983, 172) but the extent of such reconstruction is not known.

The *palisade* was apparently built in the time of the Counts of Celje. According to a description in the 'Celje Chronicle', Janko Hunjadi attacked Varaždin in 1446. He and his troops burned down the city, but they could not capture the fort (KRONES 1883), because it was well protected by a wooden palisade. This information from the 'Celje Chronicle' has in fact double importance for interpreting the dating of the wooden architecture: it confirms the presumption that the wo-

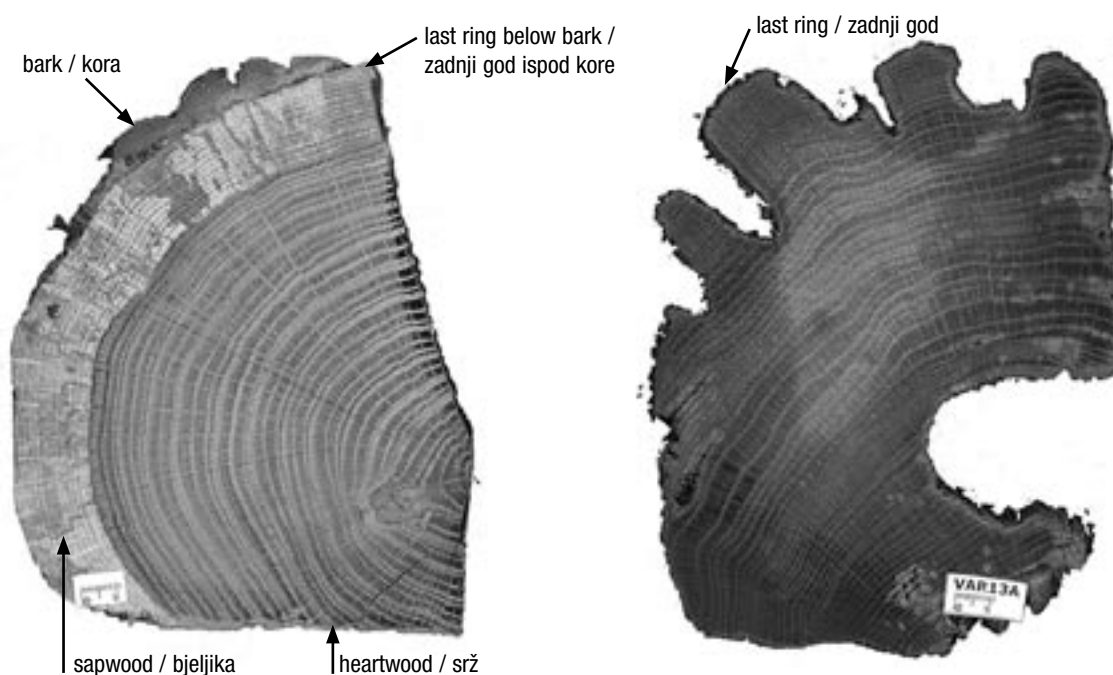


Figure 4. (a) An example of a sample that contains heartwood, sapwood and bark. The year of the last ring below the bark coincides with the last year of wood formation before the tree was felled. (b) Sample VAR13A, in which the last ring was dated 1394. Since the sample does not contain sapwood or bark we can only estimate the date of tree felling by adding a presumed number of missing rings (i.e. 1394 + approx.15-30 rings).

Slika 4. (a) Primjer uzorka koji ima srž, bjeljiku i koru. Godina zadnjeg goda ispod kore sukladna je godini pred sječom stabla. (b) Uzorak VAR13A kod kojeg je datacija zadnjeg goda 1394. Pošto uzorak nema niti bjeljiku niti koru, datum sječe stabla možemo procjeniti tako da zadnjoj godini pribrojimo pretpostavljen broj manjkajućih godina (to je 1394 + pribl.15-30 godina).

oden parts found in the western moat were really elements from the palisade, and that the palisade was complete and already functioning in 1446.

The estimate that the upper limit for dating of the wooden construction is 1445 makes sense, because it agrees with the reports that it was functioning in 1446.

Before application of dendrochronology, we could only approximately date the wooden constructions between the 13th and 16th centuries. This presumption was based on historical data about Varaždin Old Castle, and on the stratigraphy of the finds. We assumed that the oldest architectural elements of the fort and its northern tower originated from the 13th century (ILIJANIĆ - KAPUSTIĆ 1983, 170). This gave the earliest date of the bridge leading toward the object.

The pillars, boards and beams were found at the bottom of a wide moat, which was presumably made in the 16th century, when Domenico de Lallo modernised the medieval castrum.

We also presumed that during the rebuilding of the defence complex, when the older, narrower moat was widened, the old wooden bridge was dismantled since it did not fit into the new concept of defensive architecture.

The main modifications of Varaždin castle were done from 1544 to 1563, when de Lallo died (ILIJANIĆ 1961). Due to new building regulations for castles, the biggest reconstruction took place in the second half of the 16th century, and the old, medieval architectural structures were partly demolished. That is why we presumed that the upper limit for approximate dating of the investigated wooden constructions could be mid-16th century.

The wide range of dating, from the 13th to the mid-16th century was considerably narrowed by application of dendrochronology.

