Človekov vpliv na rastlinstvo zahodnega Ljubljanskega barja v pozni prazgodovini (pribl. 1000–50 pr. n. št.). Primer: Vrhnika (Dolge njive)

Human impact on the vegetation of the western Ljubljansko barje in late prehistory (ca. 1000–50 cal. BC). Case study: Vrhnika (Dolge njive)

Maja ANDRIČ

Izvleček

V članku sta predstavljena razvoj vegetacije in človekov vpliv na okolje na območju današnjega mesta Vrhnika (rimski Navport) v pozni prazgodovini (1. tisočletje pr. n. št.). Raziskava temelji na rezultatih pelodne analize aluvialnega sedimenta, ki se je odlagal na desnem bregu Ljubljanice (lokacija Dolge njive) pred drugo polovico prvega stoletja pr. n. št., ko je bila postavljena rimska naselbina Dolge njive. Pelodni zapis kaže, da je bila pokrajina okrog najdišča v prvem tisočletju pr. n. št. močvirna, medtem ko je mešani gozd (bukev, hrast, jelka in navadni gaber) poraščal bližnja bolj suha območja. Pokrajina je bila le deloma pogozdena; vidni so močni sledovi kultivacije žit in paše, kar lahko povežemo z gospodarskimi aktivnostmi prebivalcev prazgodovinskih (halštatskih in latenskih) naselbin v bližini. Izsekavanje gozda je še pred nastankom rimske naselbine na Dolgih njivah verjetno postalo intenzivnejše. Zaradi suhih hidroloških razmer v arheoloških kulturnih plasteh rekonstrukcija razvoja vegetacije v času rimske naselbine ni bila mogoča.
Ključne besede: Slovenija, Vrhnika, Dolge njive, 1. tisočletje pr. n. št., pelodna analiza, *Juglans*, paleoekologija

Abstract

This article investigates the vegetation composition and human impact on the environment in the vicinity of the modern town of Vrhnika (Roman Nauportus) in late prehistory (ca. 1000–50 cal. BC). The research is based on pollen analysis of alluvial sediment, which was deposited on the right bank of the Ljubljanica River before the construction of the Dolge njive Roman settlement in the second half of the 1st century BC. The pollen record suggests that in the 1st millennium cal. BC the landscape around the study site was marshy, and that mixed woodland (beech, oak, fir and hornbeam) was growing on drier land. The landscape was partly open, with strong traces of cereal cultivation and grazing, which can be associated with the economic activities of prehistoric, Early and Late Iron Age populations living in the area. The forest clearance presumably intensified before the establishment of the Roman settlement at Dolge njive. Due to dry hydrological conditions in the archaeological cultural layers, it is not possible to reconstruct the vegetation composition at the time of the Roman settlement.
Keywords: Slovenia, Vrhnika, Dolge njive, 1st millennium cal. BC, pollen analysis, *Juglans*, palaeoecology

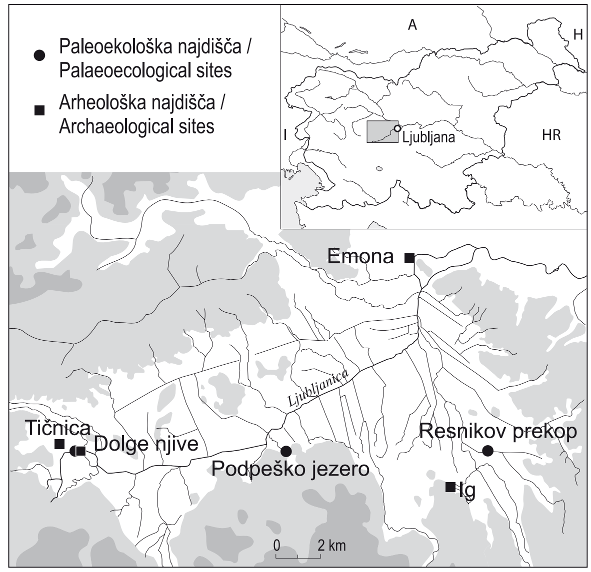
1. UVOD

Navport, prazgodovinska in rimska naselbina na obrežju Ljubljanice na Vrhniki, je bila strateško zelo pomembna postojanka. V drugem stoletju pr. n. št. je bil Navport še trgovska postojanka keltskih Tavriskov, v prvem stoletju pr. n. št. pa so ga že nadzorovali Rimljani (Šašel Kos 1990), ki so na desnem bregu Ljubljanice, na Dolgih njivah, zgradili utrjeno postojanko z velikimi skladišči. Na Dolgih njivah so tovor (trgovsko blago in material za oskrbovanje vojske), ki je prihajal iz Italije, nalagali na ladje in prevažali proti vzhodu (Horvat 1990; Horvat 2009a in Horvat et al. 2016). Čeprav je bila postojanka na Dolgih njivah opuščena že v 1. stoletju n. št., je naselje Navport na levem bregu Ljubljanice vztrajalo vse do začetka 5. stoletja n. št. (Horvat et al. 2016).

Palinološki podatki o razvoju vegetacije v pozni prazgodovini (po letu 2500 pr. n. št.) in rimskem obdobju so na območju Ljubljanskega barja zelo skopi. Rezanje in požiganje šote v 18. in 19. stoletju n. št. (izsuševanje barja za potrebe poljedelstva) je skoraj popolnoma uničilo pelodni zapis v osrednjem delu Ljubljanskega barja, medtem ko so na obrobju bazena (npr. pri Vrhniki) hidrološke razmere pogosto presuhe in onemogočajo ohranitev peloda. Palinološki zapis je zato pogosto fragmentiran ali pa podvržen kompleksnim tafonomskim (aluvialnim) procesom, kar ovira izvajanje paleoekoloških raziskav z visoko ločljivostjo vzorčenja.

Do zdaj sta bili palinološko raziskani le dve paleoekološki najdišči, Podpeško jezero in Resnikov prekop (*sl. 1*), kjer je ohranjen zapis razvoja vegetacije v rimskem obdobju. Najboljše informacije nam daje pelodni diagram s Podpeškega jezera (Gardner 1997; Gardner 1999), kjer lahko šibkejši človekov vpliv (manjše izsekavanje in spremembe v sestavi gozda) zaznamo že okrog leta 4000 pr. n. št., medtem ko se pritisk človeka na okolje okrepi šele v obdobju po letu 1000 pr. n. št. Zelo obsežno izsekavanje gozda na večjih površinah (upad peloda dreves in grmov na pribl. 50 odstotkov in porast peloda zeli) se pojavi šele po letu 300 pr. n. št., ko nastane današnji podobna pokrajina. Tudi na pelodnem diagramu z Resnikovega prekopa (Andrič 2006) lahko vidimo podoben razvoj vegetacije vsaj od leta 200 pr. n. št. dalje.

Rezultati dosedanjih palinoloških raziskav torej kažejo, da se je večja sprememba v sestavi vegetacije na Ljubljanskem barju (intenzivno izsekavanje gozda in nastanek današnji podobne pokrajine) zgodila v drugi polovici prvega tisočletja pr. n. št.



Sl. 1: Ljubljansko barje z označeno lego najdišča Dolge njive na Vrhniki ter arheoloških in paleoekoloških najdišč, ki se omenjajo v besedilu.
Fig. 1: Ljubljansko barje with the position of Dolge njive (Vrhnika) site and archaeological and palaeoecological sites mentioned in the text.

Tak razvoj vegetacije odpira številna vprašanja v zvezi z nekdanjim okoljem, sestavo rastlinstva in gospodarstvom pred zgodnjo rimsko dobo in v času te. Na osnovi dosedanjih raziskav ni jasno, ali so prvi rimski trgovci in vojaki prišli v pokrajino z zelo intenzivno kmetijsko dejavnostjo, kjer so bile velike površine gozda že izsekane, ali pa so šele oni bistveno spremenili sestavo vegetacije z uvedbo novih metod kultivacije in drugih oblik izrabe okolja, ki so povzročile nastanek današnji zelo podobne pokrajine. Glede na naravne značilnosti raziskovanega območja (pomanjkanje najdišč, primernih za pelodno analizo) in trenutno stanje raziskanosti so številna od postavljenih raziskovalnih vprašanj preveč ambiciozna, da bi nanje lahko odgovorili v tem članku, ne glede na to pa nam bodo rezultati raziskav peloda v stratigrafskem stolpcu z Dolgih njiv (Vrhnika), ki jih predstavljamo v nadaljevanju, pomagali osvetliti razvoj vegetacije in gospodarstva v obdobju pred ustanovitvijo rimske postojanke na Dolgih njivah. Zaradi suhih, za ohranitev peloda neugodnih razmer v arheoloških kulturnih plasteh rekonstrukcija razvoja vegetacije v času rimske naselbine na Dolgih njivah ni bila mogoča. To je v nasprotju z rezultati arheoloških in arheozooloških raziskav arheoloških kulturnih plasti na Dolgih njivah, ki nam ponujajo veliko informacij o nekdanji rimski naselbini in njenem gospodarstvu (Horvat et

