Paleookolje v Sloveniji in severnemu delu hrvaške Istre v pozni prazgodovini

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Izvleček

Uveljavitev poljedelsko-živinorejskega gospodarstva in prehod na metalurgijo v pozni prazgodovini sta, poleg klimatskih sprememb, močno vplivala na razvoj nekdanjega okolja. Kljub jasno vidnim spremembam paleookolja pa so vzroki za spremembe vegetacije in nastanek današnje kulturne krajine še nejasni. V članku predstavljeni rezultati palinološke analize treh paleoekoloških najdišč, ki so locirana v različnih fitogeografskih regijah Slovenije in severne Istre, kažejo, da je zaradi sekanja in požiganja gozda pokrajina v pozni prazgodovini postajala vse bolj odprta in raznolika, pojavile pa so se tudi spremembe v sestavi gozda. Porast jelke morda lahko povežemo z vlažnejšo klimo in manj intenzivno gozdno pašo.

Ključne besede: Slovenija, Hrvaška, bronasta doba, železna doba, arheologija, klima, paleoekologija, pelodna analiza

Abstract

In the late prehistory, climatic fluctuations and human activity associated with transition to farming and metallurgy triggered significant changes in vegetation and in the palaeoenvironment. However, the reasons for these vegetation changes and mechanisms, which led to the formation of present-day cultural landscape are still poorly understood. This paper presents the results of pollen analysis at three palaeoecological sites, located in four different phytogeographic regions of Slovenia and northern Istria. The results indicate that, while the landscape in late prehistory became increasingly open due to forest clearance and burning, the biodiversity also increased. Changes of forest composition also occurred, and the increase in fir pollen might be associated with increased precipitation and possibly less intensive forest pasture.

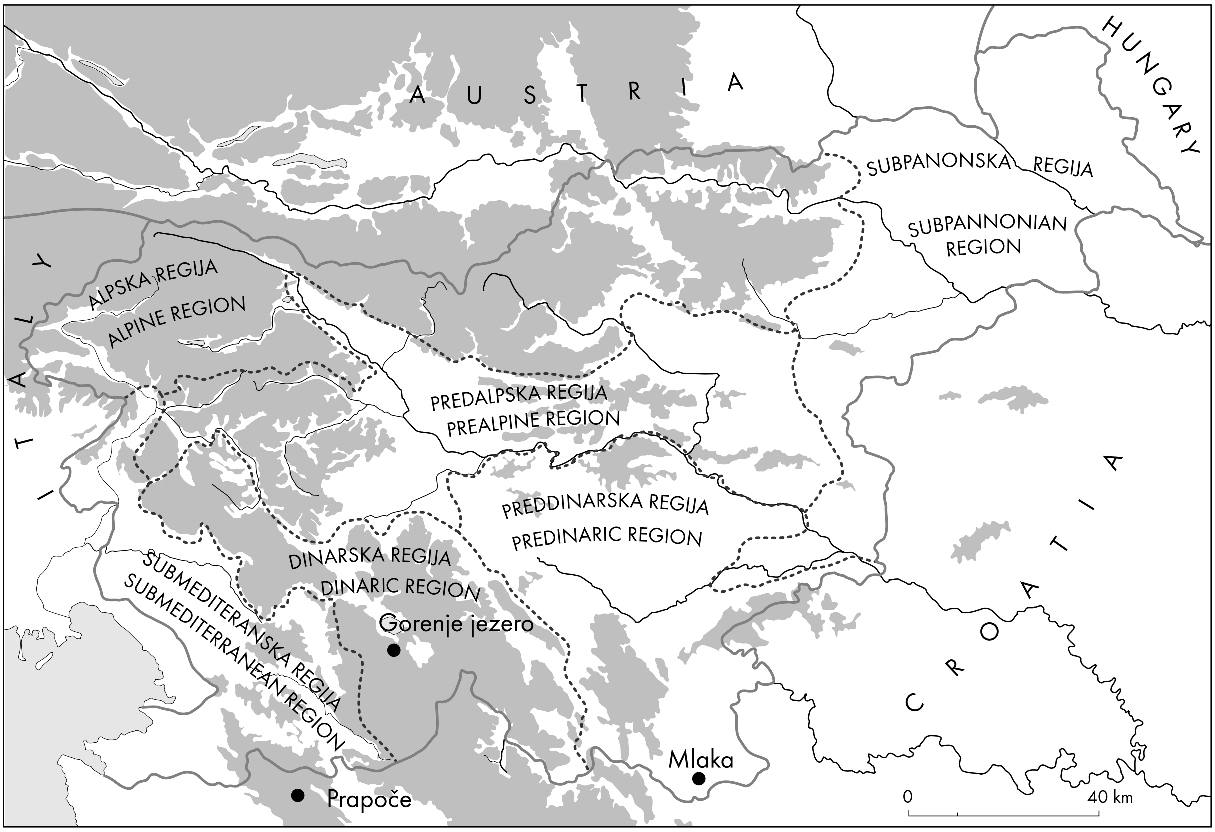
Keywords: Slovenia, Croatia, Bronze Age, Iron Age, archeaology, climate, paleoecology, pollen analysis