CONCLUSION

The information obtained by dendrochronological analysis gave much narrower dating of wooden elements from Varaždin Old Castle than previous estimates obtained by other sources. This shows the importance of interdisciplinary cooperation and the use of dendrochronology in archaeology. The current work, together with the dating of Torečec gradić (ČUFAR and SEKELJ IVANČAN, article in this issue) was among the first successful dendrochronological datings of archaeological wood in Croatia.

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DENDROKRONOLOŠKO DATIRANJE DRVA S LOKALITETA TORČEC - GRADIĆ U SJEVERNOJ HRVATSKOJ

THE DENDROCHRONOLOGICAL DATING OF WOOD FROM THE SITE OF TORČEC - GRADIĆ IN NORTHERN CROATIA

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SAŽETAK

U radu se donose rezultati dendrokronoloških analiza uzoraka drva prikupljenih pri arheološkim istraživanjima srednjovjekovne utvrde Gradić u Torčecu tijekom 2005. i 2007. godine. Analiza je pokazala da svi datirani uzorci pripadaju istoj fazi gradnje - Fazi III te da su drvene grede bile ugrađene u drvenu konstrukciju utvrde nakon 1263. godine, koja se smatra godinom terminus post quem.

ABSTRACT

The article presents the results of dendrochronological analysis of wood samples collected during archaeological excavation of the medieval fortification of Gradić at Torčec in 2005 and 2007. The analysis has shown that all the dated samples belong to the same construction phase - Phase III, and that the wooden posts were built into the wooden construction of the fortification after 1263, which can be considered the terminus post quem.

UVOD

Arheološki lokalitet iz srednjeg vijeka Gradić ili Turski brijeg smješten je sjeverno od mjesta Torčec pokraj Koprivnice u Podravini (približne koordinate 46°09' N, 16°50'), u blizini sutoka potoka Segovina i Gliboki, odnosno Gliboki i Vratnec. Lokalitet predstavlja nizinsko srednjovjekovno gradište s jasno uočljivim zemljanim bedemom istaknutih uglova te opkopom koji se punio vodom. Nalazište se prvi put spominje u arheološkoj literaturi 70-ih godina (Kolar, 1976). U isto vrijeme otkriveni su i dijelovi drvenih konstrukcija ili objekata. Te drvene konstrukcije bile su izrađivane od hrastovine (*Quercus* sp.), a njihovo radiokarbonsko datiranje dalo je godinu 625 BP (e.g. Januška, 2000). Arheološka istraživanja pod vodstvom dr. Tajane Sekelj Ivančan poduzeta su 2002. i 2003. godine (Tkalčec 2003; Sekelj Ivančan, Tkalčec 2004).

Nakon istraživanja nalazišta 2005. na Odjel za znanost i tehnologiju drva, Biotehničkog fakulteta Sveučilišta u Ljubljani, dopremljena su tri uzorka drva na dendrokronološku analizu. Tom je prigodom ustanovljeno da uzorci drva imaju dendrokronološki potencijal, ali kako bi dendrokronološko datiranje bilo moguće, bila je potrebna veća količina uzoraka (Čufar et al. 2006).

Daljnji uzorci drva s nalazišta dopremljeni su na Odjela za znanost o drvu zimi 2006./2007. godine. Na tom se mjestu prezentiraju rezultati dendrokronoloških istraživanja.

MATERIJAL I METODE

Tijekom istraživanja upotrebljene su standardne drvene anatomske i dendrokronološke procedure (e.g. Čufar et al. 2006). Drvo je obrađeno strojevima i izravnata je površina za identifikaciju i mjerenje širine godova. Uzorci

INTRODUCTION

The archaeological site of the medieval settlement of Gradić or Turski brijeg is located north of Torčec near Koprivnica, Croatia (approx. coordinates 46°09'N, 16°50'), near the junctures of the Segovina and Gliboko streams, and the Gliboko and Vratnec streams. The site consists of a typical lowland medieval fortified settlement that was protected by clearly visible earthen ramparts with prominent corners and surrounded by a moat filled with water. The settlement was first mentioned in the archaeological literature in the 1970s (Kolar, 1976). Parts of wooden constructions or structures were discovered at the same time. They were made of oak (*Quercus* sp.) and radiocarbon dating established their age as approx. 625 years BP (e.g. Januška, 2000). Archaeological excavations directed by Dr. Tajana Sekelj Ivančan were conducted in 2002 and 2003 (Tkalčec 2003; Sekelj-Ivančan and Tkalčec 2004).

Three wood samples collected during the excavations were brought to the Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana for dendrochronological investigations in 2005. It was found that the wood had dendrochronological potential, but a larger quantity of samples would be needed to enhance the possibility of dendrochronological dating (Čufar et al. 2006).

Additional samples from the site were brought to the Department of Wood Science in the winter of 2006/2007. The results of dendrochronological investigations are presented here.

MATERIAL AND METHODS

The standard wood anatomy and dendrochronological procedures were used for the investigations (e.g. Čufar et al. 2006). The wood was processed on wood working machines to make samples and smooth the cross-sections.

su pregledani pod stereomikroskopom kako bi se odredila vrsta drva. Na glatko obrađenim poprečnim površinama drva izmjerene su širine godova pomoću mjernog stolića LINTAB, stereo mikroskopa Olympus SZ 11 i programa TSAP/X. Rezultati mjerenja su grafički prikazani kao serije širina godova ovisno o vremenu. Nizovi širina godova (grafovi) uzoraka s istog nalazišta su međusobno uspoređeni, odnosno sinkronizirani. Svi nizovi (serije) koji su pokazivali optičko i statističko poklapanje ujedinjani su u plivajuću nedatiranu kronologiju. U sljedećem koraku obavljeno je datiranje, odnosno usporedba s raspoloživim referentnim kronologijama koje su sastavljene u laboratorijima u Ljubljani, Beču ili su dobivene razmjernom s drugim laboratorijima.