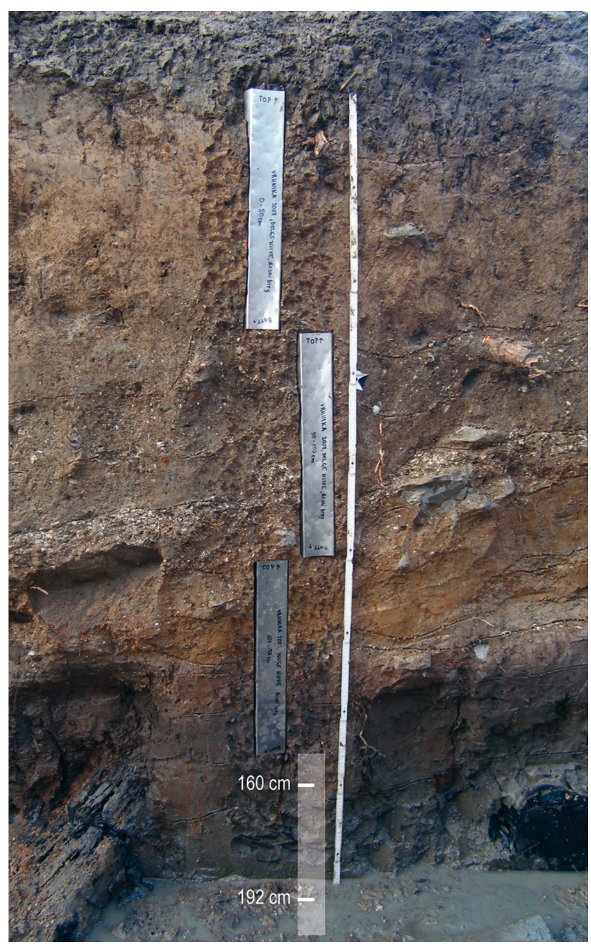
Sl. 2: Vrhnika, Dolge njive. Severni profil izkopa 1 (profil C–D).
Fig. 2: Vrhnika, Dolge njive. Northern profile of the archaeological Sector 1 (Cross section C–D).

al. 2016). Zaradi teh razlik so palinološki rezultati, ki obravnavajo le razvoj rastlinstva v predrimskem obdobju (1. tisočletje pr. n. št.), predstavljeni posebej.

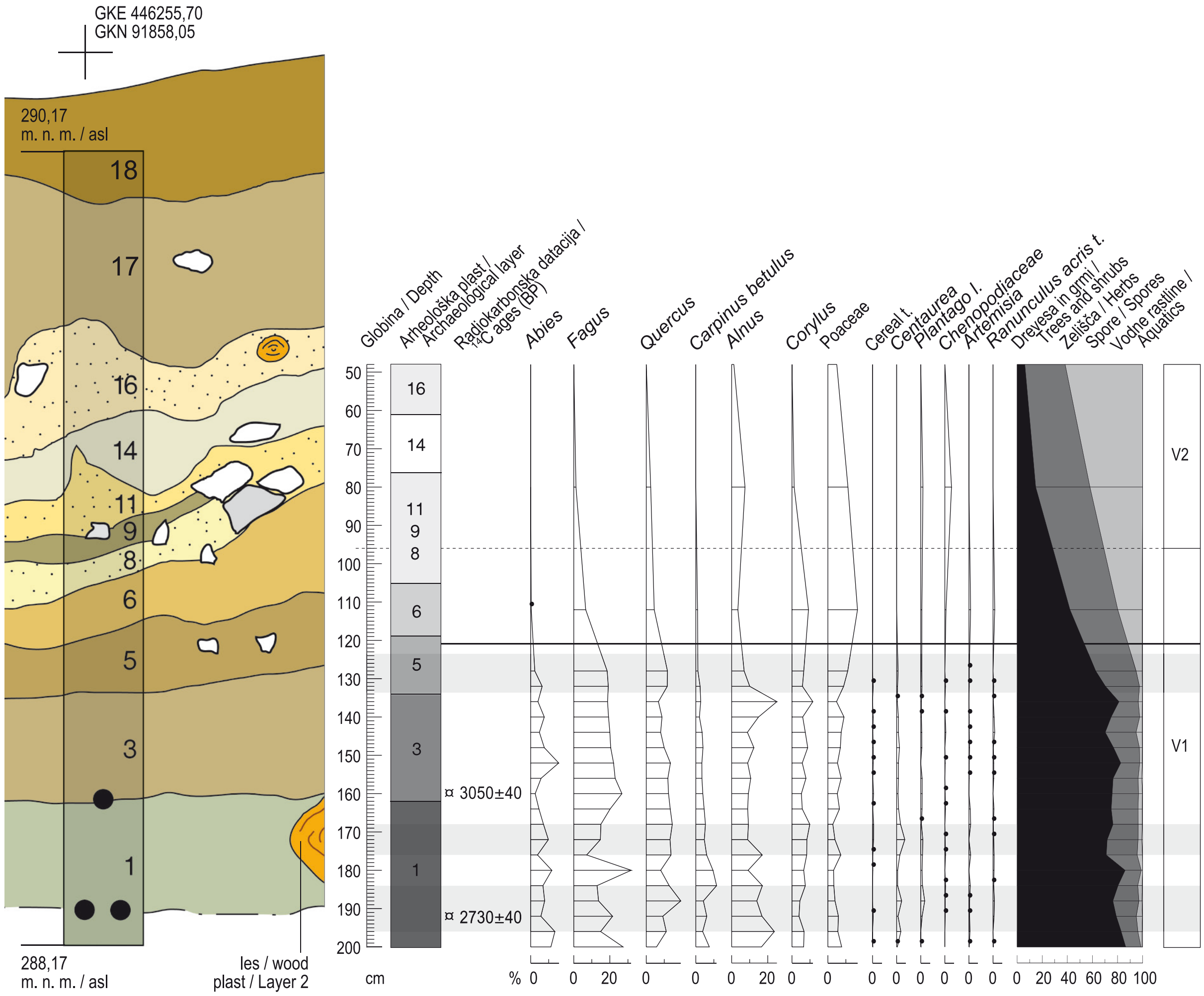
2. METODE

Vzorci za palinološke raziskave so bili odvzeti leta 2007 iz severnega profila arheološke sonde (146 m^2) na desnem bregu Ljubljanice, med Ljubljanico in jugozahodnim vogalom naselbine na Dolgih njivah (Horvat et al. 2016, sl. 4, izkop 1, profil C–D). Metodologija arheoloških izkopavanj in rezultati arheološke, arheobotanične in arheozoološke raziskave so predstavljeni v članku Jane Horvat in sodelavcev (Horvat, Peterle Udovič, Tolar, Toškan 2016) v tej številki Arheološkega vestnika, za lego palinološkega stratigrafskega stolpca glej ib., sl. 6a.

Da bi se izognili vzorčenju najbolj meljastega in premešanega sedimenta v neposredni bližini reke, smo vzorce za pelodno analizo odvzeli pribl. 10 m od desnega brega Ljubljanice (*sl. 2*), kar je bilo še



Sl. 3: Vrhnika, Dolge njive. Palinološki stratigrafski stolpec, vzorčen na severnem profilu izkopa 1 (profil C–D).
Fig. 3*:* Vrhnika, Dolge njive. Palynological stratigraphic column, collected from the northern cross section of archaeological Sector 1 (Cross section C–D).



Sl. 4: Vrhnika, Dolge njive. Del severnega profila izkopa 1 (profil C–D), palinološki stratigrafski stolpec, arheološke plasti (glej Horvat et al. 2016, sl. 6) in radiokarbonske datacije (●), v primerjavi s kratkim pelodnim diagramom. Siv raster označuje obdobja močnejšega človekovega vpliva na okolje.

Fig. 4: Vrhnika, Dolge njive. Part of northern sedimentary profile (Cross section C–D) of Sector 1 with palynological stratigraphic column, archaeological layers (see Horvat et al. 2016, Fig. 6) and radiocarbon dates (●), in comparison with summary pollen diagram. Grey shaded areas mark periods of more intensive human activities.

vedno dovolj blizu reke, da je bil sediment zaradi prekritosti z vodo primeren za pelodno analizo. Palinološki stratigrafski stolpec, dolg 200 cm, je bil pobran iz severnega profila s pomočjo 50 cm dolgih kovinskih škatel (*sl. 3; sl. 4*), vzorčenje smo začeli pribl. 20 cm pod površino (288,17–290,17 m n. m.). Vzorci so bili zaviti v prozorno in aluminijasto folijo in debel polivinil ter shranjeni v hladilnici pri temperaturi 4 °C. Opis sedimenta je bil izveden po Troels-Smithu (1955).

Starost je bila določena s pomočjo AMS-radiokarbonskega datiranja organskega ogljika in rastlinskih makrofosilov, ki so bili izločeni iz dveh vzorcev sedimenta na globinah 160 in 192 cm (*tab. 1; sl. 4*). Radiokarbonske datacije so bile kalibrirane z računalniškim programom CALIB Rev 7.0 (spletna stran CALIB 7.0; Stuvier in Reimer 1993) in IntCal 13 kalibracijskim nizom (Reimer et al. 2013).

Pri pripravi palinoloških vzorcev smo uporabili standardni laboratorijski postopek (7 % HCl, 10 % NaOH, 40 % HF, acetoliza, barvanje s safraninom, silikonsko olje; Bennett, Willis 2002). Vzorčili smo po 1 cm^3 sedimenta, na segmentu stratigrafskega

Tab. 1: Vrhnika, Dolge njive. Rezultati radiokarbonskega datiranja palinološkega stratigrafskega stolpca. Konvencionalna starost je bila kalibrirana s programom CALIB Rev 7.0 (spletna stran CALIB 7.0; Stuvier in Reimer 1993) in IntCal 13 kalibracijsko podatkovno bazo (Reimer et al. 2013).
Tab. 1: Vrhnika, Dolge njive. Radiocarbon dating. Conventional ages were calibrated using CALIB Rev 7.0. (CALIB 7.0 Website; Stuvier and Reimer 1993) on IntCal 13 calibration dataset (Reimer et al. 2013).