UVOD

Bronasta doba (2200-800 pr. n. št.) je obdobje, za katero so značilne močne spremembe arheološke materialne kulture, družbe in ekonomije, povezane z razvojem metalurgije in uveljavitvijo poljedelsko-živinorejskega gospodarstva. Dosedanje arheološke in paleoekološke raziskave v Evropi kažejo, da so bronastodobni kmetje gojili živali, ki so bile udomačene že v neolitiku (ovca, koza, svinja, govedo; Bökönyi 1974; Gerrard et al. 1996; Legge 1996; Hole 1996) in pridelovali širok spekter poljščin, kot so na primer pšenica, ječmen, proso, oves, stročnice in lan (Renfrew 1973; Zohary, Hopf 1993; Behre 1998). Čeprav se seznam udomačenih rastlin in živali v času od neolitika do bronaste dobe ni bistveno spremenil, pa sta kmetijska proizvodnja in gojenje domačih živali zaradi izrabe 'sekundarnih produktov', kot so mleko, sir, volna, gnoj, delovna sila za vleko rala in transport, v bronasti dobi postala intenzivnejša (Sherratt 1981, 1997; Harding 2000). Srednjeevropska bronasta doba je tudi obdobje, ko je bila živina pozimi verjetno prvič stalno nastanjena v hlevu, prvi stalni travniki pa se domnevno pojavijo šele na začetku železne dobe (*ca.* 800 pr. n. št.; Behre 1988; Behre, Jacomet 1991; Knörzer 1991; Behre 1998; Kalis et al. 2003). Zaradi ornega poljedelstva in sekanja gozda za potrebe proizvodnje keramike in metalurgije je človekov vpliv na okolje naraščal, tako da je že nekaj stoletij kasneje, v času grško-rimskega rudarjenja, dosegel globalne razsežnosti, na kar kaže povečana koncentracija bakra in svinca v grenlandskih ledenih vrtinah (Hong et al. 1994, 1996).

V kakšnem okolju pa so živeli bronastodobni prebivalci Slovenije? Zelo pomemben del paleookolja predstavlja nekdanja vegetacija, ki jo lahko rekonstruiramo s pomočjo analize cvetnega prahu, ki se je odlagal v močvirskih in jezerskih sedimentih. Dosedanje palinološke raziskave so pokazale, da je v poznem glacialu Slovenijo prekrival odprt, pretežno borovo-brezov gozd, ob otoplitvi in domnevno vlažnejši klimi na prehodu poznega glaciala v holocen pred *ca.* 11000 leti (Kutzbach et al. 1998) pa so se močneje razširili listavci, hrast, lipa, leska in brest (Culiberg 1991; Šercelj 1996). Druga večja sprememba vegetacije v Sloveniji je datirana v čas okrog 6800 pr. n. št., ko sta najpogostejši drevesni vrsti postali bukev in jelka (n.pr. Šercelj 1963, 1965, 1966, 1971, 1975, 1976, 1981-1982, 1988, 1996, Culiberg, Šercelj 1987; Culiberg, Šercelj 1980 a, b; Culiberg 1991; Andrič 2001, 2002). Ta razširitev sencovzdržnih drevesnih vrst na začetku 7. tisočletja pr. n. št. je verjetno povezana z regionalnimi spremembami klime, kot so na primer zmanjšanje kontinentalnosti klime v južnih Alpah (*ca.* 7100 pr. n. št., Tinner et al. 1999, Tinner, Ammann 2001), napredovanje ledenika Pasterze v avstrijskih Alpah 6900 pr. n. št., Nicolussi, Patzelt 2000) in domnevno tudi začetek pluvialnega obdobja na vzhodnojadranskem območju, datiranega v čas med 7000 in 4800 pr. n. št. (Schmidt et al. 2000). Zaradi vse močnejšega človekovega vpliva na okolje v drugi polovici holocena se je sestava gozda še spreminjala, na kar kaže porast hrasta in upad bukve in jelke na mnogih pelodnih diagramih (n.pr. Šercelj 1988; Culiberg, Šercelj 1991; Šercelj 1996; Gardner 1997). Človekov vpliv na vegetacijo v okolici bronastodobnih naselij je, na primer, viden na pelodnem diagramu iz Dolnjega Lakoša, kjer so leskova grmišča verjetno uspevala na še ne docela degradiranih pašnikih (Šercelj 1987, 1996).

Kakšno pa je bilo paleookolje bronastodobnega človeka v drugih delih Slovenije? Je bil razvoj vegetacije v Sloveniji enoten ali pa specifičen za posamezne fitogeografske regije? Kakšne so bile spremembe okolja ob prehodu na metalurgijo in v čem se paleookolje v bronasti dobi loči od neolitskega/eneolitskega in železnodobnega? Kako je domnevna klimatska sprememba v bronasti dobi (ohladitev in domnevna suha in topla faza v pozni bronasti dobi, n.pr. Lamb 1977, Jockenhövel 1998, Baillie 1998, Ložek 1998, Behre 1998) vplivala na vegetacijo in človekov način življenja? So neenotna kultura in poselitveni vzorec Slovenije (Dular 1999, Teržan 1999) ter spremembe paleookolja v bronasti dobi med seboj vzročno povezani? Oglejmo si razvoj okolja na treh paleoekoloških najdiščih.



