Človekov vpliv na okolje v prazgodovini: primer z obrežja Ljubljanice pri Špici (Ljubljana)

Embankment of the Ljubljanica River at Špica (Ljubljana) and human impact on the environment in late prehistory

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Izvleček

V članku so predstavljeni rezultati paleoekoloških multidisciplinarnih raziskav, s pomočjo katerih smo rekonstruirali nekdanje okoljske razmere in vpliv prazgodovinskih prebivalcev Ljubljane na takratno vegetacijo. Rezultati luminiscenčnega datiranja in pelodne analize kažejo, da je bila poznoeneolitska (pribl. 2500 cal. BC) naselbina na obrežju Ljubljanice na Špici postavljena neposredno na meljast sediment, ki se je odlagal med viškom zadnje poledenitve pred približno 20.000 leti. Poznoglacialni in zgodnje-/srednjeholocenski sediment, ki manjka, je verjetno odnesla voda, zato lahko rekonstruiramo le prazgodovinske okoljske razmere od sredine 3. tisočletja pr. n. št. naprej. Na podlagi rezultatov palinološke raziskave lahko sklepamo, da so v bližini arheološke naselbine na Špici uspevali mešani gozdovi, v katerih so prevladovali bukev, jelka, hrast in navadni gaber. Človekov vpliv je bil zmeren, zaznamo lahko šibke sledove poljedelskih aktivnosti. Po opustitvi naselbine na Špici sledovi človekovega vpliva na okolje postanejo intenzivnejši, še zlasti v železni dobi, ko naraste delež peloda rastlin, značilnih za (opuščena) polja in ruderalna tla (žita, metlikovke, pelin) ter pašnike (ozkolistni trpotec). Delež jelke, ki je občutljiva za pašo in požiganje gozda, upade. Večje izsekavanje bukovega gozda je datirano v zgodnjerimsko obdobje, najverjetneje v sredino 1. st. pr. n. št. (162 pr. n. št.–52 n. št.). Opisane spremembe vegetacije lahko povežemo s prazgodovinskimi in rimskodobnimi arheološkimi najdišči na Tribuni in Prulah, v neposredni bližini Špice.

Ključne besede: Slovenija, Ljubljana, Špica, bakrena doba, železna doba, rimska doba, pelodna analiza, luminiscenčno datiranje, granulometrija

Abstract

This paper presents the results of multi-proxy palaeo-ecological research (luminescence and radiocarbon dating, grain size measurement, loss-on-ignition, pollen, microcharcoal and plant macrofossil analysis), with the aim of reconstructing palaeo-environmental conditions and the impact of prehistoric people on the vegetation in Ljubljana (central Slovenia). The results of luminescence dating and pollen analysis suggest that the Late Copper Age (ca. 2500 cal. BC) archaeological settlement at Špica, which is located on the embankment of the Ljubljanica River, was built directly on silty sediment, which was deposited during the Last Glacial Maximum (LGM, ca. 20 ka). Late glacial and early/middle Holocene sediment, which is missing, was presumably removed by fluvial processes. Therefore, only environmental conditions in the late prehistory after ca. 2500 cal. BC were reconstructed. The results of palynological research suggest that mixed forests with beech, fir, oak, and hornbeam were growing near the Špica settlement. Human impact on the environment was moderate, with weak traces of agricultural activities. After the abandonment of the settlement, the traces of human impact on the environment became more apparent, especially in the Iron Age, when the pollen of plants growing on (abandoned) fields and ruderal ground (cereals, goosefoot, mugwort) and grazing indicators (ribwort plantain) increases. Fir, which is sensitive to grazing and fire, declines. A major clearance of beech forest is dated in the Early Roman Age, most probably in mid-1st century BC (ca. 162 cal. BC–AD 52). These changes of vegetation can be associated with prehistoric and Roman archaeological sites of Tribuna and Prule, which is in the vicinity of Špica.

Keywords: Slovenia, Ljubljana, Špica, Copper Age, Iron Age, Roman Age, pollen analysis, luminescence dating, granulometry

UVOD

Območje Ljubljanskega barja je dobro znano po številnih eneolitskih koliščarskih naselbinah (Velušček 2009 in tam navedena literatura) in raziskavah njihovega okolja (Šercelj 1966; Culiberg, Šercelj 1978; Šercelj 1996 in tam navedena literatura; Jeraj 2004; Toškan, Dirjec 2004; Andrič et al. 2008; Turk, Horvat 2009; Verbič 2011; Tolar et al. 2011; Andrič, v pripravi[1]) v obdobju med 5. in 3. tisočletjem pr. n. št. V nasprotju s tem je zadnjih 4500 let zelo slabo raziskanih. Pomanjkanje paleookoljskih zapisov je posledica uničenja mlajših plasti v 18. in 19. st. našega štetja, ko so zaradi izsuševanja Ljubljanskega barja in izkoriščanja šote rezali in požigali šoto (Melik 1927; Andrič et al. 2008). Na Ljubljanskem barju so zato najdišča, kjer lahko proučujemo razvoj vegetacije po letu 2500 pr. n. št. (npr. Podpeško jezero; Gardner 1999), zelo redka.

Tudi nekdanje okolje (in do nedavnega tudi arheološka poselitvena slika) na območju mesta Ljubljane je zelo slabo raziskano. Razlogov za to je več. Najpomembnejša vzroka sta pomanjkanje finančnih sredstev za paleoekološke raziskave in tafonomske razmere. V urbanih, suhih predelih Ljubljane sedimenta, ki bi bil primeren za palinološke in druge paleoekološke raziskave, ni veliko, plasti so pogosto tudi poškodovane zaradi gradbenih aktivnosti. V zadnjih letih so arheologi odkrili številna nova najdišča (npr. Vojaković et al. 2011; Žerjal et al. 2012[2]), vendar pa o gospodarstvu, okolju in vplivu prebivalcev teh naselbin na okolje vemo zelo malo. Sediment na nekaterih novoodkritih arheoloških najdiščih je le deloma primeren za palinološke raziskave, vendar bo s primerjavo rezultatov z več različnih najdišč (npr. Špica, Tribuna, Prule in Krojaška ulica na desnem bregu Ljubljanice) mogoče rekonstruirati okoljsko zgodovino tudi za nekoliko daljša časovna obdobja. V tem članku bomo predstavili rezultate palinoloških, geoloških in paleobotaničnih raziskav na arheološkem najdišču Špica in analizirali paleookoljske razmere v pozni prazgodovini (2500–50 pr. n. št., glej časovni model na *sl. 5, 9* in *10*).

[1] M. Andrič, *Arheološka naselbina Stare gmajne in rastlinstvo Ljubljanskega barja v 4. tisočletju cal. BC.*

[2] Najdišče na Prulah v Ljubljani. Neobjavljeno poročilo, Zavod za varstvo kulturne dediščine, Center za preventivno arheologijo: T. Žerjal, M. Černe, T. Nanut, T. Verbič, *Poročilo o zaščitnih arheoloških izkopavanjih na območju predvidene gradnje stanovanjske hiše Glažar, Perović, Bevk,* Ljubljana 2012.

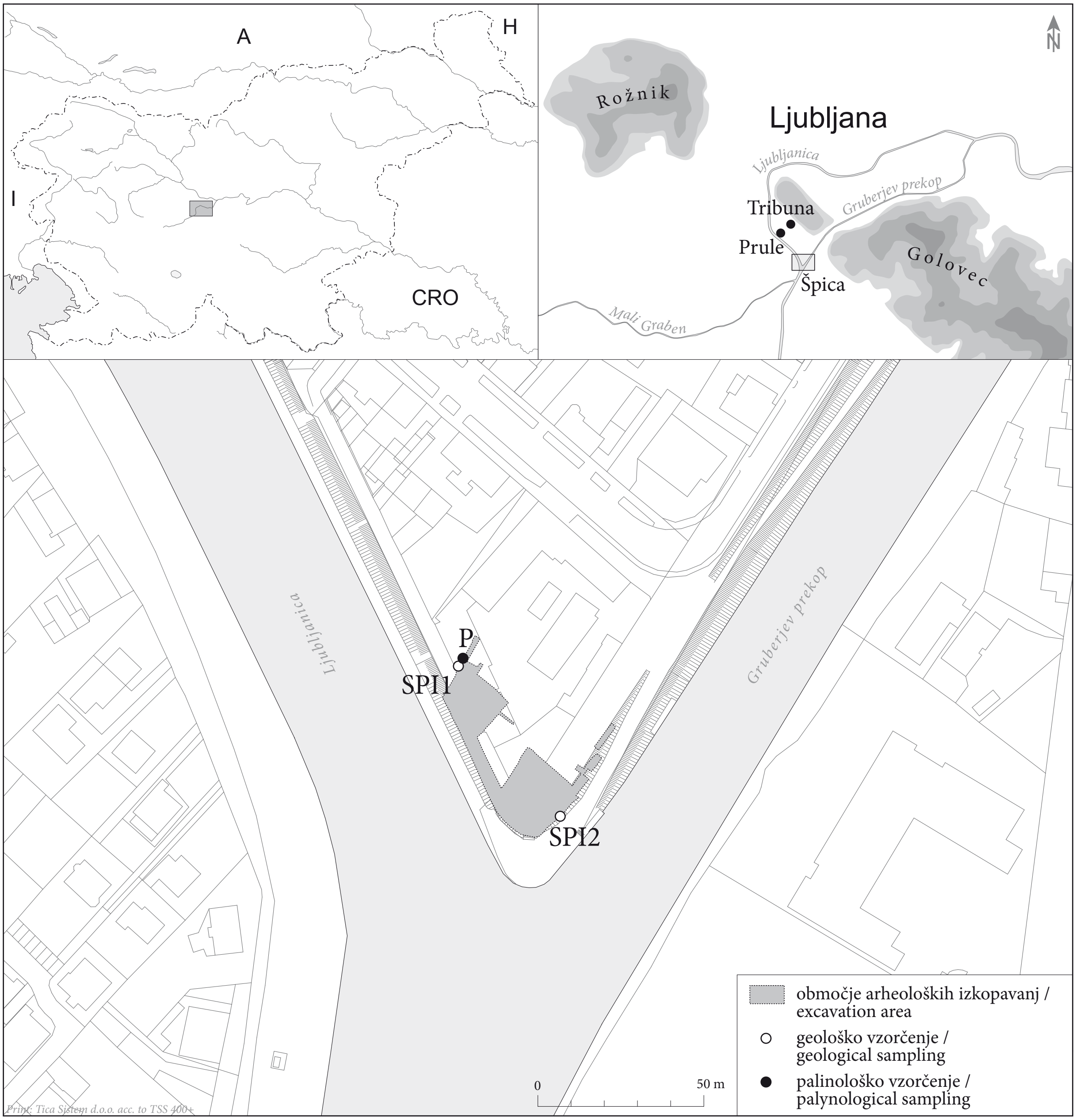
RAZISKOVANO OBMOČJE IN ARHEOLOŠKA IZKOPAVANJA

Raziskovano območje leži v osrednjem delu Slovenije, na severnem robu Ljubljanskega barja (*sl. 1;* 46°02'25"N, 14°30'41"E, GKY 462555, GKX 99678). Ljubljansko barje je tektonski bazen, ki leži na pretežno karbonatni geološki podlagi. Na jugu in zahodu ga prekrivajo triasni in jurski apnenci in dolomiti, na severu in vzhodu prevladujejo paleozojski peščenjaki, konglomerati, skrilavci in apnenci (Mencej 1988–1989). Današnje podnebje Ljubljanskega barja je zmerno kontinentalno, s subkontinentalnim padavinskim režimom in povprečno letno količino padavin 1000–1300 mm (Ogrin 1996). Območje na poplavni ravnici s številnimi vodotoki je prekrito z redkimi mešanimi gozdovi (*Pinus, Betula, Alnus, Quercus robur*), na obrobju prevladujejo gosti, pretežno bukovi (*Fagus*) gozdovi (Marinček et al. (ur.) 2006).