REZULTATI

Trima uzorcima analiziranim 2005. dodano je još osam uzoraka analiziranih 2007. godine. Svi uzorci pripadali su hrastu (*Quercus* sp.). Nijedan od njih nije imao očuvan ostatak kore drva ili posljednji god ispod kore. Štoviše nije-

We observed the samples under a stereo-microscope to identify the wood species. On smooth cross-sections tree-ring widths were measured using a LINTAB measuring table, an Olympus SZ 11 stereo-microscope, and the TSAP/X programme. The results of the measuring were graphically represented as tree-ring widths in reference to time. The tree-ring series from the same site were cross-dated (i.e. synchronized). All series that matched visually and statistically were assembled in a chronology, which was initially undated, i.e. a floating chronology. In the next step, this floating chronology was cross-dated with reference chronologies constructed by the dendrochronological laboratories at the University of Ljubljana and University of Natural Resources and Applied Life Sciences Vienna.

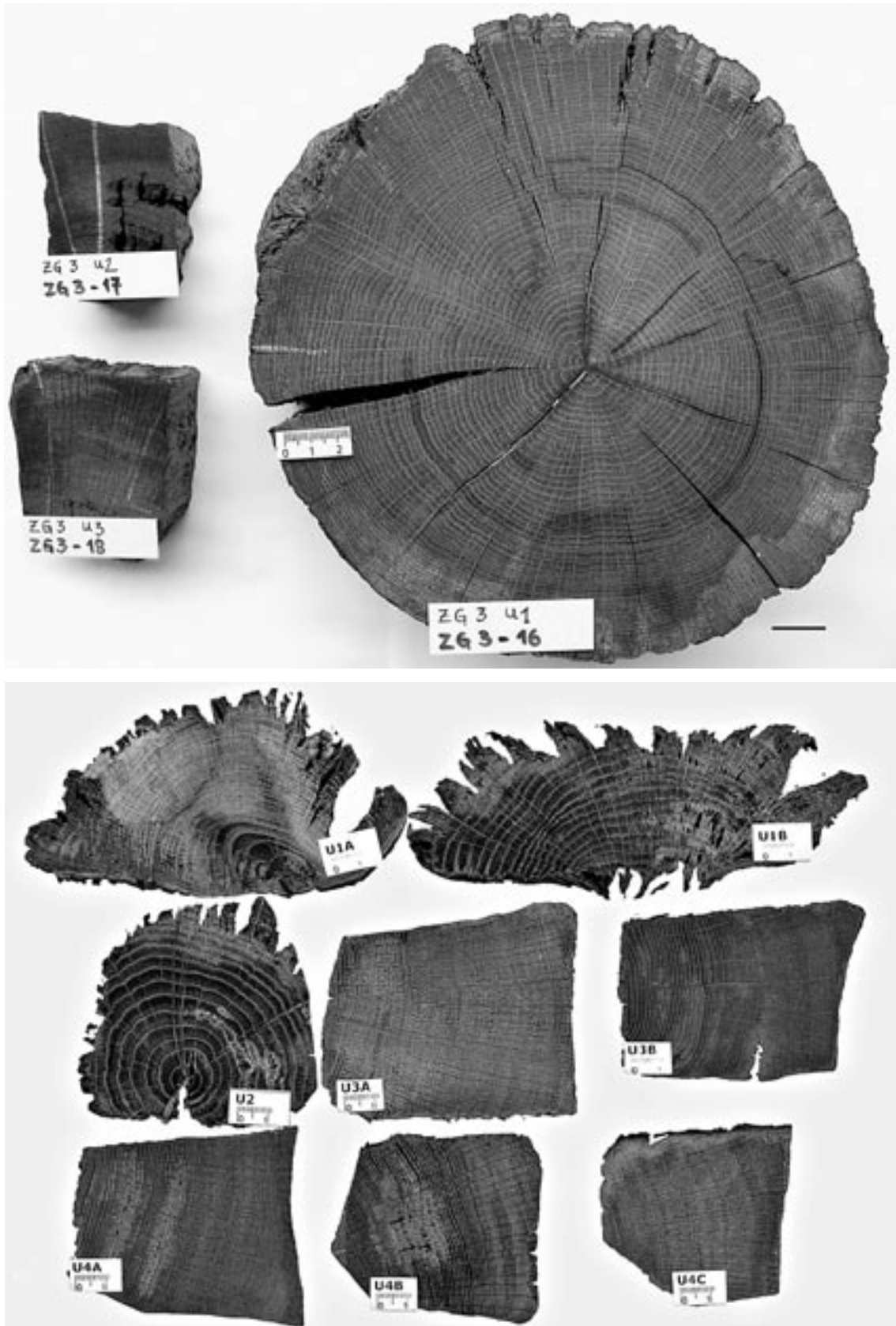
RESULTS

In addition to 3 samples investigated in 2005, a further 8 samples were investigated in 2007. All the samples were oak (*Quercus* sp.). None of them had preserved remains of bark or

Tablica 1: Opis analiziranih uzoraka i njihovo datiranje. Pretpostavka je da datirani uzorci pripadaju istoj građevinskoj fazi. Nijedan od uzoraka nije sadržavao ostatak kore drva ili posljednji god ispod kore

Table 1: Description of the analyzed samples and their dating. The dated samples are hypothesized to have belonged to the same building phase. None of the samples contained bark or the last ring below the bark.