Sl. 1: Fitogeografska delitev Slovenije (po Wrabru 1969) in lega paleoekoloških najdišč.
Fig. 1: Phytogeographic division of Slovenia (after Wraber 1969) and the position of study sites.

Tab. 1: Paleoekološka najdišča.
Table 1: Study sites.

Paleoekološko najdišče	Fitogeografska regija	Nadmorska višina
Prapoče	Submediteranska (Čičarija)	480 m
Gorenje jezero	Dinarska (Cerkniško jezero)	550 m
Mlaka	Preddinarska (Bela krajina)	140 m

PALEOEKOLOŠKA NAJDIŠČA IN RAZISKOVALNA METODOLOGIJA

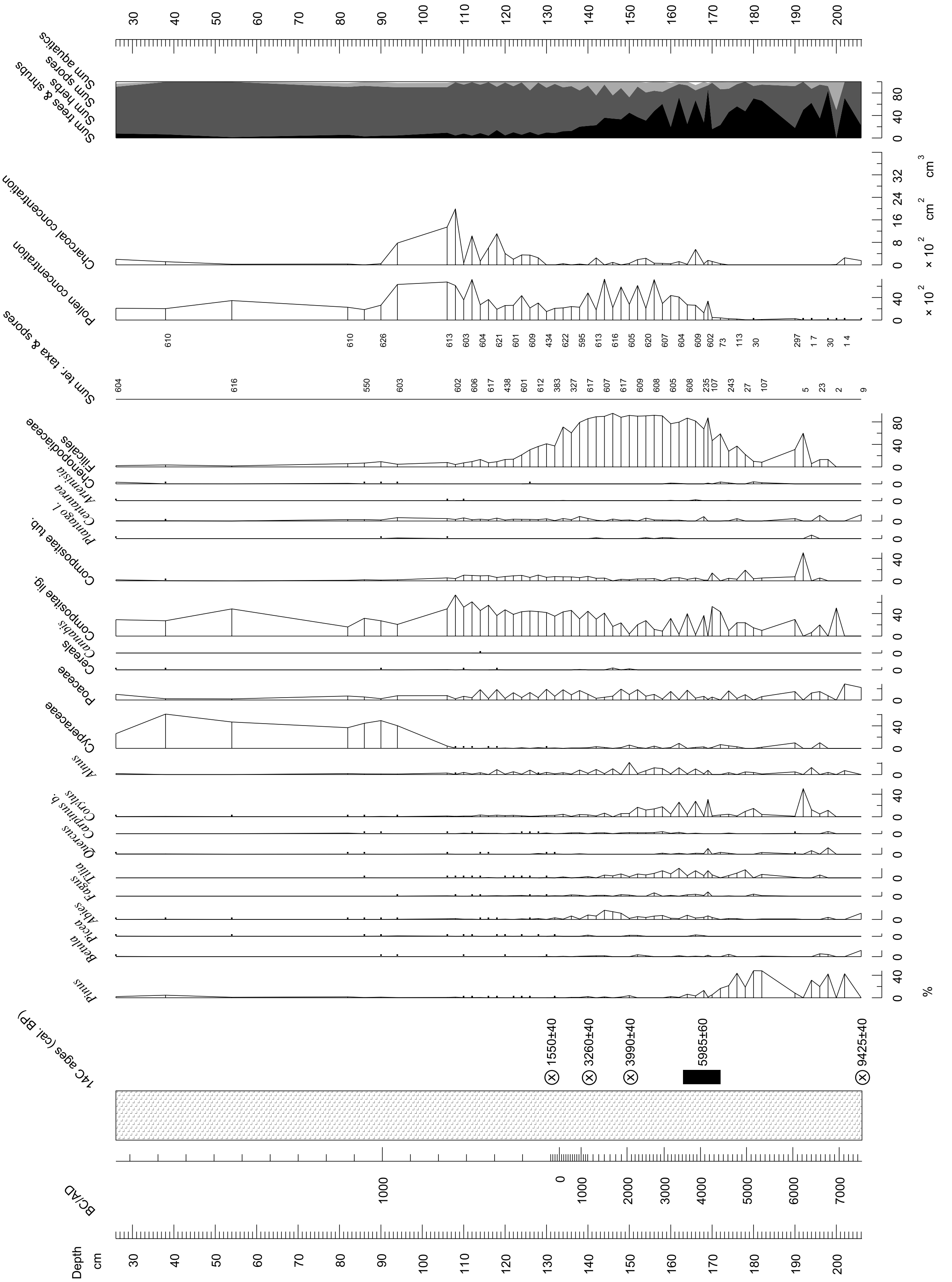
Izbrana paleoekološka najdišča (*tab. 1; sl. 1*), močvirja Prapoče (Čičarija, jugozahodna Hrvaška), Gorenje jezero (Cerkniško jezero) in Mlaka (Bela krajina) ležijo na območjih z različno klimo, od submediteranske v jugozahodni Sloveniji do kontinentalne-subpanonske klime v jugovzhodni Sloveniji (Ogrin 1996). Tudi relief, geološka podlaga in vegetacija na izbranih najdiščih so različni (Wraber 1969), v sedimentu ohranjeni pelodni zapis pa kaže, da je bila podobno raznolika tudi zgodovina razvoja vegetacije.