Št. vzorca / Sample no.	**Globina / Depth** (m n. m.) (m a.s.l.)	**Datirani material in laboratorijski postopek / Material dated and pretreatment**	**Standardne radiokarbonske datacije / Conventional radiocarbon date**	**Razmerje / Ratio 13C/12C** ‰	**2 sigma kalibrirani rezultati / 2 sigma calibrated results**	**Mediana / Median**
Beta-259684	160 cm (288,57)	organski sediment / organic sediment (acid washes)	3050 ± 40 BP	-30,1	3366–3085 cal. BP 1416–1135 cal. BC	3260 cal. BP 1320 cal. BC
Beta-241775	192 cm (288,25)	organski sediment / organic sediment (acid washes)	2730 ± 40 BP	-27,7	2923–2756 cal. BP 973–806 cal. BC	2824 cal. BP 874 cal. BC
Beta-242460	192 cm (288,25)	neidentificirani rastlinski makrofosili / unidentified plant macrofossils (acid/alkali/acid)	2300 ± 40 BP	-28,2	2363–2156 cal. BP 413–206 cal. BC	2323 cal. BP 373 cal. BC

stolpca med 128 in 200 cm globine je bila gostota vzorčenja 4 cm. Za določanje pelodne koncentracije so bile vzorcem dodane tablete spor *Lycopodium* (Stockmarr 1971). Pri identifikaciji peloda smo uporabljali svetlobni mikroskop Nikon Eclipse E400 pri 400-kratni povečavi, pelodno referenčno zbirko Inštituta za arheologijo ZRC SAZU in ključe za določanje peloda (Moore, Webb, Collinson 1991; Reille 1992; Reille 1995). Za analizo podatkov in izris pelodnih diagramov smo uporabili računalniški program PSIMPOLL 3.00 (Bennett 1998; spletna stran PSIMPOLL), pelodni diagram je bil razdeljen na dve coni (V1 in V2) s pomočjo razpolovitve po metodi najmanjših kvadratov. Taksoni z nizkimi vrednostmi (< 5 %) so zaradi boljše vidnosti označeni s piko.

3. REZULTATI

3.1 Stratigrafija in radiokarbonsko datiranje (*tab. 1–3*)

Temno siv sediment v spodnjem delu stratigrafskega stolpca (~ 125–200 cm, arheološke plasti 1, 3, 5), ki je ležal pod nivojem talne vode, je vseboval veliko organskih snovi, gline in koščkov lesa (*tab. 2; sl. 3; 4*). V najverjetneje naravni aluvialni plasti 1 ni bilo odkritih artefaktov. Plasti 2 in 4 (ki nista vidni v profilu in na *sl. 4*) predstavljata plasti posekanega lesa, ki sta ločevali arheološke plasti 1 in 3 oziroma 3 in 5. Arheološka plast 3 vsebuje drobce oglja in koščke lesa s sledovi obdelave. Plasti 4 (kosi lesa s sledovi obdelave) sledi plast 5 – sediment z drobci oglja in koščki lesa s sledovi obdelave (glej Horvat et al. 2016, sl. 9).

Ocena starosti sedimenta v palinološkem stratigrafskem stolpcu temelji na treh tipih podatkov (*tab. 3*):

– 1. treh radiokarbonskih datacijah vzorcev sedimenta in rastlinskih makrofosilov iz palinološkega stratigrafskega stolpca, pobranih na globinah 192 in 160 cm (arheološki plasti 1 in 3, 973–806 cal. BC, 413–206 cal. BC in 1416–1135 cal. BC), rezultati so prikazani v *tabeli 1*;

– 2. treh radiokarbonskih datacijah rastlinskih makrofosilov, ki so bili vzorčeni med arheološkimi izkopavanji, npr. hrastov (*Quercus*) les iz plasti 2 (379–204 cal. BC) ter jesenov (*Fraxinus*) les (194–45 cal. BC) in jelova (*Abies*) iglica (381–203 cal. BC) iz plasti 5 (Horvat et al. 2016, 204);

– 3. arheološki dataciji na osnovi tipologije (keramika iz plasti 5: pribl. 120–30 BC [Horvat et al. 2016, sl. 19, 204]).

Na podlagi navedenih podatkov je bila starost aluvialnih plasti 1–5 ocenjena na 1. tisočletje pr. n. št. (glej poglavje Diskusija/Stratigrafija, tafonomski procesi in kronologija).

Tab. 2: Vrhnika, Dolge njive. Opis sedimeta po Troels-Smithu (1955) in primerjava z arheološkimi plastmi (glej Horvat et al. 2016). Zaradi majhnih razlik med posameznimi plastmi in različne metodologije razdelitev plasti po Troels-Smithu ne sovpada vedno z razdelitvijo arheoloških plasti. Medtem ko gre pri opisu sedimenta po Troels-Smithu za grobo in subjektivno oceno količine gline, organskega materiala itd. v sedimentu, razmejitev arheoloških plasti upošteva tudi prisotnost/odsotnost artefaktov.
Tab. 2: Vrhnika, Dolge njive. Troels-Smith (1955) description of the sediment and comparison with archaeological layers (see Horvat et al. 2016). Troels-Smith units do not always coincide with archaeological layers due to only slight differences between layers and a different metodology used. While Troels-Smith description is based on rough and subjective estimation of the amount of clay, organic material etc. in the sediment, delimitation of archaeological layers takes into account also the presence/absence of the artefacts.

Opis palinološkega stratigrafskega stolpca po Troels-Smith-u / Troels-Smith description of palynological stratigraphic column			**Primerjava z arheološkimi plastmi / Comparison with archaeological layers** (Horvat et al. 2016)	
Globina / Depth cm	**Opis sedimenta / Sediment description**	**Barva / Colour**	**Arheološke plasti / Archaeological layers**	**Višina / Altitude** (m n. m. / m a.s.l.)
0–7	Sh2 As2	7.5 YR 3/2	18	290,17–290,10
7–33	As4	10 YR 4/4	17, 18	290,10–289,84
33–82	As3 $Gg_{(maj)}1$	10 YR 4/3	14, 16, 17	289,84–289,35
82–100	As2 $Gg_{(maj)}1$ $Gg_{(min)}1$	10 YR 4/3	8, 9, 11	289,35–289,17
100–125	As1 Ag2 $Gg_{(min)}1$	10 YR 4/3	6, 8	289,17–288,92
125–137	As2 Ag1 Sh1	10 YR 4/2	5	288,92–288,80
137–150	As1 Ag1 Sh2	10 YR 3/2	3	288,80–288,67
150–200	As2 Sh2	10 YR 3/2	1, 3	288,67–288,17

Sh = organski material; As = glina; Ag = melj; Gg = gramoz (mineralni drobci > 2 mm); 1 = 25 %; 2 = 50 %; 3 = 75 %; 4 = 100 %
Sh = organic material; As = clay; Ag = silt; Gg = gravel (mineral parts > 2 mm); 1 = 25%; 2 = 50%; 3 = 75%; 4 = 100%

Tab. 3: Vrhnika, Dolge njive. Primerjava radiokarbonskih datacij vzorcev iz palinološkega stratigrafskega stolpca (*tab. 1*) in arheološkega izkopa (Horvat et al. 2016).
Tab. 3: Vrhnika, Dolge njive. Comparison of radiocarbon dates from samples, collected from palynological column (*Tab. 1*) and archaeological area (Horvat et al. 2016).

Arheološka plast – datacija / Archaeological layer – datation	**Palynološki stolpec / Palynological column**	**Arheološka sonda – druge datacije / Archaeological trench – other dates**
5	–	**konec 2. st. – sredina 1. st. pr. n. št.** (keramika) / **end of the 2nd c. – mid 1st c. BC** (ceramics)
5 – Poz-46647, 2095±30 BP	–	**194–45 cal. BC** (les / wood)
5 – Poz-46649, 2225±35 BP	–	**381–203 cal. BC** (jelova iglica / fir needle)
3 – Beta-259684, 3050±40 BP	**1416–1135 cal. BC** (sediment)	–
2 – Poz-46646, 2225±30 BP	–	**379–204 cal. BC** (les / wood)
1 – Beta-242460, 2300±40 BP	**413–206 cal. BC** (rastl. makrofosili) (plant macrofossils)	–
1 – Beta-241775, 2730±40 BP	**973–806 cal. BC** (sediment)	–

Peščeno-meljasta plast 6, ki je vsebovala manjše koščke oglja in en kos keramike, je lahko aluvialnega nastanka, zelo verjetno pa je tudi, da gre za umeten nasip, ki so ga nasuli tik pred ustanovitvijo rimske naselbine na Dolgih njivah (Horvat et al. 2016). Sledijo tri rimskodobna nasutja v srednjem delu stratigrafskega stolpca. Gre za tri kamnite podlage tlakov (plasti 7, 10 in 15), ki jih prekrivajo trije tlaki iz peska in gramoza (plasti 8, 11 in 16, Horvat et al. 2016, sl. 6). Te tri rimske faze so bile s pomočjo tipologije keramike, najdene v podlagah za tlake in tlakih, datirane v avgustejsko obdobje (pribl. 27 pr. n. št.–14 n. št.), kar je sočasno z utrdbo na Dolgih njivah (Horvat et al. 2016). Rimskodobne kulturne plasti so prekrite z aluvialnim sedimentom (plast 17).

3.2 Pelodna analiza

Rezultati pelodne analize so prikazani na *slikah 4* (kratki pelodni diagram, ki prikazuje najpomembnejše taksone, v primerjavi z arheološko stratigrafijo) in *5* (podrobni pelodni diagram). V vsakem vzorcu (z izjemo vzorcev s slabo pelodno ohranjenostjo/koncentracijo) je bilo preštetih najmanj 500 pelodnih zrn kopenskih taksonov in spor praproti (= pelodna vsota). Odstotki peloda posameznih taksonov so bili izračunani glede na to pelodno vsoto. V stratigrafskem stolpcu na levi strani (*sl. 4*) so označene številke arheoloških plasti. Oba diagrama sta razdeljena na dve pelodni coni (V1 in V2, meja med conama je na globini 120 cm). Pelod je v spodnjem delu cone V1 (128–200 cm) zelo dobro ohranjen, pelodna koncentracija je razmeroma visoka (~ 2000–8000 pelodnih zrn na 1 cm^3 sedimenta), medtem ko je pelodna koncentracija v zgornjem delu cone V1 (nad 128 cm) nižja od 2000 pelodnih zrn na 1 cm^3 sedimenta, delež degradiranih pelodnih zrn pa naraste (> 10 %). Pelodna koncentracija v coni V2 je zelo nizka (~ 500 pelodnih zrn na 1 cm^3), odstotek degradiranih pelodnih zrn je visok (~ 7–30 %), zato ni bilo mogoče doseči statistično zanesljive pelodne vsote (≥ 300 pelodnih zrn na vzorec).