Code	Part of construction	Wood species	No. of tree-rings	Date End
U1 (ZG3-16)	Bridge / Most	oak/hrast	49	
U2 (ZG3-17)	Posts / Kosnici	oak/hrast	89	
U3 (ZG3-18)	Posts / Kosnici	oak/hrast	102	1263
U1 A	Fence in the ditch (Ograda u jarku)	oak/hrast	33	
U1 B	Fence in the ditch (Ograda u jarku)	oak/hrast	19	
U2	Bridge / Pristupni most	oak/hrast	20	
U3 A	Posts / Kosnici	oak/hrast	94	1254
U3 B	Posts / Kosnici	oak/hrast	81	1242
U4 A	Posts / Kosnici	oak/hrast	87	1223
U4 B	Posts / Kosnici	oak/hrast	91	1243
U4 C	Posts / Kosnici	oak/hrast	87	



Slika 1 - Uzorci drva iz 2005. (a,b) i 2007. godine (c) pripremljeni za dendrokronološku analizu
Figure 1. The samples of wood from 2005 (a,b) and 2007 (c) prepared for dendrochronological analysis.

dan uzorak nije sadržavao bjeljiku (svjetlije drvo ispod kore). Uzorci su prikazani na Slici 1. Mjerena je širina godova na svim uzorcima, ali samo oni koji su sadržavali više od 45 godina bili su uzeti u obzir jer samo oni imaju dovoljno godina za potencijalno datiranje.

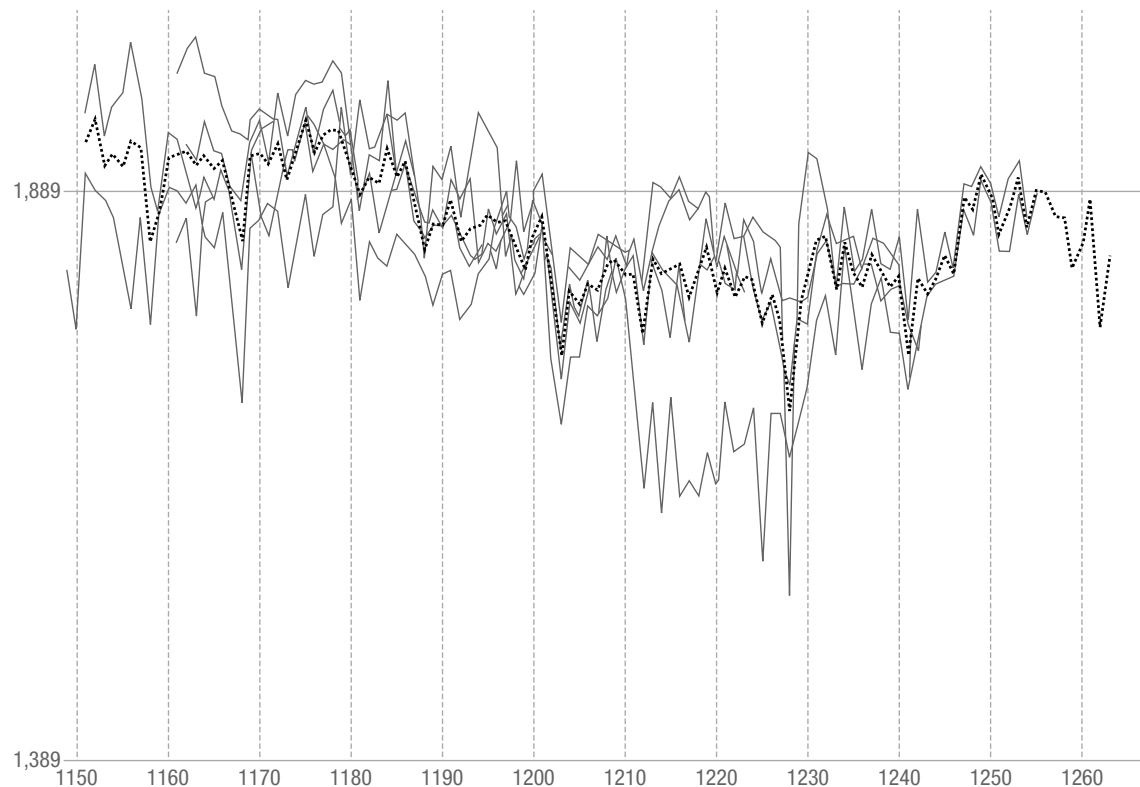
Serijs godova pet individualnih uzoraka bile su sinkronizirane među sobom (T.2) te ujedinjene u plivajuću kronologiju nalazišta. Ta je kronologija sinkronizirana s različitim referentnim kronologijama dendrokronološkog laboratorija u Ljubljani.