Na vsakem paleoekološkem najdišču je bilo opravljeno vzorčenje (vrtanje z vrtalnikom Livingston) ter analiza koncentracije mikrooglja, peloda in določanje starosti sedimenta s pomočjo radiokarbonskega datiranja (*tab. 2*). Uporabljena metodologija in rezultati raziskave so bili že predstavljeni (Andrič 2001, 2002, Andrič, Willis 2003), vendar pa je bilo tokrat v segmentu vrtine, ki se je odlagal v pozni prazgodovini, opravljeno dodatno radiokarbonsko datiranje, kar omogoča podrobnejšo predstavitev razvoja vegetacije. Izbrani rezultati raziskave so prikazani v obliki pelodnih diagramov, tokrat je na njih nekoliko podrobneje predstavljen tudi pelod zelišč (*sl. 2-4*). Na levi strani vsakega diagrama je prikazana globina vzorcev, sledita časovna skala in procentni delež za posamezne taksone. Ocena starosti sedimenta, prikazana na časovni skali, je bila določena z linearno interpolacijo med posameznimi radiokarbonskimi datumi (*tab. 2*), katerih pozicija je označena na diagramih. Vsak diagram se zaključi s krivuljama, ki prikazujeta koncentracijo mikrooglja in pa delež peloda dreves, zelišč, spor praproti in vodnih rastlin.

HOLOCENSKA IN BRONASTODOBNA VEGETACIJA

Podroben razvoj holocenske vegetacije na vseh treh najdiščih je bil predstavljen drugje (Andrič 2002, Andrič, Willis 2003), zato naj glavne izsledke pelodne analize le na kratko ponovim. V zgodnjem holocenu (*ca.* 8000-6800 pr. n. št.) je Slovenijo prekrivala razmeroma enotna vegetacija - pretežno listnati gozd, v katerem so uspevali hrast (*Quercus*), leska (*Corylus*), lipa (*Tilia*) in brest (*Ulmus*). Okrog 6800 pr. n. št. se je sestava gozda nenadoma močno spremenila, razširile so se sencovzdržne drevesne vrste, v osrednji Sloveniji pretežno jelka (*Abies*) in bukev (*Fagus)*, v severovzhodni in jugozahodni Sloveniji pa domnevno lipa (*Tilia*). Ta nenadna sprememba vegetacije je bila verjetno posledica klimatske spremembe (povečanje količine padavin). Na povečanje biodiverzitete in nastanek fitogeografskih regij Slovenije pa je verjetno vplival tudi vse močnejši človekov pritisk na okolje (Andrič, Willis 2003), ki je povzročil tudi nastanek današnje pokrajine nekaj tisočletij kasneje.

O nekem enotnem bronastodobnem paleookolju v Sloveniji torej ne moremo govoriti. V okolici Prapoč (Čičarija, SZ Hrvaška) je v tretjem tisočletju pr. n. št. uspeval pretežno lipov gozd. Pelodni zapis kaže, da so poleg lipe (*Tilia*) v okolici rastli tudi hrast (*Quercus*), beli gaber (*Carpinus betulus)*, leska (*Corylus)*, jelka (*Abies*) in bukev (*Fagus*); jelša (*Alnus*) pa je verjetno uspevala na močvirnem dnu doline. Na začetku drugega tisočletja pr. n. št. je pokrajina postajala vse bolj odprta - količina drevesnega peloda na diagramu je upadla, delež peloda zelišč pa narastel (*sl. 2*). Pojav prvih pelodnih zrn tipa 'Cerealia' je datiran okrog 2100 pr. n. št. Ker žitarice proizvajajo le malo peloda, ki se ne širi daleč proč od rastline (Behre 1988; Rösch 2000), ta pelodni zapis kaže, da so bila polja locirana v neposredni bližini vrtine južno od vasi Prapoče. Hkrati pa je v bronasti dobi, v času med 2000 in 1400 pr. n. št., na pelodnem diagramu opazna tudi sprememba v sestavi gozda, količina peloda jelke (*Abies*) je namreč narastla. V drugem tisočletju pr. n. št. se je človekov vpliv na okolje še okrepil in današnji zelo podobna pokrajina je nastala že v pozni bronasti dobi okrog 1200 pr. n. št.. V železni dobi je, domnevno zaradi človekove dejavnosti (sekanje gozda), biodiverziteta okolja še narastla (število taksonov na pelodnem diagramu naraste, Andrič 2002, sl. 15).