V coni V1 prevladuje pelod dreves, nad 5 % so zastopani taksoni: *Fagus* (bukev, ~ 10–30 %), *Quercus* (hrast, ~ 5–20 %), *Alnus* (jelša, ~ 10–25 %), *Abies* (jelka, ~ 5–15 %), *Carpinus betulus* (navadni gaber, ~ 5–10 %) in *Corylus* (leska, ~ 5–10 %). V spodnjem delu cone V1 (128–200 cm) se delež peloda dreves in grmov giblje med 70 in 85 %. Med pelodom zeli (15–25 %) prevladujejo Poaceae (trave, ~ 5 %), Cyperaceae (šaši, ~ 1–5 %), *Filipendula* (brestovolistni oslad, ~ 1–5 %) in t. i. "antropogeni indikatorji": pelodna zrna žita, *Plantago lanceolata* (ozkolistni trpotec), *Centaurea* (glavinec), Chenopodiaceae (metlikovke) in *Artemisia* (pelin). V zgornjem delu cone V1 in v coni V2 delež peloda zeli naraste na ~ 25–45 %, delež peloda dreves in grmov pa upade na ~ 10–40 %.

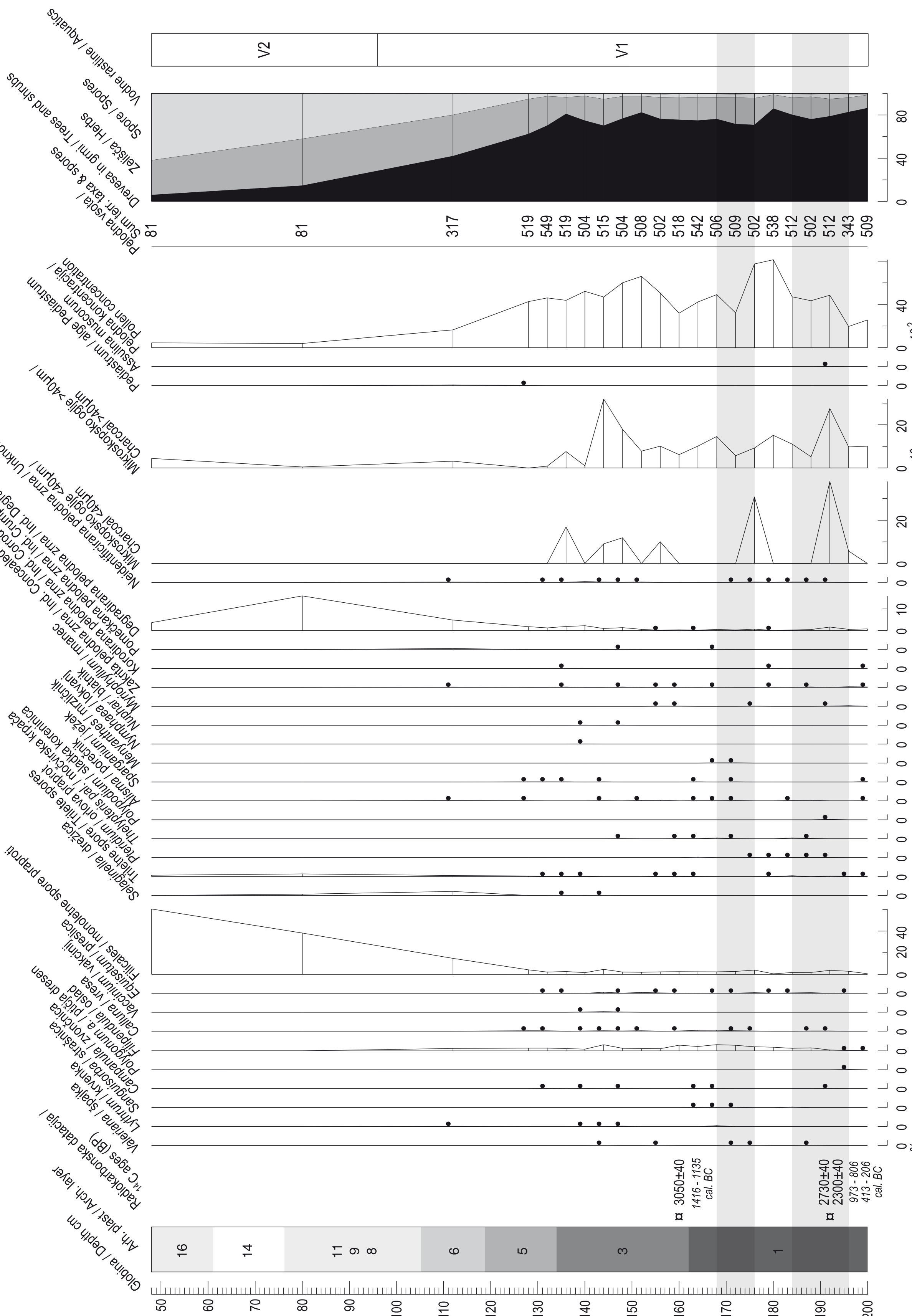
4. DISKUSIJA

4.1 Stratigrafija, tafonomski procesi in kronologija

Kronologija pelodne sekvence z Dolgih njiv temelji na radiokarbonskih datacijah dveh vzorcev (*tab.1*), ki sta bila vzorčena v spodnjem, aluvialnem delu stratigrafskega stolpca, na globini pod ~ 120 cm. V tem delu (= večina pelodne cone V1; *sl. 4:* plasti 1, 3, 5) je pelod zaradi visokega nivoja talne vode in anaerobnih razmer dobro ohranjen, zato so rezultati palinološke raziskave zanesljivi. Aluvialni sediment je bil prekrit s peščenimi plastmi (*tab. 2; sl. 4:* plasti 6–16), ki so bile umetno nasute med gradnjo rimske postojanke na Dolgih njivah v obdobju okrog leta 30 pr. n. št. (Horvat et al. 2016). Pelod v teh arheoloških plasteh je zaradi aerobnih razmer in človekovih aktivnosti zelo slabo ohranjen.

Aluvialne plasti (1, 3 in 5, 120–200 cm) so nastale pred ustanovitvijo rimske postojanke na Dolgih njivah (= pred pribl. 30 pr. n. št.), vendar pa je zaradi zapletenih tafonomskih procesov na najdišču točen čas njihovega odlaganja zelo težko določiti. Dva vzorca, aluvialni sediment in neidentificirani rastlinski material, vzorčena na globini 192 cm (plast 1), sta bila poslana na radiokarbonsko datiranje v laboratorij Beta Analytic in rezultati so prikazani v *tab. 1.* Razlika med datacijo "sedimenta" (Beta-241775; 2730 ± 40 BP) in "rastlinskih makrofosilov" (Beta-242460; 2300 ± 40 BP) je zelo velika. Dva sigma vrednosti radiokarbonskih datacij (973–806 cal. BC in 413–206 cal. BC) se ne prekrivata, razlika med medianama je 503 leta (*tab. 1*). Čeprav je običajno, da so vzorci sedimenta nekoliko starejši od rastlinskih makrofosilov (npr. za 5500 let stare vzorce s kolišča Stare gmajne ta razlika znaša največ pribl. 100 let [Andrič, neobjavljeno]), je časovna razlika datacij z Dolgih njiv prevelika in potrebuje razlago. V bližini palinološkega stratigrafskega stolpca v plasti 2 (ki

Sl. 5a: Vrhnika, Dolge njive. Odstotkovni pelodni diagram. (Siv raster = obdobja močnejšega človekovega vpliva na okolje).
Fig. 5a: Vrhnika, Dolge njive. Percentage pollen diagram. (Grey shaded areas = periods of more intensive human activities).



Sl. 5b: Vrhnika, Dolge njive. Odstotkovni pelodni diagram. (Siv raster = obdobja močnejšega človekovega vpliva na okolje).
Fig. 5b: Vrhnika, Dolge njive. Percentage pollen diagram. (Grey shaded areas = periods of more intensive human activities).

leži med plastema 1 in 3 v bližini palinološkega profila [plast 2 ni vidna v stratigrafskem stolpcu in na *sl. 3* in *4*]) so bili odkriti številni ostanki lesa. Nekateri večji kosi lesa so se tudi pogreznili v plast 1 (glej *sl. 4*, del profila). Tako dopuščamo možnost, da so tudi manjši degradirani koščki lesa (ali korenine) iz mlajše plasti 2 potonili v starejšo plast 1. Radiokarbonska datacija hrastovega (*Quercus*) debla iz plasti 2, datiranega v obdobje 384–203 cal. BC (Horvat et al. 2016, 204), se ujema z datacijo "rastlinskih makrofosilov" iz plasti 1 palinološkega stratigrafskega stolpca, kar nakazuje, da rastlinski makrofosili v plasti 1 izvirajo iz mlajše, nad njo ležeče plasti 2. Vsi ti podatki govorijo v prid starejši dataciji spodnjega dela profila, zato domnevamo, da se je pelodni zapis na dnu stratigrafskega stolpca (192 cm, plast 1) predvidoma odlagal okrog 974–807 cal. BC (Beta-241775, 2730 ± 40 BP).