U prvom koraku dobivenu kronologiju nije bilo moguće usporediti s reprezentativnom 550 godina dugom referentnom kronologijom hrasta za Sloveniju. To je sugeriralo da su uzorci stariji od 550 godina, kao što je pokazalo ranije radiokarbonsko datiranje. U sljedećem koraku glavna krivulja Torčeca uspoređena je s dužom - istočno-austrijskom kronologijom hrasta (Wimmer et al. 1998, Geihofer et al. 2005). Datiranje je bilo potvrđeno u 1263. godinu. Datiranje je potvrđeno istočno-austrijskom kronologijom (Eichenchronologie Ostö-

the last ring below the bark. Furthermore none of the samples contained sapwood. The samples are presented in Figure 1. Tree-ring widths were measured in all samples, but only those containing more than 45 rings were considered to have enough rings for dating.

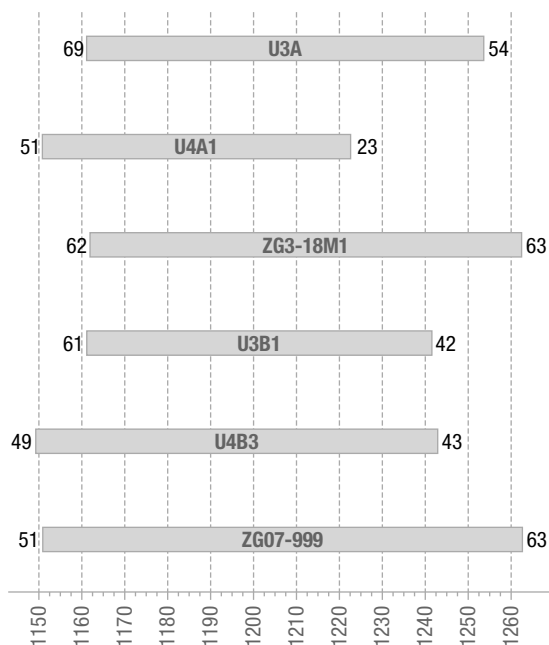
The tree-ring series of five individual samples were cross-dated (Pl. 2) and assembled in a floating chronology for the site. First we attempted to cross-date this floating chronology with various reference chronologies of the laboratory in Ljubljana.

We found that the floating chronology did not match the most representative 550 years long regional oak chronology for SE Slovenia, which suggested that the samples were older, as had also been indicated by the earlier radiocarbon dates. The next step was the comparison of the floating chronology of Torčec with the longer eastern Austria oak chronologies (Wimmer et al. 1998, Geihofer et al. 2005). The dating to the year 1263 AD was obtained by cross-dating with the oak chronology of eastern Austria (Eichenchronologie Ostösterrei-



Slika 2a - Grafikon individualnih serija godova (sivo) i krivulja poprečja (crno)

Figure 2a - The graphs of individual tree ring series (gray) and the mean curve (black)



Slika 2b - Raspon datuma godova proteže se od 1151. do 1260. godine.

Figure 2b - The time spans of individual tree-ring series and the mean curve (ZG07-999), spanning the period of 1151-1260.

sterreich) za hrast (OVL=92, GLK=72%, t_{BP} =4.7).

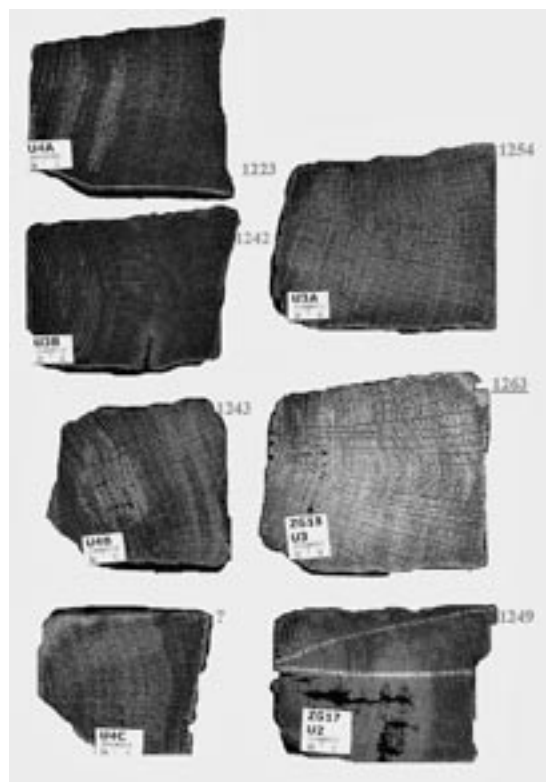
Statistički parametri označavaju: OVL- (Overlapping) preklapanje referenci i datiranje krivulje po godinama; GLK- (Gleichläufigkeit) koeficijent preklapanja; i t_{BP} - (t-value, Baillie and Pilcher), t-varijable prema Baillie i Pilcher, koje su statistički znakovite. Datiranje je statistički važno kada je $GLK \geq 70\%$ i $t_{BP} \geq 4$ i kada je moguće istodobno vizualno usporediti kronologiju datiranog objekta s odgovarajućom referentnom kronologijom (Levanič 1996).

Uzorci na slici 3 prema svojim karakteristikama (oblik, širina godova) pripadaju istoj fazi gradnje. Pet od sedam krivulja preklapaju se između sebe i datirana su (Slika 2). Zadnja godina (Date End) predstavlja datum, odnosno kalendarsku godinu nastanka najmlađega goda.

ch) with statistical parameters of OVL=92, GLK=72%, t_{BP} =4.7.