Sl. 2: Prapoče. Procentni pelodni diagram za izbrane taksone.
Fig. 2: Prapoče. Percentage pollen diagram (selected taxa).

Tab. 2: Radiokarbonski datumi (Andrič 2002).
Table 2: Radiocarbon dates (Andrič 2002).

Številka vzorca **Sample number**	**Globina (cm)** **Depth (cm)**	**Konvencionalna C14 starost** **Conventional C14 age**	**13C/12C delež** **13C/12C ratio**	**Kalibriran rezultat** **Intercept of radiocarbon age with calibration curve cal. BC (cal. BP)**	**2 sigma kalibriran rezultat** **2 sigma calibrated results**
Prapoče					
Beta-183918	131	1660±40 BP	-26.3 o/oo	400 cal. AD (1550 cal. BP)	260-290 cal. AD 320-450 cal. AD
Beta-145368	140	3050±40 BP	-24.5 o/oo	1310 cal. BC (3260 cal. BP)	1410-1200 cal. BC
Beta-183919	150	3680±40 BP	-22.9 o/oo	2040 cal. BC (3990 cal. BP)	2190-2170 cal. BC 2150-1940 cal. BC
Beta-123732	163-172	5250±60 BP	-27.7 o/oo	4035 cal. BC (5985 cal. BP)	4235-3960 cal. BC
Beta-141212	206	8360±40 BP	-25.4 o/oo	7475 cal. BC (9425 cal. BP)	7530-7330 cal. BC
Gorenje jezero 2					
Beta-183920	47	2000±40 BP	-27.9 o/oo	10 cal. AD (1940 cal. BP)	80 cal. BC - 80 cal. AD
Beta-145367	55	2670±40 BP	-28.2 o/oo	820 cal. BC (2770 cal. BP)	900-790 cal. BC
Beta-183921	60	2830±40 BP	-29.0 o/oo	990 cal BC (2940 cal. BP)	1100-900 cal. BC
Beta-141213	77	8710±40 BP	28.4 o/oo	7730 cal. BC (9680 cal. BP)	7915-7905 cal. BC 7830-7605 cal. BC
Mlaka					
Beta-148848	102	1000±40 BP	-28.3 o/oo	1020 cal. AD (930 cal. BP)	980-1060 cal. AD 1080-1150 cal. AD
Beta-183922	115	2400±40 BP	-29.2 o/oo	410 cal. BC (2360 cal. BP)	760-680 cal. BC 550-390 cal. BC
Beta-183923	125	3360±40 BP	-29.5 o/oo	1650 cal. BC (3600 cal. BP)	1740-1530 cal. BC
Beta-141215	136	3480±40 BP	-29.2 o/oo	1765 cal. BC (3715 cal. BP)	1900-1695 cal. BC
Beta-141216	168	7350±40 BP	-27.4 o/oo	6220 cal. BC (8170 cal. BP)	6250-6090 cal. BC
Beta-124727	204-212	8720±40 BP	-26.7 o/oo	7700 cal. BC (9650 cal. BP)	7915-7590 cal. BC

Vegetacija v okolici Cerkniškega jezera (lokacija Gorenje jezero, *sl. 3*) je bila v bronasti dobi popolnoma drugačna kot v Čičariji. Najpomembnejša drevesna vrsta je bila jelka (*Abies*), pa tudi bukve (*Fagus*), smreke (*Picea)* in jelše (*Alnus*) je bilo več kot v okolici Prapoč. Pelodni zapis kaže, da se je vegetacija v času med zgodnjo bronasto dobo in koncem starejše železne dobe (*ca.* 2200-

300 pr. n. št.) postopno spreminjala - količina jelše (*Alnus*) je upadla, kar je lahko posledica sprememb v hidrologiji Cerkniškega polja in/ali izsekavanja ter požiganja gozda. V tem obdobju je človekov vpliv na okolje vsekakor naraščal, pokrajina je postajala vse bolj odprta (naraščanje leske (*Corylus*), trav (*Poaceae*), rastlin iz družine košaric (*Compositae*)); pelod tipa 'Cerealia' in porast 'antropogenih indikatorjev', kot so na primer rastline iz rodov pelin (*Artemisia*) ter glavinec (*Centaurea*) in družine metlikovk (*Chenopodiaceae*), ki pogosto uspevajo na opuščenih poljih, pa kažejo na močno poljedelsko dejavnost še zlasti po letu 1000 pr. n. št. Še močnejši poseg v okolje in nastanek današnje pokrajine pa je, za razliko od Prapoč, datiran šele v rimsko obdobje (300 n. št., Andrič 2002).