Ljubljana ima zelo pomembno geostrateško lego, ker leži na stičišču poti, ki povezujejo Apeninski polotok in Balkan. Območje je bilo poseljeno vse od bronaste dobe, ko so ljudje živeli na desnem bregu Ljubljanice (Grajski grič in Prule), grobišča pa so imeli na levem bregu (SAZU, NUK II). Arheološka izkopavanja so razkrila, da je železnodobno naselje pokrivalo večje območje (predvidoma > 10 ha), vključno s predmestji Tribuna ter Gornji in Stari trg, kjer so živeli obrtniki in trgovci (Vojaković 2013, 361). Rimska utrjena naselbina in vojaški tabor, ki je bil zgrajen ob koncu 1. st. pr. n. št. in opuščen na začetku 1. st. n. št., sta bila postavljena v bližini pristanišča na bregu Ljubljanice pri Prulah (Gaspari et al. 2014).

Arheološko najdišče Špica leži na desnem bregu Ljubljanice zahodno od Golovca na nadmorski višini 290 m. Leži ravno na stiku z Gruberjevim kanalom, ki je bil kot protipoplavna zaščita izkopan v 18. st. n. št. (*sl. 1*). Območje je bilo v zadnjih treh stoletjih močno preoblikovano zaradi gradnje kanala in regulacij struge Ljubljanice. Zaščitna arheološka izkopavanja, ki so bila potrebna zaradi prenove obrežja, so bila izvedena leta 2010. Izkopavanja so razkrila, da je 5–40 cm debela arheološka kulturna plast z lesenimi strukturami kljub številnim gradbenim posegom v preteklosti na večjem delu izkopnega polja še vedno ohranjena (Klasinc et al. 2010;[3] Šinkovec 2012). Keramika,

[3] Neobjavljeno poročilo, Tica sistemi d. o. o.: R. Klasinc, M. Ravnik, J. Kusetič, M. Jančar, S. Vučković,



Sl. 1: Špica. Območje arheoloških izkopavanj, geoloških (SPI1 in SPI2) in palinoloških profilov (P).
Fig. 1: Špica. The position of archaeological excavation area, geological (SPI1 and SPI2) and palynological profiles (P).

odkrita na Špici, je podobna keramiki z drugih poznoeneolitskih najdišč na Ljubljanskem barju (Parte in Založnica: dendrokronološko in po C14 datirani v pozno 26./25. st. pr. n. št., kultura Somogyvár-Vinkovci; Dežmanova kolišča pri Igu: prva polovica in sredina 3. tisočletja pr. n. št., vučedolska kultura, kultura Somogyvár-Vinkovci in Ljubljanska kultura; Velušček et al. 2000; Velušček, Čufar 2003; Korošec, Korošec 1969; Velušček, Čufar 2014), zato najdišče na podlagi arheološke tipologije uvrščamo v pozni eneolitik (pribl. 2500 pr. n. št.; Šinkovec 2012). Odkrita so bila tudi bakrena orodja ter pripomočki za predelavo kovin in ulivanje bakra (Šinkovec 2012).

Poročilo o zaščitnih arheoloških izkopavanjih na najdišču Špica, Kranj 2010.

METODE

Na najdišču so bili pobrani trije vzorci za palinološke in granulometrične analize ter luminiscenčno datiranje (stratigrafski stolpci P, SPI1 in SPI2; *sl. 1*). Vzorci za pelodno analizo so bili pobrani iz zahodnega profila arheološke sonde (*sl. 1*) s pomočjo kovinskih škatel (pribl. 7 × 7 × 50 cm; *sl. 2*). Skupna dolžina stratigrafskega stolpca je 130 cm. Sedimenta iz zgornjih 30 cm profila nismo vzorčili, ker je bil oksidiran in zato neprimeren za palinološko raziskavo. Vzorci so bili zaviti v tanek polivinil, aluminijasto folijo in še eno plast debelega polivinila ter shranjeni v hladilnici pri 4 °C.

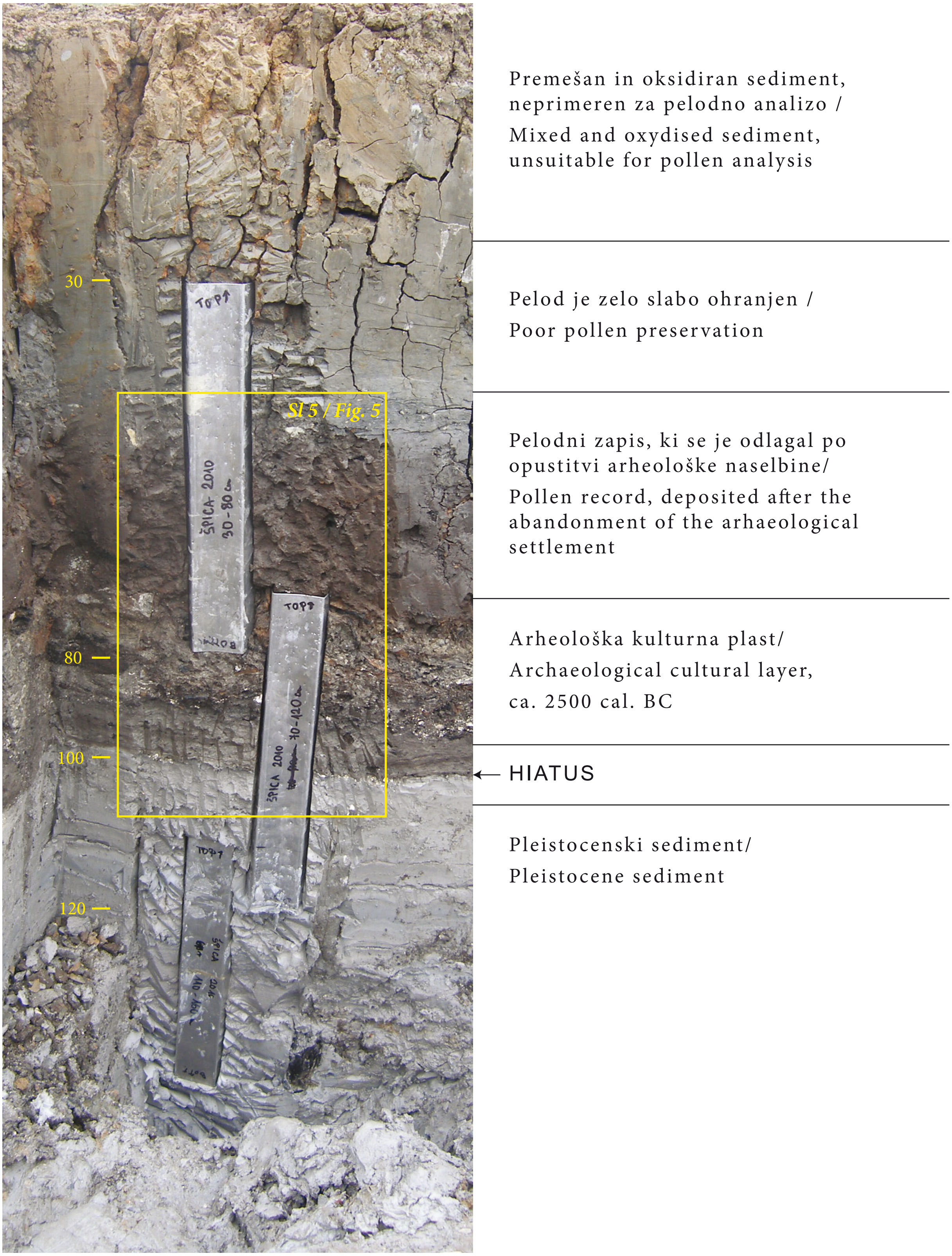
Vzorec SPI1 za luminiscenčno datiranje in granulometrično raziskavo je bil odvzet iz istega profila kot palinološki vzorec, medtem ko je bil vzorec SPI2 pobran na najjužnejšem delu izkopnega polja (*sl. 1*). Luminiscenčno datiranje je bilo izvedeno v laboratoriju Inštituta za aplikativno geologijo (University of Natural Resources and Life Sciences – BOKU) na Dunaju. Meritve vzorca SPI1 so potekale na grobi kremenovi frakciji s standardnim postopkom OSL SAR (Murray, Wintle 2000; 2003) pri temperaturi 220 in 260 °C. Pri obeh vzorcih, SPI1 in SPI2, je bil luminiscenčni signal kremena zelo nejasen. Zato smo pri meritvi drugega vzorca SPI2 uporabili protokol post-IR IRSL na grobozrnati frakciji glinenca, ki vsebuje veliko kalija. V tem primeru so bile temperature predgretja 250 °C, IRSL 50 °C in post-IRSL 225 °C (Buylaert et al. 2009). Vse meritve so bile izvedene na napravi Risø luminescence reader TL-DA 15, z masko premera 2 mm. Za granulometrično analizo smo 100 g vzorca za 48 ur namočili v destilirani vodi, razpustili v ultrazvočni kopeli in mokro presejali skozi sita z velikostjo odprtin 0,1 mm, da bi odstranili drobce, manjše od 0,1 mm. Meritev velikosti zrn na preostalem vzorcu (84,9 g) je bila izvedena na laserskem merilcu zrnavosti Fritsch Analysette 22 na Geološkem zavodu Slovenije.

Odstotek organskih snovi, karbonatov in mineralnega preostanka v sedimentu palinološkega profila je bil določen s pomočjo žarilne izgube (loss-on-ignition) po žganju pri 550 °C in 950 °C (Bengtsson, Ennell 1986) in s 4 cm gostoto vzorčenja na večjem delu profila.