These statistical parameters are regularly used in dendrochronology. OVL represents the overlapping of tree-ring chronologies in years. GLK (German Gleichläufigkeit) is a coefficient of agreement, and t_{BP} is the t-value of Baillie and Pilcher. The dating is statistically confirmed when the parameters match the conditions: $GLK \geq 70\%$ and $t_{BP} \geq 4$ and when the patterns of two tree-ring curves are visually similar (e.g. Levanič 1996).

The samples on figure 3 belong to the same phase of construction according to their characteristics (form, width of tree-rings). Five of seven tree-ring series mutually overlap and are dated (Slika 2). The last year (Date End) represents the date, i.e. the calendar year of the creation of the youngest tree-ring.



Slika 3 - Uzorci po svoj prilici pripadaju istoj fazi gradnje, a datirani su posljednjim (periferijskim) godom.

Figure 3 - The samples probably belonging to the same phase of construction, dated by the last (peripheral) tree-ring.

INTERPRETACIJA REZULTATA

Dobivenim rezultatima utvrđeno je da svi datirani uzorci pripadaju istoj fazi gradnje. Razlike u krajnjim datumima pripisuju se različitom broju perifernih godova koji su bili odstranjeni tijekom obrade drva (ili su bili uništeni tijekom vremena). Kalendarska godina AD 1263 najbliža je godina sječe stabla i gradnje drvene konstrukcije.

Uzorak datiran u 1263. godinu ne sadrži koru drva, posljednji god koji pripada kori kao niti bjeljiku, stoga se datum 1263. mora smatrati kao *terminus post quem* (c.f. Kaennel and Schweingruber 1995). Procjenjuje se da se barem (oko) 30 godina mora dodati kako bi se dobio datum sječe drva i izrade konstrukcije.

ZAKLJUČNA RAZMATRANJA

Prvi rezultati analiza provedenih 2005./06. godine prošireni su. Zaključci su:

- drvo iz Torčeca, naročito oskudni broj uzoraka s dovoljnim brojem godova pokazali su da imaju dendrokronološki potencijal
- potvrđeno je da istraživanje većeg broja uzoraka povećava vjerojatnost datiranja
- drvo je datirano s referentnim austrijskim kronologijama za hrast iz Panonske nizine; to potvrđuje pretpostavku da se dendrokronološke krivulje drva iz Hrvatske mogu datirati s kronologijama susjednih zemalja
- datirani uzorci drva relativno su mali (poprečni presjek otprilike 8x5 cm), ali su sadržavali relativno mnogo godova (81-102) koji su presudni za uspješno datiranje
- važnost ovakvih datiranja je iznimna jer omogućuju preciznije tumačenje pojedinih slojeva, u ovom slučaju faze gradnje i podizanja fortifikacijskog sklopa.

INTERPRETATION OF THE RESULTS

The results have confirmed that all of the dated samples belonged to the same phase of construction. The differences in end dates are attributed to the different number of peripheral tree-rings that had been removed during preparation of the wood (or had been destroyed in the course of time). The calendar year AD 1263 is the closest to the year of tree felling and building of the wooden structure.

Since the sample dated to 1263 does not contain bark, the last ring below the bark, or sapwood, the date 1263 must be considered as the *terminus post quem* (c.f. Kaennel and Schweingruber 1995; Čufar and Štamcar 2004). We estimate that at least 30 years should be added to obtain the actual date of tree felling and construction.

CONCLUDING REMARKS

The preliminary results of the analysis conducted in 2005/2006 (Čufar et al. 2006) can now be extended, as follows:

- The wood from Torčec, and particularly the scarce number of samples with a sufficient amount of tree-rings, proved to have dendrochronological potential;
- It was confirmed that the investigation of a larger number of samples increased the probabilities of dating;
- The wood was dated using reference Austrian chronology for oak from the Pannonian plain; this confirms the hypothesis that wood from Croatia can be cross-dated with the chronologies of neighbouring countries;
- The dated samples were relatively small (approx. 8 x 5cm in cross-section) but they contained a relatively large number of tree rings (81-102), which was decisive for successful dating;
- Such dating is of exceptional significance as it enables a more precise interpretation of individual phases, in this case the construction of the fortification complex.

Naime, arheološkim je istraživanjima prepoznato šest faza lokaliteta Torčec - Gradić, od kojih je početak gradnje drveno-zemljane utvrde označen Fazom IIIa,b. Raniji slojevi predstavljaju geološku fazu nalazišta (F I), odnosno sporadične prapovijesne slojeve (F II), a kasniji slojevi ukazuju na kontinuitet nalazišta do kraja kasnoga srednjega vijeka (F IV-VI) (Sekelj Ivančan, Tkalčec 2004).

Svi uzorci drva koji su dali rezultate dendrokronološke analize¹ pripadaju drvenom učvršćenju relativno niskoga središnjeg uzvišenja. Naime, koso uz padinu uzvišenja postavljen je niz kvadratično obrađenih drvenih kosnika koji su svojim šiljastim dijelom bili u pravilnim razmacima ubodeni pod kutom od oko 45° duboko u zemlju. Pri gradnji je na te kosnike bila nanesena veća količina drva i namjerno zapaljena. Nakon toga se zasipavala zemlja kako bi se na vatri čvrsto zapekla. Tako je postignuto učvršćivanje ruba, odnosno padine središnjeg uzvišenja radi sprečavanja njegova urušavanja u jarak s vodom koji ga je okruživao.