Drugi problem je neskladje med radiokarbonskimi datacijami na globinah 192 cm (plast 1, Beta-241775, 2730 ± 40 BP, 2 sigma: 973–806 cal. BC) in 160 cm (plast 3, Beta-259684, 3050 ± 40 BP, 2 sigma: 1416–1135 cal. BC). Datacija na globini 160 cm je glede na stratigrafsko lego "prestara", nizka vrednost 13C/12C (–30,1) pa kaže na to, da je vzorec morda vseboval resedimentiran organski material in/ali degradiran material vodnih rastlin, katerih radiokarbonske datacije so zaradi specifičnega fotosintetskega cikla prestare (Björck, Wolfarth 2001). Na tej globini je bil najden tudi pelod nekaterih vodnih rastlin, npr. rmanca (*Myriophyllum*) (*sl. 5*). Domnevo, da je radiokarbonska datacija vzorca na globini 160 cm "prestara", podpirajo tudi radiokarbonske datacije iz nad njo ležeče plasti 5. To so: jesenov (*Fraxinus*) les [194–45 cal. BC], jelova (*Abies*) iglica [381–203 cal. BC] in keramika [datirana od konca 2. do sredine 1. stoletja pr. n. št. – Horvat et al. 2016, 204]. Datacije na globini 160 cm zato nismo upoštevali pri oceni starosti plasti, prav tako za pelodni diagram nismo izdelali časovnega modela.

Neskladje med vsemi tremi radiokarbonskimi datacijami je najverjetneje posledica kompleksnega in dinamičnega aluvialnega sedimentacijskega okolja v bližini Ljubljanice, zato je predlagana časovna opredelitev palinološke sekvence nenatančna in jo je treba obravnavati previdno. Lahko rečemo le, da pelodni diagram (*sl. 4; 5*) prikazuje razvoj vegetacije v prvem tisočletju pr. n. št., v obdobju pred nastankom naselbine na Dolgih njivah (= pred pribl. 30 pr. n. št.), vendar pa je brez natančne časovne kontrole.

4.2 Rastlinstvo in vpliv človeka na okolje v pozni prazgodovini

Pelodni diagram (*sl. 4; 5*) prikazuje, da je v pozni prazgodovini (plast 1, po pribl. 970 cal. BC) v okolici Dolgih njiv rastel mešani gozd, v katerem so uspevale predvsem naslednje drevesne vrste: bukev (*Fagus*), jelka (*Abies*), hrast (*Quercus*), navadni gaber (*Carpinus betulus*) in jelša (*Alnus*). Okolica Ljubljanice je bila zamočvirjena, najdemo pelod jelše (*Alnus*), brestovolistnega oslada (*Filipendula*) ter pelod vodnih in močvirskih rastlin, kot so porečnik (*Alisma*), ježek (*Sparganium*), mrzličnik (*Menyanthes*), lokvanj (*Nymphaea*), blatnik (*Nuphar*) in rmanec (*Myriophyllum*). Tudi v naslednjih stoletjih (plast 3, arheološko datirana v 3. in 2. stoletje pr. n. št.) se vegetacija v okolici Dolgih njiv ni bistveno spremenila. Podobne okoljske razmere so bile ugotovljene tudi z arheobotaničnimi raziskavami (glej Horvat et al. 2016, 208–217, plasti 2, 3 in 5).

Razmeroma majhen delež peloda dreves in grmov (~ 70–80 %) v spodnjem delu stratigrafskega stolpca (plasti 1 in 3) nakazuje, da je bila pokrajina le deloma pogozdena. Zaradi visokega odstotka peloda leske (*Corlyus*) in zeli domnevamo, da so bile kmetijske dejavnosti v regiji intenzivne. T. i. antropogeni indikatorji, kultivirane rastline in pleveli (npr. žita, glavinec [*Centaurea*], metlikovke [Chenopodiaceae] in pelin [*Artemisia*]) so rastli na poljih, pašni indikatorji (ozkolistni trpotec [*Planatgo lanceolata*], zlatice [*Ranunculus*]) pa so značilni za pašnike. Na pelodnem diagramu lahko opazimo dve obdobji intenzivnejšega človekovega vpliva na okolje (siv raster na glob. 198–182 in 178–166 cm, arheološka plast 1, *sl. 4; 5*), ki ju ločuje kratko obdobje manj intenzivnega človekovega vpliva in zaraščanja gozda (porast bukve [*Fagus*] na 180 cm). Takšna palinološka slika je posledica intenzivnih poljedelskih in živinorejskih aktivnosti prazgodovinskih populacij v regiji. Gradišče Tičnica, ki je bilo na osnovi tipologije keramike datirano v srednjo/pozno bronasto in železno dobo (Gaspari, Masaryk 2009), leži le približno kilometer zahodno od Dolgih njiv (*sl. 1*). Stanje raziskanosti nekdanjega rastlinstva in gospodarskih aktivnosti v regiji pa seveda ni zadovoljivo, zato v prihodnosti potrebujemo dodatne arheološke in paleoekološke raziskave z dobro kronološko kontrolo.

Tudi arheološki in arheobotanični podatki kažejo na človekovo navzočnost. V prazgodovinskih plasteh 2–5 so bili odkriti koščki lesa z znaki obdelave, drobci oglja in redki koščki keramike, ni pa bilo makrofosilov kulturnih rastlin. Posekan les kaže, da so ljudje verjetno sekali gozd na obrežju Ljubljanice, ni pa sledov stalne naselitve na tem mestu. Kot arheološki plasti (2 in 4) sta bili odkriti dve fazi sekanja obrežnega gozda, datirani v obdobje med starejšo in mlajšo železno dobo (plast 2; pribl. 379–204 cal. BC) in v srednji laten (plast 4; datirano glede na višje ležečo plast 5 [Horvat et al. 2016]). Upad peloda dreves v plasti 5 (zgornji del cone V1) morda lahko povežemo z aktivnostmi prebivalcev naselbine v bližini. Ker so bile na območju Dolgih njiv odkrite številne latenskodobne arheološke najdbe (keramika, fibule, meč), je bila postavljena domneva, da je na območju Dolgih njiv, pribl. 100–150 m severno od izkopnega polja 1, v drugem in prvem stoletju pr. n. št. stala latenska naselbina (Horvat et al. 2016).

Ljudje, ki so naseljevali območje Navporta v starejši železni dobi in latenu, so gojili žita in se ukvarjali z živinorejo. Njihov vpliv na okolje je bil intenziven, sekali so gozd, morda so tudi gojili drevesa. Zanimivo je, da je bil v stratigrafskem stolpcu z Dolgih njiv v dveh plasteh (v plasti 1 in 3, ki je okvirno datirana v 3. in 2. stoletje pr. n. št.) najden tudi pelod oreha (*Juglans*; *sl. 5*). Pelod oreha je bil najden tudi na Obali (Škocjanski zatok pri Kopru), v plasteh, ki bi jih lahko datirali v prazgodovino ali zgodnjerimsko obdobje (Culiberg 1995; Culiberg 1997). Palinološke raziskave v Italiji kažejo, da delež peloda oreha na diagramih začne naraščati (pogosto skupaj s kostanjem [*Castanea sativa*], Conedera et al. 2004) šele z razširitvijo grške in rimske kulture med pribl. 500 pr. n. št in 500 n. št. (Gobet et al. 2000; Tinner et al. 1999), zato so številni raziskovalci (npr. Behre 1988) menili, da se je oreh – ki je avtohtona vrsta v Anatoliji – v Evropo razširil šele z Rimljani. Kljub tej domnevi ne moremo izključiti možnosti, da so posamezna orehova drevesa v Evropi uspevala skozi celoten holocen in/ali pa se je vrsta razširila v Evropi prej, kot so domnevali do zdaj. Na območju Colli Euganaei (Lago della Costa, severovzhodna Italija), na primer, je pelod oreha (skupaj s kostanjem, kulturnimi rastlinami, pleveli in sledovi požigalništva) stalno prisoten (in dosega 1–2 %) že od pribl. 4300 pr. n. št., kar je najstarejša kultivacija tega taksona v Evropi (Kaltenrieder et al. 2010).

4.3 Rastlinstvo in vpliv človeka na okolje po ustanovitvi rimske postojanke na Dolgih njivah

Zaradi slabe ohranjenosti peloda ni bilo mogoče rekonstruirati razvoja vegetacije v obdobju po ustanovitvi rimske utrdbe. Pelodni zapis v plasti 6 (112 cm), ki se je odložila oz. je bila nasuta tik pred rimsko naselitvijo, na eni strani nakazuje intenzivno izsekavanje gozda (odstotek peloda dreves upade na ~ 40 %), vendar pa zelo nizka pelodna koncentracija (~ 2000 pelodnih zrn na 1 cm^3) in višji odstotek degradiranega peloda (> 5 %) na drugi strani kažeta, da ohranjenost peloda v tej plasti ni bila zelo dobra.

Pelod v še bolj oksidiranih plasteh 14 in 16 je zelo slabo ohranjen (5–15 % degradiranega peloda, izjemno nizka pelodna koncentracija ~ 500). Povečan odstotek odpornih tipov peloda (Havinga 1964), kot sta pelod radičevk (Compositae lig.) in monoletnih spor praproti (Filicales), je verjetno povezan s selektivno degradacijo. Zaradi neugodnih razmer za ohranitev peloda v arheoloških kulturnih plasteh ni mogoče rekonstruirati sestave vegetacije v času obstoja rimske naselbine na Dolgih njivah.