Približno 2–3 cm^3 velike vzorčke sedimenta z izbranih delov profila smo nežno razredčili z destilirano vodo in preiskali pod stereomikroskopom Leica MZ75 pri 50-kratni povečavi. Rastlinski makrofosili so bili izločeni iz sedimenta, sortirani, identificirani in poslani na radiokarbonsko datiranje.

Za pelodno analizo smo vzorčili po 1 cm^3 sedimenta, z ločljivostjo 4 cm vzdolž večjega dela profila. Uporabljen je bil standardni laboratorijski postopek (HCl, NaOH, HF, acetoliza, barvanje s safraninom, silikonsko olje; Bennett, Willis 2002), pelodna koncentracija je bila določena s pomočjo dodajanja spor *Lycopodium* (Stockmarr 1971). Za identifikacijo peloda smo uporabljali svetlobni mikroskop Nicon Eclipse E400 pri 400-kratni povečavi, pelodno referenčno zbirko Inštituta za arheologijo ZRC SAZU in ključe za določanje peloda (Reille 1992; 1995; Moore, Webb, Collinson 1991). V vsakem vzorcu je bilo preštetih najmanj 500 (= pelodna vsota) pelodnih zrn kopenskih rastlin in spor praproti. Za določanje koncentracije mikroskopskega oglja smo uporabili dve metodi: mikroskopsko oglje (v dveh velikostnih razredih, < 40 µm in > 40µm) smo šteli hkrati s pelodom; poleg tega smo uporabili še Clarkovo (1982) "point-count" metodo. Rezultate smo analizirali in diagrame zrisali s pomočjo programa PSIMPOLL 3.00 (Bennett 1998; PSIMPOLL website 2006). Pelodni diagram (*sl. 10*) je bil razdeljen na dve statistično relevantni coni z razpolovitvijo po metodi najmanjših kvadratov. Vrednosti, ki so manjše od 0,5, so označene s piko. Raster označuje arheološko kulturno plast.

Ocena starosti na "loss-on-ignition" (*sl. 9*) in pelodnem diagramu (*sl. 10*) za del stratigrafskega stolpca nad arheološko kulturno plastjo je bila določena s pomočjo linearne interpolacije med medianami radiokarbonskih datacij (*sl. 4; 5*). Pri oceni starosti nismo upoštevali vseh radiokarbonskih datacij. Neidentificiran rastlinski material, najden v pleistocenskem sedimentu (glej rezultate luminiscenčnega datiranja na *sliki 3*) na globini 112 cm (Poz-45538), verjetno pripada koreninam ali drugemu mlajšemu rastlinskemu materialu, ki je potonil v mnogo starejši sediment. Popek, najden na globini 64 cm (Poz-45541), ni vseboval dovolj ogljika (0,15 mg), zato te radiokarbonske datacije nismo uporabili pri oceni starosti sedimenta (*sl. 5; 9; 10*). Dva sigma razpon vseh radiokarbonskih datacij je naveden na *sliki 4*, na *sliki 5* pa je s šrafuro označeno možno odstopanje (± 94–185 let) od predlaganega časovnega modela.



Sl. 2: Špica. Palinološko vzorčenje.
Fig. 2: Špica. The position of sedimentary column for pollen analysis.

Vzorec Sample	Globina Depth (m)	Mineral	Protokol Protocol	N	Relativni standardni odklon (%) Relative standard deviation (%)	Voda Water (%)	D_0 (Gy/ka)	2σ	De (Gy)	2σ	Leta Age (years)	2σ
SPI1	**1.3**	Kremen Quartz	OSL SAR*	11	9	17±7	2.40	0.20	43.6	2.1	18.100	1.7
SPI2	**1.3**	Glinenec Feldspar	PostIR-IRSL**	8	12	17±7	2.25	0.17	47.9	2.4	21.200	1.9

* OSL: Optično stimulirana luminiscenca / Optically stimulated luminescence; SAR: Single Aliquot Regeneration (Murray and Wintle 2000, 2003).
** PostIR-IRSL: Post-Infrared Luminescence (Buylaert et al. 2009).
D_e: ekvivalentna doza radiacije / equivalent dose of radiation, Gy: Gray.
D_o: hitrost absorpcije / rate of dose absorption; Gy/ka: Gray per kilo years.

Sl. 3: Špica. Rezultati luminiscenčnega datiranja v profilih SPI1 in SPI2.
Fig. 3: Špica. The results of luminescence dating in profiles SPI1 and SPI2.

Globina / Depth cm	**Datirani material / Dated material**	**Laboratorijska št. / Laboratory no.**	**Konvencionalen C14 datum / C14 date**	**Kalibriran rezultat / Calibrated result** (2 sigma), Intcal13 (median)
52	neidentificirani rastlinski ostanki / unidentified plant material	Poz-55944	2035 ± 35 BP	162 cal. BC–AD 52 (39 BC)
64	oglje / charcoal	Poz-45645	2260 ± 30 BP	397–209 cal. BC (288 BC)
*64	popek / bud	Poz-45541	2420 ± 110 BP (0,15 mgC)	804–232 cal. BC (554 BC)
72	les / wood	Poz-55943	2499±30 BP	787–536 cal. BC (636 BC)
94	*Quercus* sp. (oak) želod / acorn	Poz-45540	4040 ± 40 BP	2840–2468 cal. BC (2562 BC)
*112	neidentificirani rastlinski ostanki / unidentified plant material	Poz-45538	3750 ± 40 BP	2286–2035 cal. BC (2161 BC)
130 cm	luminiscenčno datiranje / luminescence dating: 18.1–21.2 ka (SPI-1, SPI-2); glej *sl. 3* / see *Fig. 3*			

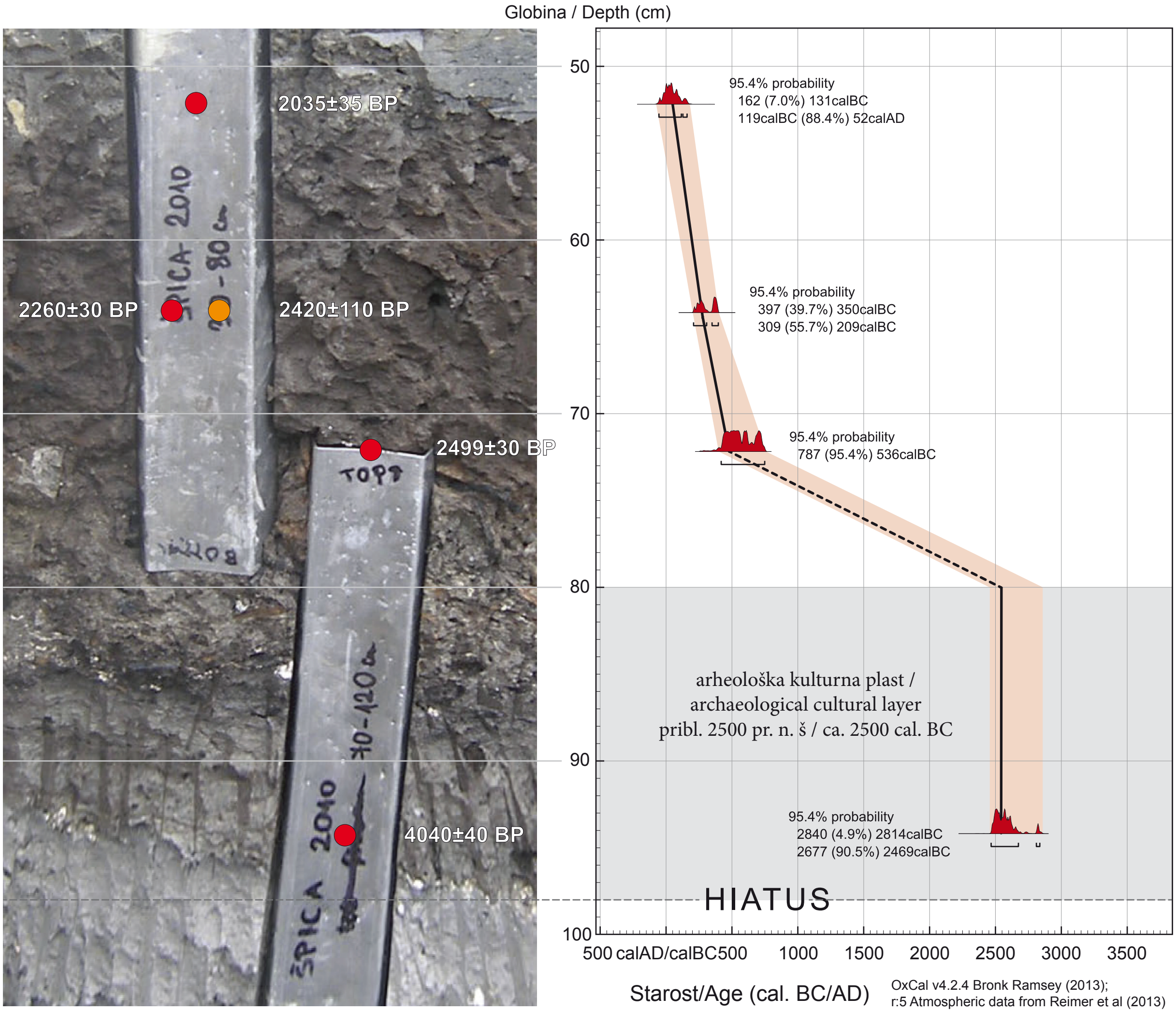
Sl. 4: Špica. Rezultati radiokarbonskega in luminiscenčnega datiranja (glej še *sl. 3*). Radiokarbonske datacije, označene z *, niso bile upoštevane pri oceni starosti (glej poglavje Metode).
Fig. 4: Špica. The results of radiocarbon and luminescence dating (see also *Fig. 3*). Radiocarbon dates, marked with * were not used for age-depth modelling (see chapter Methods).

REZULTATI

Kronologija

Rezultati luminiscenčnega datiranja (*sl. 3*; analizirana sta bila stratigrafska stolpca SPI2 in SPI1, ki leži v neposredni bližini palinološkega profila; *sl. 1*) so pokazali, da se je sediment na dnu sekvence (100–160 cm) odlagal med viškom zadnje ledene dobe (pred 18.100–21.200 leti). Arheološka kulturna plast v palinološkem stratigrafskem stolpcu P, ki leži nad ledenodobnim sedimentom (tj. na globini 80–98 cm), je mnogo mlajša in je radiokarbonsko datirana pribl. 2500 pr. n. št. (*sl. 2; 4; 5*). Hiatus med ledenodobnim sedimentom in arheološko kulturno plastjo (20.000–2500 pr. n. št.) na 99 cm globine je verjetno nastal zaradi delovanja vode (en ali več erozijskih dogodkov v poznem glacialu in zgodnjem/srednjem holocenu).