Pri objavi rezultata arheoloških istraživanja Faza III torčanske utvrde okvirno je datirana u široko razdoblje od druge polovine 12. do oko sredine 13. stoljeća. Datiranje je provedeno na osnovi C14 analiza triju uzorka iz iste faze gradnje, i to uzorka ugljena iz sloja paljevine na središnjem uzvišenju koji je rezultirao sta-

Archaeological investigations have revealed six phases at the site of Torčec - Gradić. The start of constructing the wooden-earthen fortifications is classified to Phase IIIa and b. Earlier phases consist of the phase of geological formation of the site (Phase I), and sporadic prehistoric layers (II), while later layers (IV-VI) indicate the continuity of the site to the end of the late Middle Ages (Sekelj Ivančan, Tkalčec 2004).

All the wood samples with positive results in the dendrochronological analysis¹ belong to the wooden reinforcement of the relatively low-lying central elevation. A row of squarely worked wooden posts or timbers was placed at regular intervals at a slant to the slope of this elevation, with their pointed ends driven deeply into the ground at a circa 45° angle. During construction, a large quantity of wood was placed on these posts and deliberately burnt. After this soil was added so that it would fire hard. In this manner the edge of the central elevation was reinforced to prevent it from collapsing into the ditch filled with water that surrounded it.

In the publication of the results of the archaeological excavations, Phase III of the Torčec earthworks was approximately dated to a broad chronological span from the second half of the 12th century to around the middle of the 13th century. The dating was carried out on the basis of the C14 analysis of three samples from the same phase of construction. The first was a

¹ Uzorak drva upornjaka mosta preko potoka Gliboki (U1), zatim dva uzorka drva ograde u jarku gradišta (U1A, U1B), kao i uzorak pristupnog mosta gradištu (U2) nisu imali dendrokronološki potencijal. Prema zaključcima rezultata arheoloških iskopavanja za ogradu u jarku se pretpostavlja da je istovremena s kosnicima (Faza III), dok je jedan od hrastovih upornjaka pristupnog mosta poslan na C14 analizu koja je pokazala starost 565± 65 godina, odnosno raspon kalibrirane vrijednosti AD 1300-1370 sa 39% vjerojatnosti i AD 1380-1430 sa 29,2% vjerojatnosti (Faza IV) (Sekelj Ivančan, Tkalčec 2004, 74-79). Uzorak iz današnjeg potoka Gliboki vjerojatno potječe iz još mlađeg vremena.

¹ The wood sample from the support of a bridge across the Gliboki Stream (U1), as well as two samples of wood from a fence in the ditch of the fortification (U1A, U1B), and a sample from the access bridge to the fortress (U2) did not have dendrochronological potential. According to the conclusions resulting from the archaeological excavations, the fence in the ditch is hypothesized to be contemporaneous with the posts (Phase III), while one of the oaken supports for the access bridge sent for C14 analysis exhibited an age of 565 ± 65 years, meaning a span of calibrated values of AD 1300-1370 with 39% probability and AD 1380-1430 with 29.2% probability (Phase IV) (Sekelj Ivančan, Tkalčec 2004, 74-79). The sample from the present day Gliboki Stream probably comes from an even later period.

ročću od 830 ± 65 g.,² a kalibrirane vrijednosti dale su raspon starosti AD 1150-1280 sa 68,2% vjerojatnosti, zatim uzorka drvenog šiljastog kosnika koji je rezultirao starošću od 950 ± 65 g., odnosno kalibriranom vrijednosti AD 1020-1160 sa 68% vjerojatnosti. Treći uzorak potječe s dna unutarnjeg bedema koji je dao starost 840 ± 90 , odnosno raspon kalibrirane vrijednosti AD 1150-1280 sa 51% vjerojatnosti (Sekelj Ivančan, Tkalčec 2004, 75-77).

Kako su nedostajali pokretni arheološki nalazi koji bi preciznije datirali ovu fazu gradišta, priklonili smo se širokom datiranju, a u sklopu poznatih povijesnih zbivanja obilježenih, najkasnije, provalom Tatara u ovaj prostor.

Nakon provedene dendrokronološke analize može se s većom sigurnošću govoriti o užem vremenu u kojem je sagrađena utvrda. S obzirom na to da na svim sagledanim uzorcima nedostaje kora, posljednji god ispod kore, a nemaju niti bjeljiku, koji su vjerojatno odstranjeni prigodom obrade drva te se na dobivene datume treba dodati barem 30 godina kako bi se dobio datum sječe stabla, a onda daka i izgradnje, ranije široko datiranje moguće je suziti. Naime, doda li se uzorku s najstarijim datumom tridesetak godina (U4A-1223+30), dobiva se vrijeme gradnje neposredno nakon tatarskog prodora u ove krajeve. Uzme li se u obzir da su svi kosnici morali biti istodobno pobodeni uokolo padine središnjeg uzvišenja, indikativan je najmlađi uzorak datiran godinom 1263. koju treba smatrati godinom *terminus post quem*. Rezultati ostalih analiziranih uzoraka uklapaju se u to vrijeme, a i ranije provedena analiza C14 s krajnjim datumima dvaju uzorka do 80-ih godina 13. stoljeća ide tome u prilog.

charcoal sample from the burnt layer on the central elevation, which resulted in an age of 830 ± 65 ,² while the calibrated values gave an age span of AD 1150-1280 with a 68.2% probability, followed by a sample from a wooden pointed post, which resulted in an age of 950 ± 65 , recalibrated to AD 1020-1160 with a 68% probability. The third sample came from the base of the interior rampart, which resulted in an age of 840 ± 90 , recalibrated to AD 1150-1280 with a 51% probability (Sekelj Ivančan, Tkalčec 2004, 75-77).