5. ZAKLJUČEK

V pozni prazgodovini (1. tisočletje pr. n. št.) je bilo obrežje Ljubljanice pri Vrhniki zamočvirjeno (mokri travniki in jelše [*Alnus*]), medtem ko je na okoliških bolj suhih tleh uspeval mešani gozd, v katerem so rastli bukev (*Fagus*), jelka (*Abies*), hrast (*Quercus*) in navadni gaber (*Carpinus betulus*). Pokrajina je bila le deloma pogozdena, prebivalci bronastodobnega in železnodobnega gradišča Tičnica (Gaspari, Masaryk 2009) na drugi strani reke in domnevne latenske naselbine na Dolgih njivah (Horvat et al. 2016) so gojili žita in se ukvarjali s pašništvom. Glede na zgodnje najdbe peloda oreha (*Juglans*) lahko domnevamo, da so prazgodovinske in rimskodobne skupnosti imele stike s severno Italijo, kjer je bil oreh verjetno kultiviran že v neolitiku.

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ANDRIČ, M. 2006, Ali lahko analiza pelodnega zapisa v kulturni plasti arheološkega najdišča pove, kakšna vegetacija je rasla v okolici? Primer: Resnikov prekop / Does pollen record in archaeological "cultural layer" tell us what vegetation was growing around the settlement? Case study: Resnikov prekop. – V / In: A. Velušček (ur. / ed.), *Resnikov prekop, najstarejša koliščarska naselbina na Ljubljanskem barju / Resnikov prekop, the oldest pile-dwelling settlement in the Ljubljansko barje.* – Opera Instituti Archaeologici Sloveniae 10, 103–113.

BEHRE, K. E. 1988, The role of man in European vegetation history. – V / In: B. Huntley, T. Webb III (ur. / eds.), *Vegetation history,* 633–672, Dodrecht.

BENNETT, K. D. 1998, *Documentation for PSIMPOLL 3.00 and PSCOMB 1.03: C programs for plotting pollen diagrams and analysisng pollen data* [http://chrono.qub.ac.uk/psimpoll/psimpoll.html].

BENNETT, K. D., K. J. WILLIS 2002, Pollen. – V / In: J. P. Smol, H. J. Birks, W. M. Last (ur. / eds.), *Tracking Environmental Changes Using Lake Sediments,* Vol. 3. *Terrestrial, Algal and Siliceous Indicators,* 5–32, Dordrecht, Boston, London.

BJÖRCK, S., B. WOHLFARTH 2001, ^{14}C chronostratigraphic techniques in paleolimnology. – V / In: W. M. Last, J. P. Smol (ur. /eds.), *Tracking environmental change using lake sediments,* Vol. 1. *Basin analysis, coring and chronological techniques,* 205–245, Dordrecht.

CALIB 7.0 = spletna stran / Website, 2016 [http://calib.qub.ac.uk/].

CULIBERG, M. 1995, Detzertifikacija in reforestacija slovenskega Krasa. – *Poročilo o raziskovanju paleolitika, neolitika in eneolitika v Sloveniji* 22, 210–217.

CULIBERG, M. 1997, Paleovegetacijske razmere v Koprskem primorju. – V / In: J. Horvat, *Sermin. Prazgodovinska in zgodnjerimska naselbina v severozahodni Istri,* Opera Instituti Archaeologici Sloveniae 3, 135–139.

CONEDERA, M., P. KREBS, W. TINNER, M. PRADELLA, D. TORRIANI 2004, The cultivation of *Castanea sativa* (Mill.) in Europe, from its origin to its diffusion on a continental scale. – *Vegetation history and archaeobotany* 13, 161–179.

GARDNER, A. 1997, Biotic response to early Holocene human activity: results from palaeoenvironmental analyses of sediments from Podpeško jezero. – *Poročilo o raziskovanju paleolitika, neolitika in eneolitika v Sloveniji* 24, 63–77.

GARDNER, A. 1999, The ecology of Neolithic environmental impacts – re-evaluation of existing theory using case studies from Hungary & Slovenia. – *Documenta Praehistorica* 26, 163–183.

GASPARI, A., R. MASARYK 2009, Na sledi prazgodovinskega Navporta. Gradišče na hribu Tičnica na Vrhniki / Tracing the prehistoric Nauportus. The hillfort on Tičnica hill near Vrhnika. – *Arheološki vestnik* 60, 195–206.

GOBET, E., W. TINNER, P. HUBSCHMID, I. JANSEN, M. WEHRLI, B. AMMANN, L. WICK 2000, Influence of human impact and bedrock differences on the vegetational history of the Insubrian Southern Alps. – *Vegetation History and Archaeobotany* 9, 175–178.

HAVINGA, A. J. 1964. Investigation into the differential corrosion susceptibility of pollen and spores. – *Pollen et spores* 6, 621–635.

HORVAT, J. 1990, *Nauportus (Vrhnika).* – Dela 1. razreda SAZU 33.

HORVAT, J. 2009a, *Nauportus* – naselje na začetku transportne poti po Ljubljanici. – V: P. Turk, J. Istenič, T. Knific, T. Nabergoj (ur.), *Ljubljanica – kulturna dediščina reke,* 89–94, Ljubljana.

HORVAT, J. 2009b, *Nauportus* – a settlement at the beginning of the transportation route along the Ljubljanica. – In: P. Turk, J. Istenič, T. Knific, T. Nabergoj (eds.), *The Ljubljanica – a River and its Past,* 96–101, Ljubljana.

HORVAT, J., P. PETERLE UDOVIČ, T. TOLAR, B. TOŠKAN 2016, Območje pristanišča v Navportu / The port area of Nauportus. – *Arheološki vestnik* 67, 177–258.

KALTENRIEDER, P., G. PROCACCI, B. VANNIÈRE, W. TINNER 2010, Vegetation and fire history of the Euganean Hills (Colli Euganei) as recorded by lateglacial and Holocene sedimentary series from Lago della Costa (northeastern Italy). – *The Holocene* 20/5, 679–695.

MELIK, A. 1927, *Kolonizacija Ljubljanskega barja.* – Ljubljana.

MOORE, P. D., J. A. WEBB, M. E. COLLINSON 1991, *Pollen analysis.* – Oxford.

PSIMPOLL Spletna stran / Website 2006 [http://chrono.qub.ac.uk/psimpoll/psimpoll.html].

REIMER, P. J. et al. 2013 = Reimer, P. J., E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. Bronk Ramsey, C. E. Buck, H. Cheng, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, H. Haflidason, I. Hajdas, C. Hatte, T. J. Heaton, D. L. Hoffmann, A. G. Hogg, K. A. Hughen, K. F. Kaiser, K, B. Kromer, S. W. Manning, M. Niu, R. W. Reimer, D. A. Richards, E. M. Scott, J. R. Southon, R. A. Staff, C. S. M. Turney, J. Van der Plicht 2013, INTCAL13 and Marine 13 Radiocarbon Age Calibration Curved 0–50,000 Years Cal BP. – *Radiocarbon* 55/4, 1869–1887.

REILLE, M. 1992, *Pollen et Spores d'Europe et d'Afrique Du Nord*. Laboratoire de Botanique Historique et Palynologie. – Marseille.

REILLE, M. 1995, *Pollen et Spores d'Europe et d'Afrique Du Nord*. Supplement 1. Laboratoire de Botanique Historique et Palynologie. – Marseille.

STOCKMARR, J. 1971, Tablets with spores used in absolute pollen analysis. – *Pollen et spores* 13, 615–621.

STUIVER, M., P. REIMER 1993, Extended 14C database and revised CALIB radiocarbon calibration program. – *Radiocarbon* 35, 215–230.

ŠAŠEL KOS, M. 1990, Nauportus: antični literarni in epigrafski viri / Nauportus: Literary and Epigraphical Sources. – V / In: J. Horvat, *Nauportus (Vrhnika),* Dela 1. razreda SAZU 33, 17–33 / 143–159.

TINNER, W., P. HUBSCHMID, M. WEHRLI, B. AMMANN, M. CONEDERA 1999, Long-term forest fire ecology and dynamics in southern Switzerland. – *Journal of Ecology* 87, 273–289.

TROELS-SMITH, J. 1955, Karakterising af løse jordater (Characterisation of unconsolidated sediments). – V / In: *Geological survey of Denmark* IV. Series 3/10, 1–73.

Human impact on the vegetation of the western Ljubljansko barje in late prehistory (ca. 1000–50 cal. BC). Case study: Vrhnika (Dolge njive)

Translation

1. INTRODUCTION

The prehistoric settlement on the bank of the Ljubljanica River at Vrhnika, called Naportus in the Roman era, was a strategically significant site. In the second century BC, it was used as a merchandise post by the Celtic Tavriski, but by the first century BC it was controlled by the Romans (Šašel Kos 1990), who built a fortified settlement with large warehouses on the right bank of the Ljubljanica River (Dolge njive). Here the merchandise goods and supplies for the army that came from Italy were loaded on ships and transported towards the east (Horvat, 1990; Horvat 2009b; Horvat et al. 2016). Although the settlement at Dolge njive was abandoned in the first century AD, the Nauportus settlement on the left bank of the Ljubljanica River persisted until the beginning of the fifth century AD (Horvat et al. 2016).

Due to taphonomic reasons, the information about the vegetation composition in late prehistory (after ca. 2500 cal. BC) and the Roman period is very scarce. In the central part of the Ljubljansko barje, younger palynological archives were completely destroyed in the 18th and 19th centuries AD, when peat was cut and burnt to drain the area (Melik 1927), while hydrological conditions at the edge of the basin (e.g. at Vrhnika) are often too dry to allow for palynological research. The remaining palaeoecological record can be fragmented or suffers from taphonomic (alluvial) processes, which is an obstacle for researchers aiming at high-resolution palaeoecological research.

To date, only two palaeoecological study sites (Podpeško jezero and Resnikov prekop, *Fig. 1*) with a pollen record radiocarbon-dated to the Roman time period were investigated. The best information about the vegetation history is given by the pollen diagram from Podpeško jezero (Gardner 1997; Gardner 1999) suggesting that human impact (small scale forest clearance and changes in forest composition) can be detected from ca. 4000 cal. BC, but very intensive human pressure on the environment took place only after ca. 1000 cal. BC. A large-scale forest clearance (decline of arboreal pollen (AP) to ca. 50% and an increase of herbs) is dated after 300 cal. BC, when the open, present-day landscape formed. This is suggested by the Resnikov prekop pollen diagram (Andrič 2006) showing similar vegetation composition from at least ca. 200 cal. BC.