Radiokarbonske datacije (*sl. 4; 5*) kažejo, da je bilo odlaganje sedimenta neposredno nad arheološko kulturno plastjo (na globini 80–72 cm) zelo počasno (0,01 cm na leto), domnevno zaradi bolj sušnih hidroloških razmer, ki jih nakazujeta tudi nizka pelodna koncentracija in visok odstotek anorganskih snovi (*sl. 5; 9* in *10*). Sledov erozije nismo zaznali, zato se nam zdi manj verjetna, čeprav te možnosti v celoti ne izključujemo. Sediment v zgornjem delu palinološkega profila (na globini 72–52 cm) se je odlagal v železni dobi,



Sl. 5: Špica. Palinološki profil z označeno lego arheološke kulturne plasti, radiokarbonskih datacij in ocena starosti sedimenta (linearna interpolacija).
Fig. 5: Špica. The position of palynological profile, archaeological cultural layer and radiocarbon dates and age-depth modelling (linear interpolation).

najverjetneje med 650 in 50 pr. n. št. (kar je, če upoštevamo možno odstopanje časovnega modela, med 787–536 pr. n. št. in 162 pr. n. št.–52 n. št.; *sl. 5*). Zgornjih 22 cm profila zaradi nizke pelodne koncentracije in visokega odstotka degradiranih pelodnih zrn ni bilo datirano.

Sestava sedimenta

Ledenodobni sediment je meljast (*sl. 6; 7; 8*). Okoli 50 % zrn je velikostnega razreda 2–63 µm, 15 % je drobcev gline in 35 % drobnega peska (*sl. 8*). Sediment je svetlo in srednjesive barve in je drobno (2–15 mm) laminiran. Na južnem delu izkopnega polja se meljast sediment izmenjuje z do 10 cm debelimi plastmi srednje- do grobozrnatega peska.

Ledenodobni sediment (v stratigrafskem stolpcu P, pelodna cona Š-1; *sl. 9*) vsebuje pribl. 20 % karbonatov, 70–80 % anorganskega preostanka (večinoma kremena) in zelo nizek odstotek organskih snovi (pribl. 5 % suhe teže sedimenta).

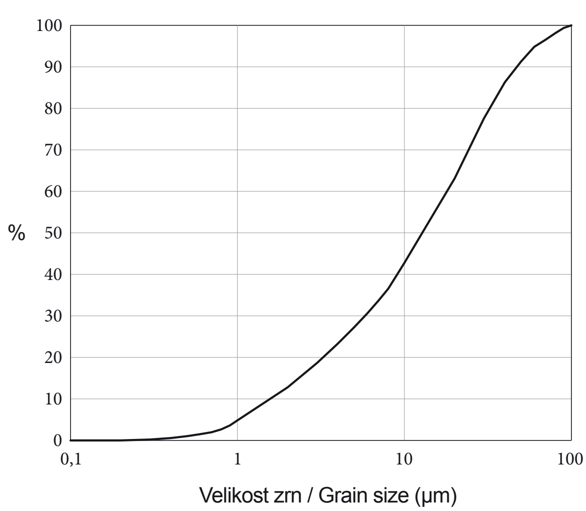
V arheološki kulturni plasti (Š-2; na globini 98–80 cm) odstotek organskega materiala naraste na 20–35 %, medtem ko anorganski preostanek upade na 50–70 %, odstotek karbonatov se bistveno ne spremeni. Vzorec z globine 76 cm vsebuje le pribl. 10 % organskega in več kot 80 % anorganskega preostanka. V zgornjem delu cone Š-2 (na globini 72–32 cm) je odstotek karbonatov zelo nizek

SPI 1	%	g
Celoten vzorec / Entire sample	100	86.8
> 0.1 mm	2.2	1.9
< 0.1 mm	97.8	84.9

Sl. 6: Špica. Vzorec SPI1, delež zrn < 0,1 mm v pleistocenskem sedimentu.
Fig. 6: Špica. Sample SPI 1, the portion of particles <0.1 mm in Pleistocene sediment.

	Frakcija < 0.1 mm / < 0.1 mm fraction		Celotni vzorec / entire sample	
	%	g	%	g
Glina / Clay <0.002 mm	12.78	10.85	12.5	10.85
Melj / Silt 0.002 – 0.06 mm	82.02	69.63	80.22	69.63
Pesek / Sand >0.06 mm	5.2	4.42	7.28	6.32

Sl. 7: Špica. Vzorec SPI1, rezultati meritve zrnatosti v pleistocenskem sedimenti (glej še *sl. 8*).
Fig. 7: Špica. Sample SPI 1, the results of grain size measurement (see also *Fig. 8*).



Sl. 8 Špica. Zrnatost pleistocenskega melja (vzorec SPI1).
Fig. 8: Špica. Granulometry of the Pleistocene lake silt (sample SPI1).

(< 5 %), količina organskega materiala upade s pribl. 45 % (72 cm) na le 10 % (48–32 cm), medtem ko količina anorganskega preostanka naraste (s 60 na 90 %).

Pelodna analiza

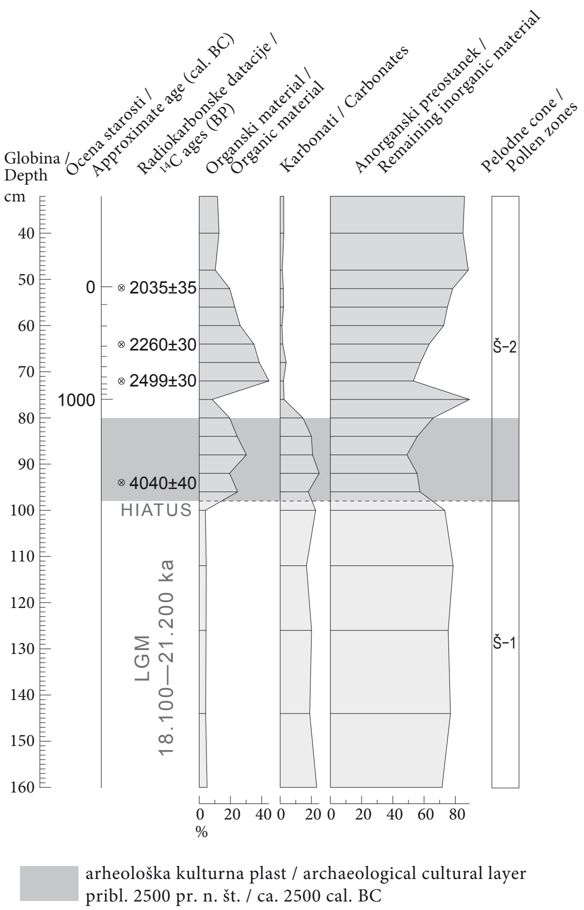
Pelodni diagram (*sl. 10*) je razdeljen na dve pelodni coni (Š-1 in Š-2). Odstotek degradiranega peloda v coni Š-1, ki se je na globini 98–160 cm odlagal pred 18.100–21.200 leti (luminiscenčno datiranje profilov SPI1 in SPI2), je visok (> 10 %), pelodna koncentracija pa zelo nizka (< 1000 pelodnih zrn na 1 cm^3), zato ni bilo mogoče doseči standardne pelodne vsote (≥ 300 pelodnih zrn na vzorec). Glavni taksoni v tej coni so bor (*Pinus*), smreka (*Picea*), šaši (Cyperaceae), trave (Poaceae) in pelin (*Artemisia*).

V pelodni coni Š-2 se koncentracija in ohranjenost peloda izboljšata. V spodnjem delu pelodne cone Š-2 (na globini 98–30 cm) koncentracija peloda v arheološki kulturni plasti (na globini 98–80 cm) naraste na 5000–15.000 pelodnih zrn na 1 cm^3 sedimenta, odstotek degradiranega peloda pa je nizek. S 70–95 % prevladuje pelod dreves (bukev [*Fagus*], jelka [*Abies*], hrast [*Quercus*], navadni gaber [*Carpinus b.*], jelša [*Alnus*] in leska [*Corylus*]), pelod zeli je manj pogost (npr. monoletne spore praproti [Filicales] in trave [Poaceae]). Koncentracija mikroskopskega oglja naraste na globini 80 cm. V srednjem delu cone Š-2 (na globini 76–56 cm) odstotek jelke (*Abies*) in navadnega gabra (*Carpinus b.*) upade, antropogeni indikatorji, značilni za polja, ruderalna tla in pašnike, kot so žita (Cerealia), glavinec (*Centaurea*), metlikovke (Chenopodiaceae), pelin (*Artemisia*) in ozkolistni trpotec (*Plantago l.*), pa se pojavljajo pogosteje. V zgornjem delu pelodne cone Š-2 (na globini 52–32 cm) se odstotek peloda dreves (npr. *Fagus*) zniža na le 10 %. Nizka pelodna koncentracija in več kot 20 % degradiranega peloda na globini 32 cm kažeta, da je prihajalo do selektivne pelodne degradacije.

RAZPRAVA

Paleookoljske razmere ob zadnjem višku poledenitve (pred pribl. 20.000 leti)

Rezultati pelodne analize na Špici se ujemajo z rezultati dosedanjih raziskav v regiji (Šercelj 1996 in tam navedena literatura), ki so pokazale, da je bilo v času zadnje poledenitve območje Slovenije prekrito s stepo/tundro/tajgo z redkimi drevesi (bor [*Pinus*], smreka [*Picea*], breza [*Betula*], hrast [*Quercus*], jelša [*Alnus*]) in zelmi (trave [Poaceae], pelin [*Artemisia]*). Nizko pelodno koncentracijo



Sl. 9: Špica. Palinološki profil (P), diagram loss-on-ignition. LGM = pleistocenski sediment.
Fig. 9: Špica. Palynological profile (P), loss-on-ignition diagram. LGM = Pleistocene sediment.