Mlaka v Beli krajini je paleoekološko najdišče, kjer je odstotek bukve (*Fagus*) med vsemi tremi pelodnimi diagrami najvišji (*sl. 4*). Okrog leta 2200 pr. n. št. je okrog Mlake uspeval pretežno bukov gozd. Poleg bukve (*Fagus*) so v neposredni okolici Mlake rastli tudi lipa (*Tilia*), hrast (*Quercus*), leska (*Corylus*) in beli gaber (*Carpinus betulus*). Večja sprememba v sestavi gozda se pojavi okrog 2000 pr. n. št., ko delež jelke (*Abies*), podobno kot v Prapočah, naraste. Rahel porast peloda 'antropogenih indikatorjev' (Cerealia, *Centaurea, Chenopodiaceae, Artemisia*) kaže, da so bila bronastodobna in železnodobna polja verjetno locirana v bližini močvirja Mlaka, krivulja koncentracije oglja pa govori o občasnem manjšem požiganju pokrajine skozi celotni holocen. Do večjega izsekavanja in požiganja gozda je v okolici Mlake prišlo šele mnogo pozneje, *ca.* 1000 n. št., ko je nastala današnja pokrajina s številnimi travniki.

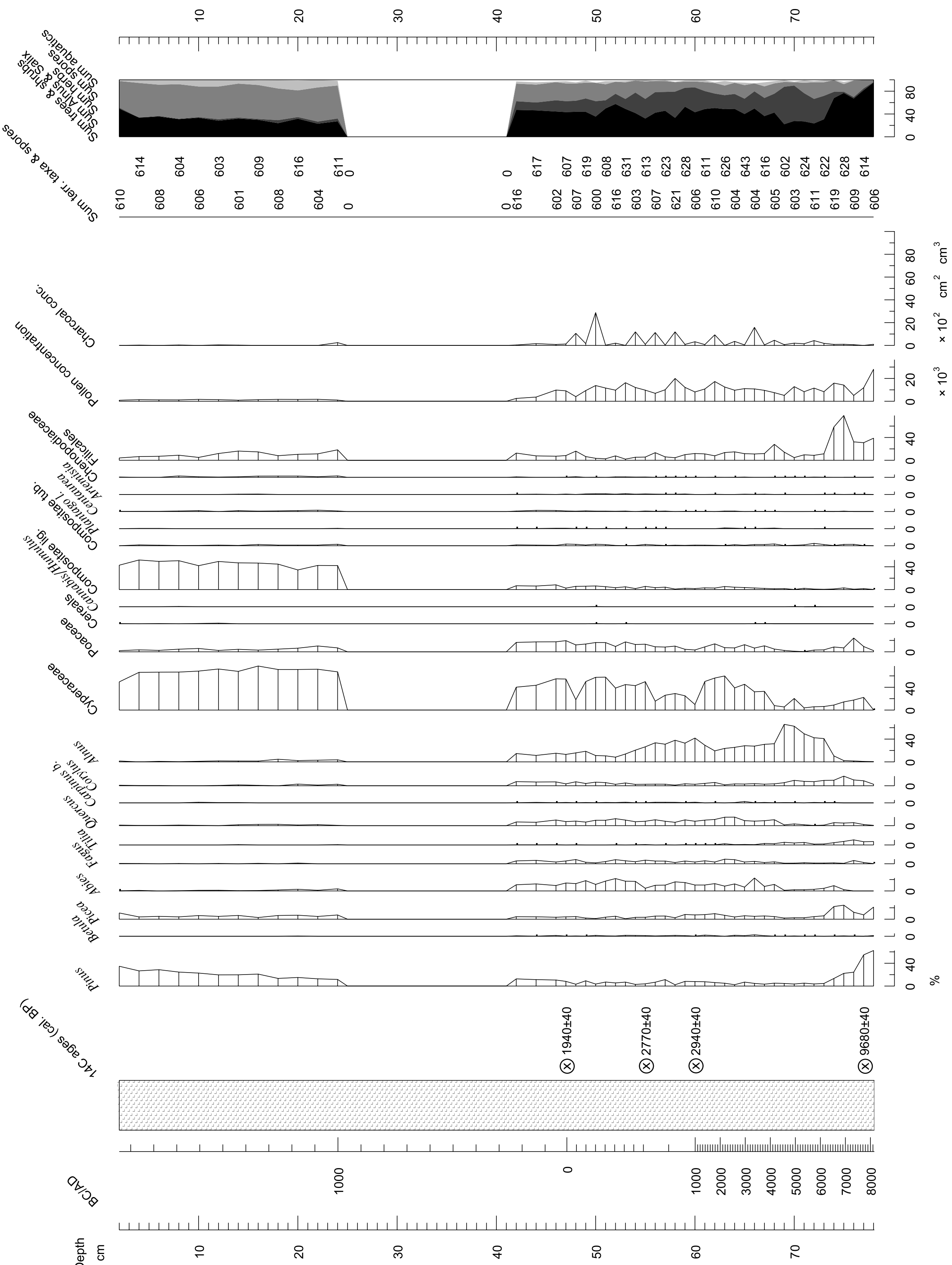
DISKUSIJA

Zakaj je bila bronastodobna vegetacija v posameznih fitogeografskih regijah Slovenije tako zelo raznolika? Na razvoj vegetacije vpliva veliko število dejavnikov, kot so, na primer, klima, človekov vpliv na okolje in notranja vegetacijska dinamika (n.pr. procesi sukcesije, konkurenčni odnosi med rastlinami). V poznem glacialu in zgodnjem holocenu je klimatski dejavnik zelo močno vplival na razvoj vegetacije, medtem ko je bila v zadnjih nekaj stoletjih (ponekod tisočletjih) holocena vegetacija močno antropogeno spremenjena. V času med obema ekstremoma, v pozni prazgodovini, sta bila zelo pomembna oba dejavnika. Meja med vegetacijskimi spremembami, ki so nastale zaradi človekovega vpliva, in tistimi, ki so posledica paleoklimatskih nihanj, je zabrisana in pogosto sta na razvoj vegetacije vplivala oba hkrati, zato je vpliv klime in človeka zelo težko oceniti.

V času med zgodnjo bronasto dobo in koncem starejše železne dobe (*ca.* 2200-300 pr. n. št.) lahko na vseh pelodnih diagramih opazimo trend naraščanja človekovega vpliva na okolje. Pokrajina je zaradi požiganja in izsekavanja gozda za potrebe poljedelstva in metalurgije postajala vse bolj odprta. To odpiranje pokrajine se na pelodnih diagramih kaže kot naraščanje količine peloda zelišč in 'kulturnih