As archaeological small finds were lacking that would more precisely date this phase of the fortified site, we were inclined to a broader dating in the framework of known historical events ending at the latest with the penetration of the Tartars into this area.

As a result of the dendrochronological analysis, it is possible to speak with greater certainty of a narrower period in which the fortification was built. As all of the examined specimens are missing the bark, the last tree-ring below the bark, and are also lacking sapwood, which were probably removed during the working of the wood, at least another 30 years should be added to the dates from the analysis to acquire the date of the tree felling and the subsequent construction, the earlier broad dating can now be narrowed. If, for instance, thirty years are added to the sample with the earliest date (U4A-1223+30), this gives a period of construction immediately after the Tartar incursion into this region. If it is taken into consideration that all posts must have been driven in along the slope of the central elevation at the same time, the latest specimen is indicative, dated to the year 1263, which should be considered the *terminus post quem*. The results for the other analyzed samples agree with such a date, and the earlier C14 analysis with maximum dates for two samples to the 1280s also supports this.

² Apsolutna starost u godinama računata je od 1950. g. C14 analize svih uzoraka drveta obavljene su u Institutu »Ruder Bošković«, Zavod za eksperimentalnu fiziku, Laboratorij za mjerenje niskih aktivnosti.

² The absolute age in years is calculated from 1950. The C14 analyses of all wood samples were carried out at the Ruder Bošković Institute, Department of Experimental Physics, Low Activity Measurement.

Što je moglo potaknuti gradnju ove drveno-zemljane utvrde oko sredine, odnosno u drugoj polovici 13. stoljeća? S jedne strane, sjećanje na nedaće koje su stanovništvo zatekle dolaskom Tatara, a s druge strane, mogao je to biti rezultat raslojavanja stanovništva i prisutnosti određenog društvenog sloja u tome kraju. Taj je sloj imao potrebu i gradnjom ovakvih utvrda označiti svoj položaj, različit od ostalog stanovništva. O sigurnoj prisutnosti pripadnika izdignutog sloja svjedoči luksuzan nalaz ostruge s kotačićem s utvrde datirane u razdoblje od druge polovine 13. do sredine 14. stoljeća (Sekelj Ivančan, Tkalčec 2004, 84, T. 5,9), kao i nalaz tipološki bliske ostruge iste vremenske pripadnosti pronađene na obližnjem groblju na Cirkvišću (Sekelj Ivančan, Tkalčec 2003, 19-20, 22-23, slika 34).

Na kraju treba istaknuti da se prožimanjem različitih struka, naročito humanističkih i prirodnih dolazi do sve boljih rezultata koji omogućavaju bolje tumačenje života na nekom prostoru tijekom povijesti. Dendrokronolozi iz Slovenije i Austrije koji sudjeluju u tim analizama iskazuju veliko zadovoljstvo što je sa slovenskim i austrijskim referentnim kronologijama moguće datirati drvo iz Hrvatske, što otvara nove mogućnosti za interdisciplinarnu i internacionalnu suradnju u budućnosti.

Budućnost je svakako u interdisciplinarnim sagledavanjima svih rezultata, što je pokazao i ovaj rad koji je omogućio sužavanje ranije šire datiranog vremena gradnje torčanske utvrde.

What could have inspired the construction of this wooden and earthen fortress around the middle or in the second half of the 13th century? On the one hand, it could have been because of memories of the misfortunes that the population had to go through with the arrival of the Tartars, while on the other hand, it could also have resulted from the stratification of the inhabitants and the presence of a given social stratum in the area. Such a social class would have needed to demark their position as different from the other inhabitants through the construction of such a fortification. The certain presence of members of an elevated class is attested by a luxurious find from the fortress of a spur with a rowel dated to the chronological period from the second half of the 13th to the middle of the 14th centuries (Sekelj Ivančan, Tkalčec 2004, 84, Pl. 5,9), as well as the find of a typologically close spur of the same date found at the nearby cemetery at Cirkvišće (Sekelj Ivančan, Tkalčec 2003, 19-20, 22-23, fig. 34).

In conclusion it should be emphasized that with the intermingling of various fields of study, particularly the humanities and the natural sciences, increasingly better results are acquired, further enabling more accurate interpretations of existence in a given area throughout history. For dendrochronologists from Slovenia and Austria it is very important to know that it is possible to date wood from Croatia by utilizing Slovenian and Austrian reference chronologies, which will create new opportunities for future interdisciplinary and international cooperation.

The future certainly lies in the interdisciplinary study of all results, as has been shown in this work, which has enabled the earlier more broadly dated period for the construction of the fortification at Torčec to be narrowed considerably.

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