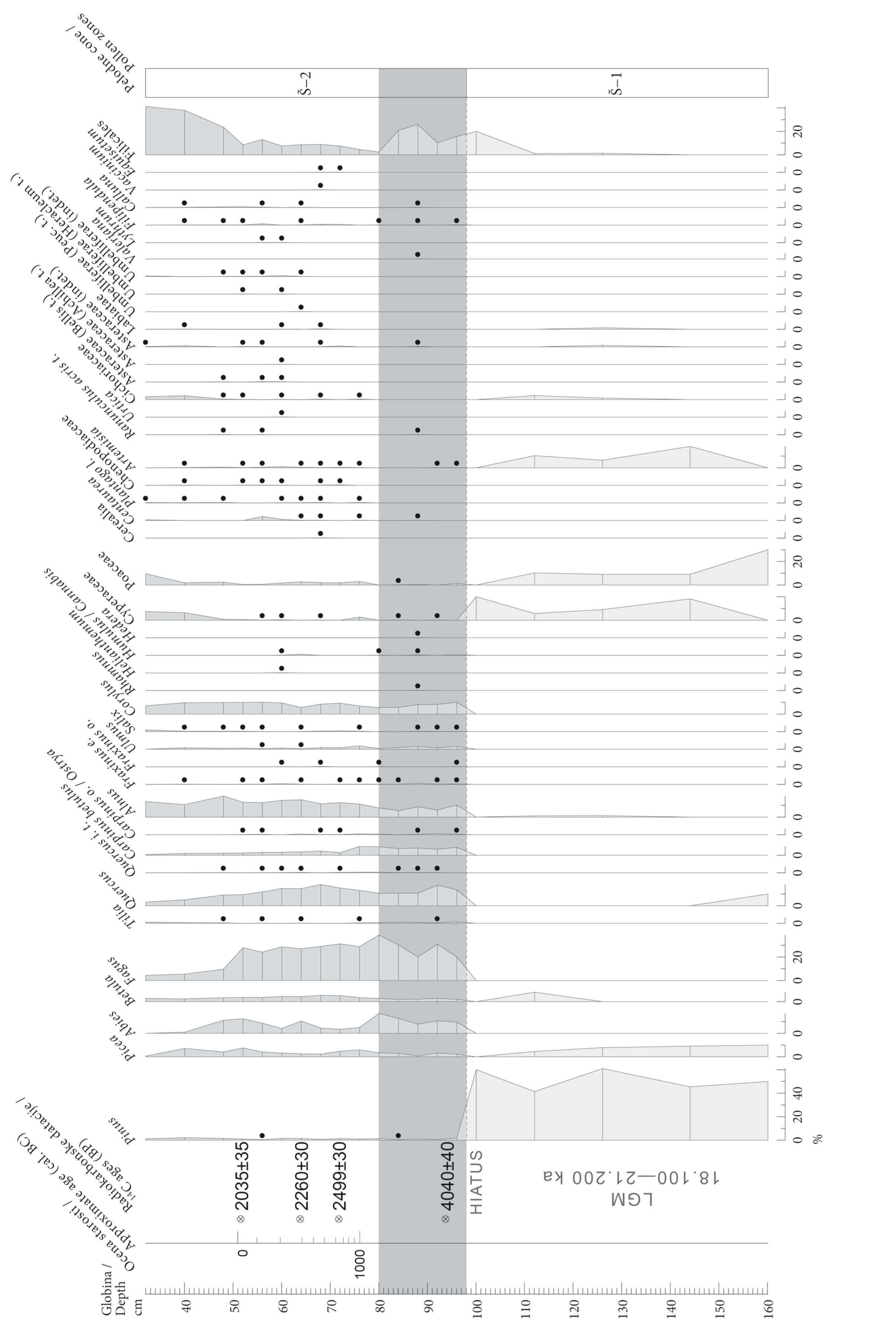
na Špici povezujemo z nizko produkcijo peloda maloštevilnih rastlin, ki so med zadnjo poledenitvijo rasle v hladni klimi, pa tudi z razmeroma hitrim odlaganjem sedimenta v tem delu profila. Ker vzorci vsebujejo visok odstotek degradiranega peloda, lahko sklepamo, da je morda prihajalo tudi do premeščanja sedimenta.

Laminiran meljast sediment, ki ga najdemo tudi drugje na Ljubljanskem barju (Verbič 2011), se je odlagal v stoječi jezerski vodi. Bližina nekdanjega čela savskega prodnega glaciofluvialnega vršaja (Verbič 2011) je verjetno razlog za sorazmerno hitro sedimentacijo laminiranega meljastega sedimenta. Vmesne plasti debelozrnatega peska v profilih SPI1 in SPI2 kažejo na terigen aluvialen sedimenten dotok. Strukturne in teksturne lastnosti sedimentov na Špici tako kažejo na rob jezerskega okolja, v katerega se je, verjetno iz jugovzhodne smeri, iz smeri Rakovnika, izlival manjši vodotok.

Okolje v času poznoeneolitske naselbine na Špici (pribl. 2500 pr. n. št.)

V okolici poznoeneolitske naselbine na Špici, ki jo glede na radiokarbonsko datacijo (*sl. 4*; Poz-45540, 2 sigma razpon: 2840–2469 cal. BC) in arheološko tipologijo (glej poglavje Raziskovano območje in arheološka izkopavanja) datiramo v sredino 3. tisočletja pr. n. št., so uspevali mešani gozdovi. Glavne drevesne vrste so bile bukev (*Fagus*), jelka (*Abies*), hrast (*Quercus*) in navadni gaber (*Carpinus b.*), kar je primerljivo z rastlinstvom, ki je uspevalo v okolici eneolitske naselbine Parte (7 km južno od Špice; Culiberg in Šercelj 1978). Ker je bil najden pelod vodnih rastlin in taksonov, ki so lahko uspevali na zamočvirjenih jezerskih ali rečnih bregovih (porečnik [*Alisma*], ježek [*Sparganium*], rmanec [*Myriophyllum*], jelša [*Alnus*] in močvirska krpača [*Thelypteris palustris*]), sklepamo, da je bila okolica Špice porasčena z obrežno (vlagoljubno) vegetacijo. Vpliv človeka na okolje je bil zmeren (upad peloda dreves na globini 88 cm; *sl. 10*), zaznamo tudi šibke sledove poljedelskih aktivnosti (pojav ruderalnih rastlin in njivskih plevelov, npr. pelin [*Artemisia*] in glavinec [*Centaurea*]). V arheološki kulturni plasti (98–80 cm) nismo odkrili peloda žit, kar je presenetljivo in v nasprotju z ostalimi sočasnimi (Parte) in starejšimi koliščarskimi naselbinami (4. tisočletje pr. n. št.: Maharski prekop, Stare gmajne, Blatna Brezovica) na Ljubljanskem barju. Na vseh omenjenih naselbinah je bil pelod žit odkrit v kulturnih plasteh, skupaj z zelo izrazitimi sledovi človekovega vpliva na okolje (npr. upad peloda dreves zaradi izsekavanja gozda ter pojav peloda kulturnih rastlin in pašnih indikatorjev; Culiberg, Šercelj 1978; Golyeva, Andrič 2014; Andrič, v pripravi[4]). Eden od vzrokov za odsotnost peloda žit so lahko manj intenzivne poljedelske (in bolj intenzivne metalurške) aktivnosti na Špici, na kar kažejo številna orodja za predelavo in vlivanje bakra (Šinkovec 2012). Te delavnice so verjetno uporabljale les iz gozda, ki je poraščal bližnji Grajski grič in Golovec. Drugi razlog za odsotnost peloda žit je lahko tudi ta, da vzorci za pelodno analizo morda niso bili vzeti iz tal hiše oz. območja, ki so ga uporabljali za shranjevanje in pripravo hrane, zato je samo na osnovi rezultatov pelodne analize pomen poljedelskega gospodarstva naselbine lahko podcenjen. Vrsto in intenzivnost poljedelskih aktivnosti na Špici bo zato možno podrobneje rekonstruirati le z nadaljnjimi arheobotaničnimi raziskavami.

[4] Glej op. 1.



Sl. 10: Špica. Pelodni diagram. LGM = pleistocenski sediment.

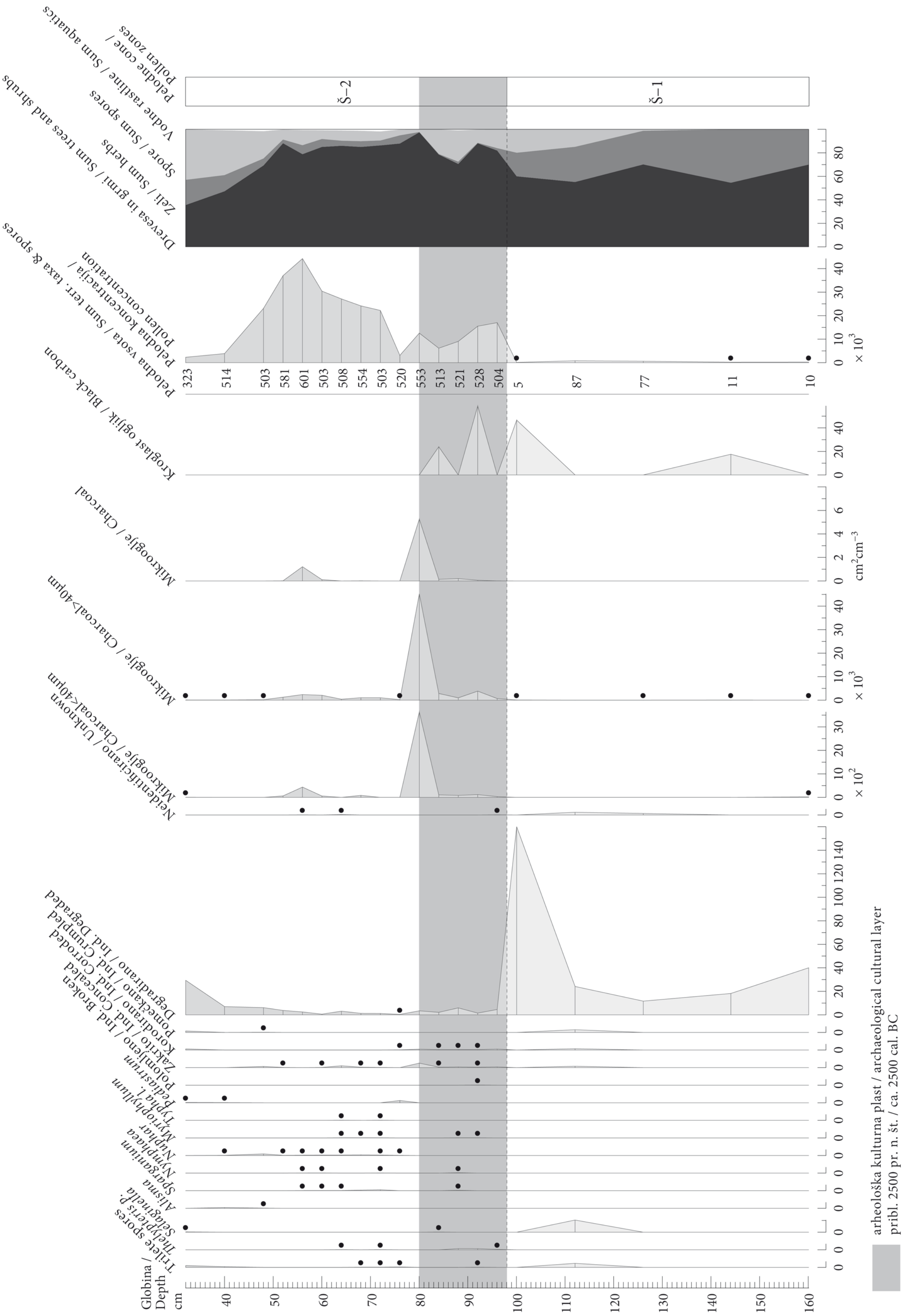


Fig. 10: Špica. Percentage pollen diagram. LGM = Pleistocene sediment.