indikatorjev' (*sensu* Behre 1981, n.pr. pelod kulturnih rastlin: tip žitarice (Cereals), na najdišču Mlaka presenetljivo tudi pelod tipa konoplja (*Cannabis*) in njivskih plevelov ter pašnih indikatorjev, *Artemisia, Chenopodiaceae, Plantago lanceloata, Centaurea*). Ta naraščajoči človekov pritisk na okolje je v okolici Prapoč povzročil nastanek današnje pokrajine že v pozni bronasti dobi okrog 1200 pr. n. št. Drugje je do obsežnega sekanja in požiganja gozda, ki je vodilo v nastanek današnje pokrajine, prišlo šele več stoletij ali tisočletij kasneje.

Poleg postopnega odpiranja pokrajine pa v bronasti dobi lahko tudi opazimo spremembo v sestavi gozda - razširitev jelke okrog 2000 pr. n. št., ki je najbolj izrazita na paleoekoloških najdiščih Prapoče in Mlaka, podoben, nekoliko slabše datiran pojav jelke pa lahko opazimo tudi na Ljubljanskem barju (Parte in Kamnik pod Krimom, Culiberg, Šercelj 1978, Šercelj 1955). Je na to širitev jelke vplivala predvsem človekova dejavnost ali klima? Možno je, da sta pomembno vlogo igrala oba dejavnika. Zaradi domnevnega sekanja bukve za potrebe metalurgije (proizvodnja oglja) je imela jelka več možnosti, da se razširi, verjetno pa je začela poraščati tudi opuščene pašnike (Culiberg, Šercelj 1978). Po drugi strani pa povečana količina organskih snovi v sedimentu vrtine Mlaka (110-135 cm) v delu s povišano vsebnostjo jelke dopušča možnost, da je do razširitve jelke prišlo zaradi vlažnejše klime. Jelka namreč potrebuje veliko vlage in je občutljiva na poletne suše (Ellenberg 1988; Mlakar 1990). Povečanje količine padavin pa je, poleg razširitve jelke, verjetno povzročilo tudi dvig gladine močvirja, anaerobne razmere in s tem boljšo ohranjenost organskih snovi.

Kaj pravzaprav vemo o klimatskih razmerah na področju Slovenije v obdobju bronaste dobe? Dozdaj raziskava, usmerjena v proučevanje holocenske klime v Sloveniji, še ni bila organizirana, zato si lahko pomagamo le posredno, s paleoklimatskimi podatki vrtin v grenlandskem ledu in rezultati modelov, ki razlagajo kroženje zemeljske atmosfere (*tab. 3*). Na osnovi teh raziskav lahko sklepamo o globalnih klimatskih dogajanjih.



Sl. 3: Gorenje jezero 2. Procentni pelodni diagram za izbrane taksone.
Fig. 3: Gorenje jezero 2. Percentage pollen diagram (selected taxa).