Palynological results, therefore, suggest that a significant vegetation change at Ljubljansko barje (i.e. intensive forest clearance and formation of vegetation similar to the present day) took place in the second half of the 1st millennium cal. BC. Such vegetation development in the area opens many questions concerning the environment, vegetation composition and the economy before and at the time of Roman occupation. It is not clear whether, in the middle of the first century BC, the first Roman merchants and soldiers came to an open landscape with an intensive farming economy, or they introduced new techniques of cultivation and exploitation that had a significant impact on the vegetation composition, and led to the formation of a very open landscape, similar to the modern one. Regarding natural characteristics of the region (lack of study sites suitable for pollen analysis) and the current state of research, many of these questions are too ambitious to be addressed here. Nevertheless, the results of pollen analysis of a stratigraphic column from Dolge njive (Vrhnika), presented in this paper, will aid in elucidating the vegetation development and economy before the establishment of the Roman settlement. Due to dry hydrological conditions in archaeological cultural layers, which are very unfavourable for pollen preservation, it was not possible to reconstruct the vegetation composition at the time of the Roman settlement. This is in contrast with the results of the archaeological and archaeozoological research, which offer very valuable information about the Roman settlement at Dolge njive and its economy (Horvat et al. 2016). Therefore, palynological results (dealing only with the vegetation development in the 1st millennium cal. BC, before the establishment of the Roman settlement) are discussed separately.

2. METHODS

Samples for pollen analysis were collected in 2007 from the northern profile of archaeological excavation area (146 m²) on the right bank of the Ljubljanica River, between the Ljubljanica River and the southwestern corner of the Dolge njive Roman settlement (see Horvat et al. 2016, Fig. 4, Sector 1, Cross section C–D). The methodology of archaeological excavation and the results of archaeological, archaeobotanical, and archaeozoological research are presented in Horvat et al. 2016; for the position of the pollen stratigraphic column, see also Horvat et al. (2016; Fig. 6a).

In order to reduce the risk of contamination, the samples for pollen analysis were collected ca. 10 m from the right river bank (*Fig. 2*), but still sufficiently close to water to sample marshy sediment, suitable for pollen analysis. A 200-cm-long palynological stratigraphic column was collected from the northern profile using four 50 cm long metal boxes (*Figs. 3; 4*) with the top box starting ca. 20 cm below the soil surface (288.17–290.17 m a.s.l.). Samples were wrapped in cling film, aluminium foil, and thick plastic and stored in cold storage at + 4°C. Sediment description follows that of Troels-Smith (1955).

The age of the sequence was determined by AMS radiocarbon dating of organic carbon and plant macrofossils, extracted from two sediment samples, collected at 160 cm and 192 cm depth (*Tab. 1; Fig. 3*). Radiocarbon ages were calibrated using CALIB Rev 7.0 (CALIB 7.0 Website; Stuiver and Reimer 1993) on IntCal 13 calibration dataset (Reimer et al. 2013).

Standard laboratory procedure was used (7% HCl, 10% NaOH, 40% HF, acetolysis, staining with safranine, TBA, mounting in silicone oil; Bennett and Willis 2002) to prepare 1 cm³ sediment subsamples (with 4 cm resolution between 128 and 200 cm depth) for pollen analysis. Two tablets with a known number of *Lycopodium* spores were added prior to laboratory preparation in order to determine the pollen concentration (Stockmarr 1971). For pollen identification, a Nikon Eclipse E400 light microscope at x400 magnification, pollen reference collection at the Institute of Archaeology ZRC SAZU in Ljubljana, and pollen keys (Moore, Webb, Collinson 1991; Reille 1992; Reille 1995) were used. Data were analysed and plotted with the PSIMPOLL 3.00 programme (Bennett 1998; PSIMPOLL Website); the pollen diagram was divided into two zones (V1 and V2) using binary splitting by the sum of squares. Taxa recorded with low values (<0.5%) are marked with a solid dot.

3. RESULTS

3.1 Stratigraphy and radiocarbon dating
(*Tabs. 1–3*)

The lower part of the profile (~ 125–200 cm; archaeological layers 1–5), which was under the groundwater level, consists of dark greyish brown sediment, rich in organic material, clay and wood fragments (*Tab. 2; Figs. 3; 4*). No archaeological artefacts were found in the presumably natural alluvial layer 1. Layers 2 and 4, which are not present on profile or *Fig. 4*, consist of wood layers, which separated archaeological layers 1 and 3, and 3 and 5, respectively. Archaeological layer 3 contains small pieces of charcoal and wood with cutting marks. Layer 4 (wood with cutting marks) is covered by layer 5 – sediment with small pieces of charcoal and wood with cutting marks (see Horvat et al. 2016, Fig. 19).

The chronology of the sequence is based on three lines of evidence (*Tab. 3*):

– 1. Radiocarbon dating of sediment and plant macrofossils from the palynological stratigraphic column (collected at 192 and 160 cm, archaeological layers 1 and 3; 973–806, 413–206 and 1416–1135 cal. BC), results are presented in *Tab. 1*.

– 2. Radiocarbon dating of plant macrofossils collected during archaeological excavation; e.g. oak (*Quercus*) wood from layer 2: ca. 384–203 cal. BC; ash (*Fraxinus*) wood (196–45 cal. BC) and fir (*Abies*) needle (385–203 cal. BC) from layer 5 (Horvat et al. 2016, 245).

– 3. Dating by archaeological typology (pottery from layer 5: ca. 120–30 BC; Horvat et al. 2016, 245).

These date the alluvial layers (1–5) to the 1st millennium cal. BC (see Discussion / Stratigraphy, taphonomic processes and chronology).

Further up the profile, sandy and silty layer 6, which contained small pieces of charcoal and a piece of pottery, is either a natural alluvial layer, or it was artificially constructed in the early Roman period (Horvat et al. 2016). It is covered by three Roman foundation layers (7, 10 and 15), which are covered by three sand/gravel pavements (8, 11 and 16; Horvat et al. 2016, Fig. 6). On the basis of the typology of pottery, which was found in the fill layers and pavements, these three Roman phases are dated to the Augustan period (ca. 27 BC–14 AD) and were constructed at the same time as the Dolge njive settlement (Horvat et al. 2016). They are covered by alluvial sediment (layer 17).

3.2 Pollen analysis

The results of pollen analysis are presented in *Fig. 4* (summary pollen diagram of most important taxa in comparison with stratigraphy) and *Fig. 5* (detailed pollen diagram). At least 500 pollen grains of terrestrial taxa and spores (= pollen sum), were counted in each sample, except layers with poor pollen concentration/preservation. Pollen percentages were calculated according to this pollen sum. The numbers of archaeological layers are added to the stratigraphic column on the left. Both pollen diagrams are divided into two statistically significant pollen zones (V1 and V2). Palynomorphs in the lower part of zone V1 (128–200 cm) are well preserved and sediments display a pollen concentration of between ~ 2000–8000 pollen grains per 1 cm^3 of sediment, whereas pollen concentration in the upper part of V1 (above 128 cm) declines below 2000 grains cm^{-3} and the percentage of degraded pollen increases (> 10%). In pollen zone V2 (96–48 cm), pollen concentration is very low (~ 500 grains cm^{-3}) with a high (~ 7–30%) percentage of degraded pollen; it was not possible to count a statistically significant pollen sum (≥ 300 pollen grains per sample).

Several woody taxa are present in zone V1 with values > 5%, such as: *Fagus* (beech, ~ 10–30%), *Quercus* (oak, ~ 5–20%), *Alnus* (alder, ~ 10–25%), *Abies* (fir, ~ 5–15%), *Carpinus betulus* (hornbeam, ~ 5–10%) and *Corylus* (hazel, ~ 5–10%). In the lower part of zone V1 (128–200 cm), the percentage of arboreal pollen (AP) fluctuates between 70% and 85%. Among non-arboreal pollen (NAP, ~ 15–25%) the most abundant taxa are Poaceae (grasses, ~ 5%), Cyperaceae (sedges, ~ 1–5%), *Filipendula* (meadowsweet, ~ 1–5%) and 'anthropogenic indicator' taxa such as cereal-type pollen grains, *Plantago lanceolata* (ribwort plantain), *Centaurea* (cornflower), Chenopodiaceae (goosefoot) and *Artemisia* (mugwort). Towards the top of zone V1 and in V2 NAP increases to ~25–45% and AP declines to ~10–40%.

4. DISCUSSION

4.1 Stratigraphy, taphonomic processes and chronology

The chronology of the Dolge njive pollen profile is based on two radiocarbon-dated alluvial sediment samples (*Tab. 1*), which were collected in the section below ~ 120 cm (= most of the pollen zone V-1; *Fig. 4*; layers 1, 3, 5), where the pollen record is reliable due to a high groundwater level; anaerobic conditions are thus favourable for the preservation of fossil pollen and plant macrofossils. This alluvial sediment is covered by sandy layers (*Tab. 2; Fig. 4*; layers 6–16), which are not natural and were constructed during the establishment of the Roman settlement Dolge njive at ca. 30 cal. BC (Horvat et al. 2016). Palynomorphs in these archaeological layers are poorly preserved due to aerobic conditions and human activities at the study site.