Spremembe okolja in človekov vpliv na vegetacijo po opustitvi naselbine

Spremembe okolja takoj po opustitvi naselbine je zaradi slabe kronološke kontrole in počasnega odlaganja sedimenta, o čemer sklepamo na osnovi radiokarbonskih datacij (*sl. 4*), težko rekonstruirati. Bronastodobni sediment nad arheološko kulturno plastjo na globini 76 cm vsebuje veliko mineralnih snovi in le zelo malo peloda. Na pelodnem diagramu so opazni šibki sledovi človekovega vpliva na okolje (ozkolistni tropotec [*Plantago l.*], glavinec [*Centaurea*], pelin [*Artemisia*]), odstotka peloda jelke (*Abies*) in bukve (*Fagus*) se nekoliko zmanjšata, kar je (poleg človekovega vpliva) lahko posledica bolj suhe klime. Morda se je ta del profila (80–76 cm) odlagal v bolj suhih razmerah (nad nivojem talne vode), ko so se pojavljale le sezonske poplave. Tudi multidisciplinarne raziskave na drugih paleoekoloških najdiščih po Evropi in v Sloveniji kažejo, da je bila (zgodnje)bronastodobna klima verjetno sušna (npr. Magny 2004; Bohinjsko jezero: Andrič et al., neobjavljeni podatki).

V zgornjem delu profila (72–32 cm) boljša kronološka kontrola ter večja hitrost sedimentacije (in posledično večja resolucija vzorčenja) omogočata nekoliko natančnejšo rekonstrukcijo paleookoljskih razmer. Sledovi človekovega vpliva na okolje se okrepijo v železni dobi. Bronastodobnemu upadu bukve (*Fagus*) in jelke (*Abies*, ki je občutljiva za pašo, Tinner et al. 1999; 2000; Nagel et al. 2015) sta v železni dobi (vzorec na globini 72 cm; Poz-55943; 2 sigma razpon: 787–536 cal. BC) sledila upad navadnega gabra (*Carpinus b.*) in pojav pašnih indikatorjev (ozkolistni trpotec [*Plantago l.]*), rastlin, značilnih za (opuščena) polja in ruderalna tla (*Centaurea*, Chenopodiaceae, *Artemisia*), ter peloda žit (pribl. 450 pr. n. št. = 592–372 pr. n. št.), kar nakazuje kmetijske aktivnosti. Večje izsekavanje bukovega gozda se začne kasneje, v poznolatenskem ali zgodnjerimskem obdobju (najverjetneje v drugi polovici 1. st. pr. n. št., radiokarbonska datacija vzorca na globini 52 cm upad bukve s 95-odstotno verjetnostjo postavlja v obdobje med 162 pr. n. št. in 52 n. št., glej verjetnostno razporeditev na *sl. 5*, mediana: 39 cal. BC; *sl. 4*).

Zgoraj omenjene sledove izrabe okolja lahko povežemo z bližnjimi arheološkimi najdišči. Čeprav po opustitvi poznoeneolitske naselbine Špica ni bila več poseljena, o navzočnosti človeka na tem mestu pričajo posamične najdbe poznobronastodobnih in rimskodobnih artefaktov (Šinkovec 2012). Arheološke raziskave na Prulah (pribl. 500 m severozahodno od Špice) so pokazale, da je bilo obrežje Ljubljanice v uporabi v pozni bronasti (1400/1200–800 pr. n. št.), starejši železni (600–300/200 pr. n. št.) in rimski dobi (začetek 1. st. n. št.) (Žerjal et al. 2012). Tudi arheološka izkopavanja na Tribuni, ki leži pribl. 500 m severno od Špice, so razkrila ostanke poznobronastodobne/starejšeželeznodobne (1050–400 pr. n. št.) in latenske naselbine (3.–1. st. pr. n. št.) ter rimskega vojaškega tabora (konec 1. st. pr. n. št–začetek 1. st. n. št. (Vojaković et al. 2011; Vojaković 2013). Izsekavanje gozda in kmetovanje, ki ga vidimo na našem pelodnem diagramu, torej lahko povežemo z železnodobno naselbino, medtem ko je bil bukov gozd posekan v prvem stoletju pred našim štetjem, kar sovpada s postavitvijo rimskega vojaškega tabora.

Rezultati paleoekoloških raziskav na Špici so omogočili prvo rekonstrukcijo razvoja prazgodovinske vegetacije na območju današnjega mesta Ljubljane. Zaradi pomanjkanja paleoekoloških raziskav v regiji le težko orišemo podrobno sliko okoljskih sprememb na širšem območju. Na najbližjem primerljivem arheološkem najdišču Vrhnika – Dolge njive (pribl. 20 km zahodno od Ljubljane), kjer je pelodni profil datiran v 1. tisočletje pr. n. št., rezultati palinološke raziskave kažejo, da je v okolici Vrhnike enako kot v Ljubljani uspeval mešani gozd (bukev, hrast, jelka in navadni gaber), podobno kot na Špici smo zaznali tudi močne sledove poljedelstva in paše v železni dobi (Andrič 2016). Na obeh najdiščih se je močno izsekavanje gozda začelo v 1. st. pr. n. št., hkrati s porastom rimskih gospodarskih in vojaških aktivnosti. Podoben trend v razvoju vegetacije (krčenje gozda po ok. 300–200 pr. n. št.) se kaže tudi na južnem delu Ljubljanskega barja (Podpeško jezero in Resnikov prekop; Gardner 1997; 1999; Andrič 2006).

ZAKLJUČEK

Rezultati paleoekološke raziskave so pokazali, da vpliv poznoeneolitskih prebivalcev naselja na Špici na okolje ni bil zelo intenziven. Glavna vzroka za naselitev na tem mestu so bile verjetno dobre transportne poti in zaloge lesa (gozd na Grajskem griču in Golovcu), potrebne za metalurške dejavnosti. Kasneje, v bronasti in še zlasti v železni dobi, so se poljedelske aktivnosti okrepile, polja in pašniki so bili verjetno locirani v bližini Špice, medtem ko se je večje izsekavanje gozda začelo šele v drugi polovici prvega stoletja pr. n. št. Pelod v mlajših plasteh zaradi suhih hidroloških razmer ni ohranjen.

Rezultati, predstavljeni v tem članku, imajo metodološke, tafonomske in paleookoljske implikacije. Tafonomski procesi so močno vplivali na odlaganje in ohranjenost sedimenta na obrežju Ljubljanice. Raziskava je pokazala, da je velik del stratigrafske sekvence, ki se je na Špici odlagala v obdobju med 18.000 in 2500 pr. n. št., erodiran. V preostalih prazgodovinskih plasteh, ki ležijo nad ledenodobnim sedimentom in so se odlagale od sredine 3. tisočletja pr. n. št., je pelod dobro ohranjen. Izjema je le zgornji del sekvence, ki se je verjetno odlagal od 1. st. n. št. in kjer so bile hidrološke razmere za ohranitev peloda presuhe. Raziskave so torej pokazale, da je sedimentno zaporedje na Špici močno fragmentirano, vendar je pelod v nekaterih delih stratigrafskega stolpca dobro ohranjen. Upamo, da bomo z nadaljnjo analizo ostalih sekvenc v regiji (Prule, Tribuna, Krojaška ulica) lahko sestavili mozaik paleookoljskih informacij, s pomočjo katerih bomo lahko rekonstruirali nekdanje rastlinstvo, okolje in človekov vpliv nanj tudi za daljša časovna obdobja.

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Embankment of the Ljubljanica River at Špica (Ljubljana) and human impact on the environment in late prehistory

Translation

Introduction

Ljubljansko barje, a marshy area south of the city of Ljubljana, is well known for its numerous Eneolithic pile dwelling settlements, dated to the 5th–3rd millennia cal. BC (Velušček 2009 and references cited there) and studies of their environment (Šercelj 1966; Culiberg, Šercelj 1978; Šercelj 1996 and references cited there; Jeraj 2004; Toškan, Dirjec 2004; Andrič et al. 2008; Turk, Horvat 2009; Verbič 2011; Tolar et al. 2011; Andrič, in preparation[1]). However, detailed palaeo-environmental conditions for the last 4500 years of the Holocene are only poorly investigated. Palaeo-ecological records, dated after ca. 2500 cal. BC are missing, because younger peat layers at Ljubljansko barje were destroyed in the 18th/19th centuries AD, when peat was cut and burnt to drain the area (Melik 1927; Andrič et al. 2008). Only very few sequences, with which the development of vegetation after 2500 cal. BC could be investigated, remained (e.g. the lake Podpeško jezero; Gardner 1999).

Furthermore, the palaeo-environment (and until recently the archaeological settlement pattern) in the city of Ljubljana has been scarcely investigated. There are several reasons for this state of research, including taphonomic conditions and lack of funding for palaeo-ecological research. In urban, hydrologically dry parts of Ljubljana, sediment suitable for palynological/palaeo-ecological research is scarce and sedimentary sequences were frequently damaged by building activities. In recent years, archaeological excavations in Ljubljana have revealed numerous new archaeological sites (e.g. Vojaković et al. 2011; Žerjal et al. 2012[2]), but data about past environments of these settlements, their economy, and their impact on the vegetation remain very rare. Some of the sedimentary sequences from new archaeological sites are only partly suitable for pollen analysis, but by combining pollen and geological results from several sites (e.g. Špica, Tribuna, Prule and, Krojaška ulica on the right bank of the Ljubljanica River) it will be also possible to reconstruct the environmental history for longer periods. In this paper, the results of palynological, geological, and palaeo-botanical investigations at the first study site, Špica, will be presented, and environmental conditions in the Late Prehistory (ca. 2500–50 cal. BC, see age-depth model: *Figs. 5; 9* and *10*) will be discussed.

STUDY AREA AND ARCHAEOLOGICAL EXCAVATIONS

The study area is in central Slovenia, in the northern part of the Ljubljansko barje tectonic basin (*Fig. 1*; 46°02'25"N, 14°30'41"E, GKY 462555, GKX 99678), which lies on predominantly carbonate bedrock. Triassic and Jurassic limestones and dolomites are in the southern and western parts of the basin, whereas Palaeozoic sandstones, conglomerates, shales and limestones prevail in the north and east (Mencej 1989). The climate at Ljubljansko barje today is temperate-continental, with total mean annual precipitation 1000–1300 mm and a sub-continental precipitation regime (Ogrin 1996). The area is covered by a dense river network, meadows and fields, and patchy woodlands of *Pinus, Betula, Alnus, Quercus robur* and *Fagus* forests surrounding the polje (Čarni et al. 2003).

Lying at W-E crossroads connecting Italy with the Balkans, Ljubljana has a significant geostrategic position. The area was settled from the late Bronze Age on, when people were living on the right side of the Ljubljanica River (Grajski grič and Prule, with cemeteries on the left bank of the Ljubljanica: SAZU, NUK II). Archaeological excavations revealed that in the Iron Age a settlement presumably covered a large area (most probably >10 ha), including Tribuna and Gornji/Stari trg suburbia, with craftsmen and merchants (Vojaković, 2013, 361). The Roman military fortified settlement and camp at Tribuna, was constructed to support military troops towards the end of the 1st century cal. BC. The camp was in the vicinity of a port on the bank of the Ljubljanica River at Prule until the beginning of 1st century AD (Gaspari et al. 2014).

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[1] M. Andrič, *Stare gmajne settlement and the vegetation of Ljubljansko barje in the 4th millennium cal. BC.*

[2] T. Žerjal, M. Černe, T. Nanut, T. Verbič, unpublished Report (Prule in Ljubljana), Ljubljana 2012.

Špica (290 m a.s.l.) is located at the edge of Ljubljana, west of Golovec Hill, on the right bank of the Ljubljanica River, at the junction with Gruberjev prekop (canal), which was dug in the 18th century AD to protect Ljubljana from flooding (*Fig. 1*). In the last three centuries, the area has been affected by numerous building activities during the construction of the Gruberjev prekop and the regulations of the Ljubljanica riverbed. Rescue archaeological excavations, which were organized before the renovation of the embankment in 2010, revealed that a 5–40 cm thick archaeological cultural layer, and wooden structures were still preserved in most of the excavation area (Klasinc et al. 2010[3]; Šinkovec 2012). Pottery that was found at Špica shows similarities to other Late Copper Age archaeological settlements at Ljubljansko barje (Parte and Založnica: dendrochronologically and C14 dated to late 26th/25th century BC, Somogyvár-Vinkovci culture; Dežman's pile-dwellings near Ig: first half and mid-3rd millennium cal. BC, Vučedol, Somogyvár-Vinkovci and Ljubljana cultures; Velušček et al. 2000; Velušček, Čufar 2003; Korošec; Korošec 1969; Velušček, Čufar 2014). Therefore, according to archaeological typology, the Špica settlement is dated to the Late Copper Age (ca. 2500 cal. BC; Šinkovec 2012). Copper artefacts and tools for processing and casting copper were also discovered (Šinkovec 2012).

Methods

Three samples for pollen analysis, granulometry, and luminescence dating (stratigraphic columns P, SPI1 and SPI 2; *Fig. 1*) were collected at the Špica study site. Samples for pollen analysis were collected from the western profile of the archaeological trench (*Fig. 1*). A 130 cm long sedimentary column was collected from the profile using metal boxes (ca. 7 × 7 × 50 cm; *Fig. 2*). Sediment in the top 30 cm of the profile (which was oxidized and thus unsuitable for pollen analysis) was not collected. The sedimentary column was wrapped in a cling film, aluminium foil and thick plastic sheeting and stored in a coldstore at +4 °C.

Sample SPI1 for luminescence dating and grain size measurements was picked from the same profile, whereas sample SPI2 was collected from a profile at the southernmost part of the excavation area (*Fig. 1*). Luminescence dating was performed in the laboratory of the Institute of Applied Geology at the University of Natural Resources and Life Sciences (BOKU) in Vienna. Sample SPI1 was measured using the coarse grain quartz fraction and applying a standard OSL SAR protocol (Murray and Wintle 2000; 2003) with preheat-cutheat temperatures of 260 and 220 °C. For both samples, SPI1 and SPI2, quartz luminescence signals were very dim. Therefore, the second sample SPI2 was measured using the coarse grain, K-rich feldspar fraction, applying a postIR-IRSL protocol. In this case, preheat temperatures of 250 °C, IRSL temperatures of 50 °C, and post-IRSL temperatures of 225 °C (Buylaert et al. 2009) were used. All measurements were performed on a Risø luminescence reader TL-DA 15, using aliquots with a mask size of 2 mm.

For grain size measurement 100 g of sediment were soaked for 48 hours in distilled water, suspended in an ultrasound bath and wet sieved through 0.1 mm sieves to remove particles >0.1 mm. Grain size measurement of the remaining sample (84.9 g) was performed with laser particle size analyser Fritsch Analysette 22 at the Geological Survey of Slovenia.

The percentage of organic material, carbonates and the remaining inorganic material in the sediment of the palynological profile was determined by loss-on-ignition analysis at 550 °C and 950 °C (Bengtsson, Ennell 1986), with 4 cm resolution throughout most of the profile.

2–3 cm^3 subsamples of sediment for C-14 dating from selected sections of the profile were gently treated with distilled water and examined under a Leica MZ75 stereomicroscope at 50× magnification. Plant macro-remains were picked out, sorted, identified and sent for radiocarbon dating.

For pollen analysis, 1 cm^3 of sediment was subsampled with a 4-cm resolution throughout most of the profile. A standard laboratory procedure was used (HCl, NaOH, HF, acetolysis, staining with safranine, mounting in silicone oil: Bennett, Willis 2002) and pollen concentration was determined by adding *Lycopodium* spores (Stockmarr 1971). The pollen was identified using a Nikon Eclipse E400 light microscope at 400× magnification, pollen reference collection at the Institute of Archaeology ZRC SAZU in Ljubljana and pollen keys (Reille 1992; 1995; Moore, Webb, Collinson 1991). A minimum of 500 pollen grains of terrestrial taxa and spores (= pollen sum) was counted in each sample. The concentration of microscopic charcoal

[3] R. Klasinc, M. Ravnik, J. Kusetič, M. Jančar, S. Vučković, unpoblished Report (Špica in Ljubljana), Kranj 2010.

was established using two methods: microscopic charcoal (in two size classes, <40 µm and >40 µm) was counted along with pollen and, in addition to this, a Clark's (1982) point count method was used. The pollen and "loss-on-ignition" data were analysed and plotted using the PSIMPOLL 3.00 software (Bennett 1998; PSIMPOLL website 2006). The resulting pollen diagram (*Fig. 10*) was divided into two statistically significant zones using binary splitting by the sum of squares. Values lower than 0.5 are marked with a solid dot. The archaeological cultural layer is marked by a shaded bar.

The age model for the section of stratigraphic column above the archaeological cultural layer, which is based on linear interpolation (using median values of radiocarbon dates; *Figs. 4; 5*), is shown also on loss-on-ignition (*Fig. 9*) and pollen (*Fig. 10*) diagrams. Not all radiocarbon dates were used for age-depth modelling. Unidentified plant material found in sediment of LGM age (see the results of luminescence dating; *Fig. 3*) at 112 cm (Poz-45538) presumably derives from younger roots or other plant material that sunk into much older sediment. Bud material, found at 64 cm (Poz-45541) did not yield enough carbon (0.15 mg) and was not used for age-depth modelling (*Figs. 5; 9; 10*). Two-sigma ranges of all radiocarbon dates were added to *Fig. 4*, whereas estimated accuracy of age model is marked on *Fig. 5*.

RESULTS

Chronology

The results of luminescence dating (*Fig. 3*; stratigraphic columns SPI1 and SPI2, which is located in vicinity of pollen column, were analysed; *Fig. 1*) indicate that the sediment at the bottom of the sequence (100–160 cm) was deposited during the Last Glacial Maximum (LGM, ca. 18.1–21.2 ka). The archaeological cultural layer in pollen stratigraphic column P, which is located above the LGM sediment, at ca. 80–98 cm depth, is much younger and is radiocarbon dated to ca. 2500 cal. BC (*Figs. 2; 4; 5*). The sedimentary hiatus between the LGM sediment and archaeological cultural layer (ca. 20 ka–2500 cal. BC) at 99 cm is probably a consequence of fluvial activity (one or several events in the Late glacial and early/mid Holocene).

Radiocarbon dates (*Figs. 4; 5*) suggest that the sedimentation rate immediately above the archaeological cultural layer (80–72 cm) was presumably extremely slow (0.01 cm/yr) due to drier hydrological conditions, suggested by low pollen concentration and high percentage of inorganic material (*Figs. 5; 9; 10*). No traces of erosion were detected; therefore, it is not very likely (but not completely ruled out) that part of the sediment was removed by water. The sediment in the upper part of the palynological profile (72–52 cm) was deposited in the Iron Age, most probably between ca. 650–50 cal. BC (which is, according to the age model on *Fig. 5;* between 787–536 cal. BC and 162 cal. BC–AD 52), whereas the top 22 cm of the profile was not radiocarbon dated due to the high percentage of degraded pollen and low pollen concentration.

Sediment composition

The Pleistocene (LGM) part of the sedimentary sequence consists mostly of silty sediment (*Figs. 6–8*), with around 50% of the grains between 2 and 63 µm, 15% are clay sized grains and 35% is fine sand (*Fig. 8*). The sediment has a light to medium grey colour and is thinly (2–15 mm thick) laminated. Lamination could be noticed through colour variations. At the southern part of the excavation area, silty sediments are intercalated with medium to coarse grained sand layers up to 10 cm thick.

The Pleistocene sediment in the pollen zone Š-1 (stratigraphic column P; *Fig. 9*) contains ca. 20% of carbonates, 70–80% of remaining inorganic material (mostly quartz grains), and very low percentage of organic material (ca. 5% of sediment dry weight).

In the archaeological cultural layer (Š-2, 98–80 cm) the percentage of organic material increases to 20–35%, whereas the percentage of remaining inorganic material decreases to 50–70%. The percentage of carbonates remains unchanged. The sediment at 76 cm contains only ca. 10% of organic and more than 80% of remaining inorganic material. In the upper part of zone Š-2 (72–32 cm), the percentage of carbonates is very low (<5%), organic material decreases (from ca. 45% at 72 cm to 10% at 48–32 cm) and inorganic material increases (from ca. 60 to 90%) towards the top of the sequence.

Pollen analysis

The pollen diagram (*Fig. 10*) is divided into two pollen zones (Š-1 and Š-2). In the pollen zone Š-1 (98–160 cm; LGM, luminescence dating of profiles

SPI1 and SPI2: ca. 18.1–21.2 ka), the percentage of degraded pollen is high (>10%) and the pollen concentration is very low (<1000 grains cm^{-3}); therefore, it was not possible to reach the standard (≥300) pollen sum. The main taxa present are pine (*Pinus*), spruce (*Picea*), sedges (Cyperaceae), grasses (Poaceae) and mugwort (*Artemisia*).