Alluvial layers (1, 3 and 5, 120–200 cm) at Dolge njive formed before the establishment of the Roman settlement (= before ca. 30 cal. BC), but due to complex taphonomic processes, it is difficult to establish a precise chronology. Two samples, alluvial sediment and unidentified plant macrofossils, collected at 192 cm (layer 1), were sent to Beta Analytic for radiocarbon dating and the results are presented in *Tab. 1*. The comparison of both radiocarbon dates (*Tab. 1*) shows a significant discrepancy between the 'sediment' (Beta-241775, 2730±40 BP) and the 'plant macrofossil' (Beta-242460; 2300±40 BP) radiocarbon date. Two sigma values (973–806 and 413–206 cal. BC respectively) do not overlap and the difference between both median values is 503 years (*Tab. 1*). Although 'sediment' samples are usually slightly older than 'plant macrofossils' (e.g., for ~ 5500 years old samples from the Stare Gmajne prehistoric pile-dwelling site this difference is about 100 years; Andrič, unpublished data), the difference at Dolge njive is too large and requires explanation.

Since many wood remains were discovered in layer 2 (lying between layers 1 and 3, in the vicinity of a pollen profile, not seen in palynological stratigraphic column and *Fig.* 3 and *4*) and some bigger pieces of wood sunk into layer 1 (see *Fig. 4*), it is also possible that smaller degraded remains of wood (or tree roots) from younger layer 2, sunk into older layer 1. Oak (*Quercus* sp.) tree trunk from layer 2 is dated to 384–203 BC (Horvat et al. 2016, 245), which coincides with the younger 'plant macrofossil' radiocarbon date (Beta-242460, 413–206 cal. BC) from the palynological stratigraphic column, suggesting that 'plant macrofossils' in layer 1 were possibly derived from younger layer 2. These data support the assumption that the pollen record at the bottom of the stratigraphic column (192 cm, layer 1) presumably deposited at ca. 973–806 cal. BC (Beta-241775, 2730±40 BP).

Another problem is the inconsistency between the radiocarbon date at 192 cm (layer 1, Beta-241775, 2730 ± 40 BP, 2 sigma: 973–806 BC) and the radiocarbon date at 160 cm (layer 3, Beta-259684, 3050± 40 BP, 2 sigma: 1416–1135 BC), which, according to its stratigraphic position, appears 'too old'. It is possible that the latter sample, which has a relatively low 13C/12C ratio (-30.1) contains some degraded material of water plants (pollen of some water plants, e.g. *Myriophyllum* was found in this level, *Fig. 5*), which tend to yield 'too old' radiocarbon dates due to their photosynthetic cycle (Björck and Wohlfarth 2001) or/and some earlier, resedimented organic material was dated. The assumption that radiocarbon date at 160 cm is 'too old' is supported by radiocarbon dates from layer 5: *Fraxinus* sp. (ash) wood (196–45 cal BC), *Abies* (fir) needle (385–203 cal. BC) and pottery remains (dated to ca. end of 2nd – mid 1st century BC – Horvat et al. 2016, 245). Therefore, this C14 date (Beta-259684) was not taken into account and no age-depth model was produced.

The observed discrepancy between all three radiocarbon dates is presumably a consequence of the complex and dynamic alluvial sedimentary environment in the vicinity of the Ljubljanica River. The proposed C14 chronology is, therefore, uncertain and should be considered with care. We can only say that the pollen diagram (*Figs. 3; 4*) shows the vegetation development in the 1st millennium cal. BC, before the establishment of the Dolge njive settlement (= before ca. 30 cal. BC), but without robust chronological control.

4.2 The vegetation and human impact on the environment of Dolge njive in late prehistory

The pollen record of Dolge njive (*Figs. 4; 5*) shows that, in late prehistory (layer 1, after ca. 970 cal. BC), the area around the study site was covered by mixed woodland with the following main tree taxa: beech (*Fagus*), fir (*Abies*), oak (*Quercus*), hornbeam (*Carpinus betulus*) and alder (*Alnus*). The marshy environment around the Ljubljanica river is suggested by alder (*Alnus*), meadowsweet (*Filipendula*) and pollen of aquatic taxa such as water plantain (*Alisma*), bur reed (*Sparganium*), bog bean (*Menyanthes*), water lily (*Nymphaea* and *Nuphar*) and water milfoil (*Myriophyllum*). Furthermore, in subsequent centuries (layer 3, archaeologically dated to the 3rd and the 2nd century BC) the vegetation composition at Dolge njive remained unchanged. A similar environment was also reconstructed from the archaeobotanical dataset (see Horvat et al. 2016, 248–250, layers 2, 3, and 5).

The landscape was only partly forested (ca. 70–80% of tree and shrub pollen), with a high percentage of hazel (*Corylus*) and herb taxa. Farming activities in the area were intensive. 'Anthropogenic indicator taxa' including cultivated plants and weeds (e.g. cereal-type pollen, cornflower [*Centaurea*], goosefoot [Chenopodiaceae] and mugwort [*Artemisia*]) were growing on fields, whereas grazing indicators (ribwort plantain [*Plantago lanceolata*], buttercups [*Ranunculus*]) suggest pastures. It seems that there were two phases of more intensive human impact (grey shade at 198–182 cm and 178–166 cm, archaeological layer 1, *Figs. 4; 5*), separated by a short time period with less intensive human pressure when the forest regenerated (*Fagus* increase at 180 cm). This vegetation composition can be associated with the activities of the prehistoric population in the area. The Tičnica fortified prehistoric hilltop settlement, dated to the Middle/Late Bronze Age and Iron Age according to pottery typology (Gaspari and Masaryk 2009) is located just ~ 1 km west of Dolge njive (*Fig. 1*). However, further archaeological and palaeoecological research with improved chronological control is needed to elucidate the economy in prehistory and more detailed vegetation development.

Furthermore, archaeological and archaeobotanical data suggest human activities. Pieces of wood with cutting marks, small pieces of charcoal, but no macrofossils of cultivated plants, and only a few pottery fragments, which were discovered in prehistoric layers 2–5, suggest that people were clearing forest on the river bank, but no traces of (permanent) settlement were discovered. Two archaeological layers/phases of forest cutting, dated to earlier-later Halstatt (layer 2, ca. 384–203 cal. BC) and Middle La Tène time periods (layer 4, dated according to layer 5) were discovered (Horvat et al. 2016). It is possible that the decline of tree pollen in layer 5 (130 cm, *Figs. 4; 5*) is associated with a settlement in the vicinity of the study site.

Furthermore, on the basis of numerous archaeological finds (pottery, fibulae, sword) discovered at Dolge njive, it was suggested that, prior to the establishment of the Roman settlement at Dolge njive, a late La Tène settlement, (2nd–1st century BC) was located ca. 100–150 m north of the archaeological Sector 1 (Horvat et al. 2016).

The early Iron Age and La Tène populations were growing cereals and raising livestock and their impact on the environment was significant. In addition to forest clearing, it is possible that they were also practising arboriculture. It is interesting that walnut tree (*Juglans*) pollen was found in two samples at Dolge njive, in layers 1 and 3, which is dated in the 3rd and the 2nd century cal. BC (*Fig.* 5). Sites on the Slovenian coast (Škocjanski zatok near Koper) record *Juglans* pollen in layers which could be dated to prehistory or early Roman time period (Culiberg 1995; Culiberg 1997). In many areas of Italy, the *Juglans* pollen curve (often together with the chestnut tree (*Castanea sativa*); Conedera et al. 2004) starts to spread only with the Greek and Roman civilisations (at ca. 500 cal. BC–500 cal. AD [e.g. Gobet et al. 2000; Tinner et al. 1999]), therefore many researchers were of the opinion that walnut (native to Anatolia) was introduced to Europe only with the Romans (e.g. Behre 1988). However, it cannot be entirely ruled out that (in small numbers) it was already present in the landscape throughout the Holocene and/or was introduced earlier than previously thought. In the area of Colli Euganei (Lago della Costa, north-eastern Italy), for example, *Juglans* pollen (together with *Castanea*, cultivated plants and weeds and an increase of regional fire activity) is continuously present (reaching 1–2%) from ~ 4300 cal. BC, which is the earliest cultivation of these taxa in Europe (Kaltenrieder et al. 2010).

4.3 Vegetation and human impact on the environment of Dolge njive after the establishment of the Roman settlement

Due to poor pollen preservation, it is not possible to reconstruct the vegetation composition after the establishment of the Dolge njive settlement. Pollen from layer 6 (112 cm), which was deposited immediately before the construction of the settlement, suggests more intensive forest clearance (the percentage of tree pollen decreases to ~ 40%), but low pollen concentration (~ 2000 pollen grains per 1 cm^3) and increased percentage of degraded pollen (> 5%) in this layer, in contrast, suggest that conditions for pollen preservation were not very favourable and might have affected pollen composition.

Pollen in the more oxidised layers 14 and 16 is badly preserved (5–15% of degraded pollen, extremely low pollen concentration ~ 500) and was presumably affected by selective pollen degradation, as suggested by the increased percentage of Compositae liguliflorae (20%) and Filicales (> 40%), which are resistant to pollen degradation (Havinga 1964).

5. CONCLUSIONS

In the late prehistory (1st millennium cal. BC), the environment around the Ljubljanica River at Vrhnika was marshy (wet meadows and alder [*Alnus*] trees), whereas mixed woodland of beech (*Fagus*), fir (*Abies*), oak (*Quercus*) and hornbeam (*Carpinus betulus*) was growing on drier land. The landscape was partly open, with strong traces of cereal cultivation and grazing, which can be associated with the activities of Bronze and Iron Age populations living at the Tičnica hillfort (Gaspari and Masaryk 2009) just across the river, and presumably La Tène settlement (Horvat et al. 2016) at Dolge njive. The pollen of walnut tree (*Juglans*) suggests that prehistoric and Roman communities at Vrhnika might have had intensive contacts with Northern Italy, where this tree was most probably cultivated in the Neolithic.

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Maja Andrič
ZRC SAZU
Inštitut za arheologijo
Novi trg 2
SI-1001 Ljubljana
maja.andric@zrc-sazu.si