Pollen concentration and preservation improve in the pollen zone Š-2. In the lower part of that zone (98–30 cm), the concentration of pollen in the archaeological cultural layer (98–80 cm) increases to ca. 5000–15.000 pollen grains per 1 cm^3 of sediment, whereas the percentage of degraded pollen is low. Tree taxa, including beech (*Fagus*), fir (*Abies*), oak (*Quercus*), hornbeam (*Carpinus b.*), alder (*Alnus*) and hazel (*Corylus*) prevail with 70–95%, whereas herb taxa are less numerous (e.g. monolete fern spores [Filicales] and grasses [Poaceae]). The concentration of microscopic charcoal increases at 80 cm. In the middle part of zone Š-2 (76–56 cm) the percentage of fir (*Abies*) and hornbeam (*Carpinus b.*) decreases, whereas anthropogenic indicator taxa, characteristic for fields, ruderal surfaces and pastures, such as cereals (Cerealia), knapweeds (*Centaurea*), goosefoot (Chenopodiaceae), mugwort (*Artemisia*), and ribwort plantain (*Plantago l.*), appear more frequently. Towards the top of the pollen zone Š-2 (52–32 cm) the percentage of tree taxa (e.g. *Fagus*) decreases to ca. 10%. Low pollen concentration, and >20% of degraded pollen indicate that pollen record at 32 cm was affected by selective pollen degradation.

DISCUSSION

Palaeo-environmental conditions during the last glacial maximum (ca. 20 ka)

The results of the pollen analysis match with all palynological research to date (Šercelj 1996 and references cited there), suggesting that the area was covered by cold steppe/tundra/taiga with individual tree stands including pine (*Pinus*), spruce (*Picea*), birch (*Betula*), oak (*Quercus*), alder (*Alnus*) and herbs (grasses [Poaceae], mugwort [*Artemisia]*). Low pollen concentration at Špica is partly a consequence of low pollen production of a small number of plants growing in cold climates during the Last Glacial Maximum and presumably also a rather fast sedimentation rate. The high percentage of degraded pollen may also suggest that the sediment was redeposited.

Laminated silty sediment, which is also present elsewhere at Ljubljansko barje (Verbič 2011), was deposited in a standing lake water. The proximity of the former front of the Sava gravel glaciofluvial fan that has flowed into the lake (Verbič 2011) is probably the reason for the relatively rapid sedimentation of the laminated silty sediment. Intercalated layers of coarse sand in profiles SPI1 and SPI2 indicate a terrigenous alluvial sediment inflow. The structural and textural properties of sediments at Špica suggest an environment on the edge of the lake in which it is, probably from the south-east (Rakovnik), pouring a small stream.

The environment of the Late Copper Age settlement at Špica (ca. 2500 cal. BC)

The Late Copper Age settlement at Špica, which is according to radiocarbon date (*Fig. 4*; Poz-45540, 2 sigma range: 2840–2469 cal. BC) and archaeological typology (see chapter Study area and archaeological excavations) dated to the middle of the 3rd millennium cal. BC, was surrounded by mixed forests. The main tree taxa were beech (*Fagus*), fir (*Abies*), oak (*Quercus*) and hornbeam (*Carpinus b.*), which is comparable with the vegetation growing around Copper Age settlement Parti (located ca. 7 km south of Špica; Culiberg, Šercelj 1978). The marshy (wetland/lakeshore) environment around the Ljubljanica River is indicated by alder (*Alnus*), marsh fern (*Thelypteris palustris*), and pollen of aquatic taxa, such as water plantain (*Alisma*), burr reed (*Sparganium*) and water milfoil (*Myriophyllum*). Human impact on the environment was moderate (decline of tree pollen at 88 cm; *Fig. 10*), with very weak traces of agricultural activities (pollen of ruderal plants and weeds. e.g. mugwort [*Artemisia*] and cornflower [*Centaurea*]). Surprisingly, no cereal-type pollen was found in the archaeological cultural layer (98–80 cm) at Špica, which is in contrast to other Late Copper Age (Parte) and older, 4th millennium cal. BC pile-dwelling settlements at Ljubljansko barje (Maharski prekop, Stare gmajne, Blatna Brezovica). On these archaeological sites, cereal-type pollen was discovered in cultural layers of all investigated settlements and traces of human impact on the environment were more pronounced (cultivated plants and grazing indicators, decline of tree pollen due to forest clearance; Culiberg, Šercelj 1978; Golyeva, Andrič 2014; Andrič, in preparation[4]). The lack of cereal pollen at Špica could be associated with less intensive agricultural (and more intensive metallurgical) activities, as suggested by numerous tools for processing and casting copper (Šinkovec 2012). Metallurgical workshops at Špica presumably used wood from forest growing on the neighbouring Grajski grič and Golovec hills. Another reason for the lack of cereal pollen could be that palynological samples were perhaps not collected within a house used for food preparation or storing; therefore, the significance of the agricultural economy in this settlement, based solely on pollen data, could be underestimated. Only with further archaeobotanical research at Špica, it will be possible to reconstruct the type and intensity of the Late Copper Age agricultural economy.

Environmental changes and human impact on the environment after the abandonment of the settlement

Due to poor chronological control (*Fig. 4*) and slow sedimentation rates, it is difficult to reconstruct environmental conditions after the abandonment of the settlement. Bronze Age sediment above the archaeological cultural layer (76 cm) has a very high mineral content and contains very little pollen. Weak traces of human impact on the environment were detected (*Fig. 10*; pollen of ribwort plantain [*Plantago l.*], knapweeds [*Centaurea*], mugwort [*Artemisia*]), whereas the percentages of fir (*Abies*) and beech (*Fagus*) pollen decrease, which can also be (in addition to human impact), triggered by drier climatic conditions. It is possible that this part of the sequence (80–76 cm) represents an environment above the water table with seasonal flooding events. Furthermore, multidisciplinary studies on other palaeo-ecological study sites suggest that (Early) Bronze Age climate was probably dry (e.g. Magny 2004; Lake Bohinj: Andrič et al., unpublished data).

Chronological control, sampling resolution, and estimates on the sedimentation rates improve in the upper part of the profile (72–32 cm). In the Iron Age, traces of human impact on the environment became more apparent. The decline of beech (*Fagus*) and fir (*Abies*, which is sensitive to grazing; Tinner et al. 1999; 2000; Nagel et al. 2015) in the Bronze Age was followed by a decline of hornbeam (*Carpinus b.*, sample at 72 cm depth, Poz-55943, 2 sigma range: 787–536 cal. BC) and the appearance of grazing indicators (ribwort plantain [*Plantago l.]*), plants characteristic for (abandoned) fields and ruderal ground (*Centaurea*, Chenopodiaceae, *Artemisia*), and cereal pollen (at ca. 450 cal. BC = 592–372 cal. BC), which can be associated with farming activities. A major clearance of beech forest is dated to the La Tène or Early Roman period (most probably in the second half of the 1st century cal. BC, radiocarbon date at 52 cm with 95% probability dates beech decline to 162 cal. BC–AD 52, see probability range on *Fig. 5*, median: 39 cal. BC; *Fig. 4*).

These traces of land-use can be associated with archaeological sites in the vicinity. Although the Copper Age settlement was not inhabited again, individual Late Bronze and Roman Age artefacts found at Špica suggest that the area was still frequented/used (Šinkovec 2012). Archaeological research at Prule (ca. 500 m north west from our study site) suggest that the embankment of the Ljubljanica River was used in the Late Bronze Age (ca. 1400–1200–800 cal. BC), Early Iron Age (ca. 600–400/200 cal. BC) and Roman Age (beginning of the 1st century BC) (Žerjal et al. 2012). Furthermore, archaeological excavations at Tribuna, located ca. 500 m to the north of Špica revealed remains of Late Bronze/Early Iron Age (ca. 1050–400 cal. BC) and La Tène (3rd–1st century BC) settlement and Roman Age military camp (end of the 1st century BC–beginning of the 1st century AD) (Vojaković et al. 2011; Vojaković 2013). Forest clearance and farming activities detected on our pollen diagram can be therefore associated with the Iron Age settlement, whereas beech forest was cut in the first century cal. BC, when the Roman military camp was constructed.

The results of palaeo-ecological research at Špica allow us for the first time to reconstruct the vegetation history in the area of the modern city of Ljubljana. Due to the lack of palaeo-ecological research in the area, it is difficult to outline a wider, regional pattern of environmental dynamics. Palynological research at the nearest comparable study site, at Vrhnika (located ca. 20 km south west of Ljubljana, pollen profile dated to the 1st millennium cal. BC), suggested a similar forest composition (mixed woodland with beech, oak, fir and hornbeam), with strong traces of cereal cultivation and grazing in the Iron Age (Andrič 2016). At both study sites, Špica and Vrhnika, forest clearance intensified in the 1st century cal.

[4] See fn. 1.

BC, which can be associated with an increase of Roman economic and military activities. Similar trends in the vegetation development (intensified forest clearance after ca. 300–200 cal. BC) were also detected in the southern part of Ljubljansko barje (the lake Podpeško jezero and Resnikov prekop archaeological site; Gardner 1997; 1999; Andrič 2006).

CONCLUSIONS

The results of palaeo-ecological research presented in this paper suggest that the impact of Late Copper Age farming activities on the environment of Špica was not very intensive. It is possible that the area was settled primarily because of good transport routes and wood resources (forest growing on Grajski grič and Golovec), which were needed for metallurgical activities. Later, in the Bronze and especially Iron Age, farming activities intensified, agricultural fields and grazing areas were possibly located in the vicinity of Špica. A major phase of forest clearance is dated in the second half of the first century BC, which supports the suggestion that a vegetation similar to that of the present-day had appeared in the Roman Age. Due to dry hydrological conditions, a younger pollen record is not preserved.

The results presented in this paper have methodological, taphonomical and palaeo-environmental implications. It was demonstrated that in the area of the modern city of Ljubljana the sediment on the bank of the Ljubljanica River was heavily affected by taphonomy. While a long section of sedimentary sequence at Špica (ca. 18,000–2500 cal. BC) is missing presumably due to water erosion, the pollen preservation in the remaining prehistoric layers, deposited after ca. 2500 cal. BC, is very good, with the exception of the upper part of the sequence (presumably deposited in the 1st century AD), where pollen is not preserved due to dry hydrological conditions. The results of our research have therefore shown that the sedimentary sequence at Špica is highly fragmented, but by analysing several sequences in the area (e.g. at Prule, Tribuna and Krojaška ulica), it will be possible to compile a mosaic of palaeo-environmental sequences and to reconstruct vegetation development and human impact on the environment throughout longer periods.

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