Starost Age (cal. BP)	Δ^{18}O (T)	Podatki o T ledu T profile	Hitrost akumulacije ledu (padavine) Ice accumulation rate (precipitation)	Nalaganje prahu (hladno in suho) Dust accumulation (cold and dry)	Koncentracija metana (padavine) CH_4 concentr. (precipitation)	Globokomorske vrtine (razširjenost plovnega leda) Deep-see Atlantic marine cores (ice rafting)	Modeli kroženja atmosfere General circulation models
0	Hladnejše/ Slightly colder	P D **Hladna doba/Colder (LIA)** Ohlajanje/Cooling	P-D	***Hladno in suho/ Cold & Dry***			
1000		Topla doba/Warmer (MWP) Otoplitev/Warming	Vlažno/Wet		Naraščanje količine padavin/ Precipitation increasing	**Hladno/Cold**	
2000		**Hladna doba/Colder**	P-D ***Suho/Dry***	***Hladno in suho/ Cold & Dry***		**Hladno/Cold**	
3000		Ohlajanje/ Cooling	P-D				P D
4000			***Suho/Dry*** P-D, suho/Dry		***Suho/Dry***	**Hladno/Cold**	
5000	Toplo/ Warm		***Suho/Dry***	***Hladno in suho/ Cold & Dry***	Upadanje količine padavin/ Precipitation decreasing	**Hladno/Cold**	
6000		Topla doba/ Warmer	P-D				Izrazitejši kontrasti med letnimi časi/ More pronounced seasonality 2-4°C višje poletne T/ 2-4°C higher summer T 25-30 % več padavin/ 25-30% more precipitation
7000			***Suho/Dry***		Naraščanje količine padavin/Precipitatiuon increasing		
8000	**Hladno/Cold**	Otoplitev/ Warming	P-D ***Suho/Dry*** P-D	***Hladno in suho/ Cold & Dry***	***Suho/Dry*** Vlažno/ Wet	**Hladno/Cold**	
9000	Toplo/ Warm	**Hladna doba/ Colder**	Porast količine padavin/ Increase of precipitation			**Hladno/Cold**	
10000	Otoplitev/ Warming			Hladno in suho/ Cold & Dry		**Hladno/Cold**	

Rezultati modeliranja kroženja zemeljske atmosfere predvidevajo, da je ob prehodu poznega glaciala v holocen, klima postala toplejša in vlažnejša. V času klimatskega optimuma med 9000 in 4000 pr. n. št. so razlike med letnimi časi narastle, poletja so postala toplejša in bolj sušna, zime pa hladnejše in vlažnejše od današnjih. Za čas pozne prazgodovine po 4000 pr. n. št. model bistvenih klimatskih odstopanj od današnje klime ne predvideva (COHMAP Members 1988; Huntley, Prentice 1993; Webb, Kutzbach 1998; Kutzbach, Guetter 1986; Kutzbach et al. 1998).

Rezultati modeliranja se v splošnem ujemajo z geokemičnim zapisom v grenlandskih vrtinah, ki prav tako kaže na večjo otoplitev in porast količine padavin ob prehodu poznega glaciala v holocen (GRIP Members 1993; Dansgaard et al. 1993). Nekaj nejasnosti je v zvezi s tem, ali je temperatura po 7200 pr. n. št. ostala podobna današnjim in razmeroma konstantna (na kar kažejo vrednosti $\delta^{18}O$ v profilu vrtine in hitrost akumulacije ledu, GRIP Members 1993; Dansgaard et al. 1993) ali pa je bila v času med 6000 in 3000 pr. n. št. temperatura za *ca.* 2,5 °K toplejša od današnje (na kar kaže modeliranje podatkov o temperaturi ledu, Alley et al. 1993; Meese et al. 1994; Dahl-Jensen et al. 1998, pa tudi paleoekološki podatki za Alpe, Tinner, Ammann 2001; Tinner, Theurillat 2003). Raziskovalci menijo, da je zmanjšanje koncentracije metana posledica zmanjšanja količine padavin med 6200 in 3000 pr. n. št., medtem, ko naj bi po 3000 pr. n. št. (v nasprotju s podatki o hitrosti akumulacije ledu) količina padavin močno narastla (Blunier et al. 1995; Chappellaz et al. 1993; Alley et al. 1997; Street-Perrott, Perrott 1990).

Rezultati paleoklimatskih raziskav v zadnjem času kažejo, da je bila holocenska klima verjetno nekoliko bolj dinamična kot smo mislili dozdaj. Nekateri podatki (vrednosti $\delta^{18}O$, hitrost akumulacije ledu in meritve električne prevodnosti grenlandskih vrtin (O'Brien et al. 1995), koncentracija kopenskega detritusa v globokomorskih sedimentih (Bond et al. 1997), podatki o gibanju alpskih ledenikov (Bray 1970; Denton, Karlén 1973) in merjenje $\delta^{14}C$ v lesu za dendrokronološke analize (Stuvier, Reimer 1993)) namreč dopuščajo domnevo o cikličnih klimatskih nihanjih s sledečimi fazami suhe in hladne klime: *ca.* 9300, 6800-5899, 4100-3000, 1100-400 pr. n. št. in 1340-1950 n. št. (Meese et al. 1994; Stuvier et al. 1995; Bond et al. 1997; Stager et al. 1997; Bianchi, McCave 1999; Chapman, Shackelton 2000; Eiríksson et al. 2000; Domack et al. 2001). V bronasti dobi naj bi torej po letu 3000 pr. n. št. količina padavin močno narastla, v času med 1100 in 400 pr. n. št. pa naj bi nastopila tudi zelo suha in hladna klima. Prav tako se domneva, da so bile te klimatske spremembe, zabeležene v grenlandskih in globokomorskih vrtinah, globalnega značaja.

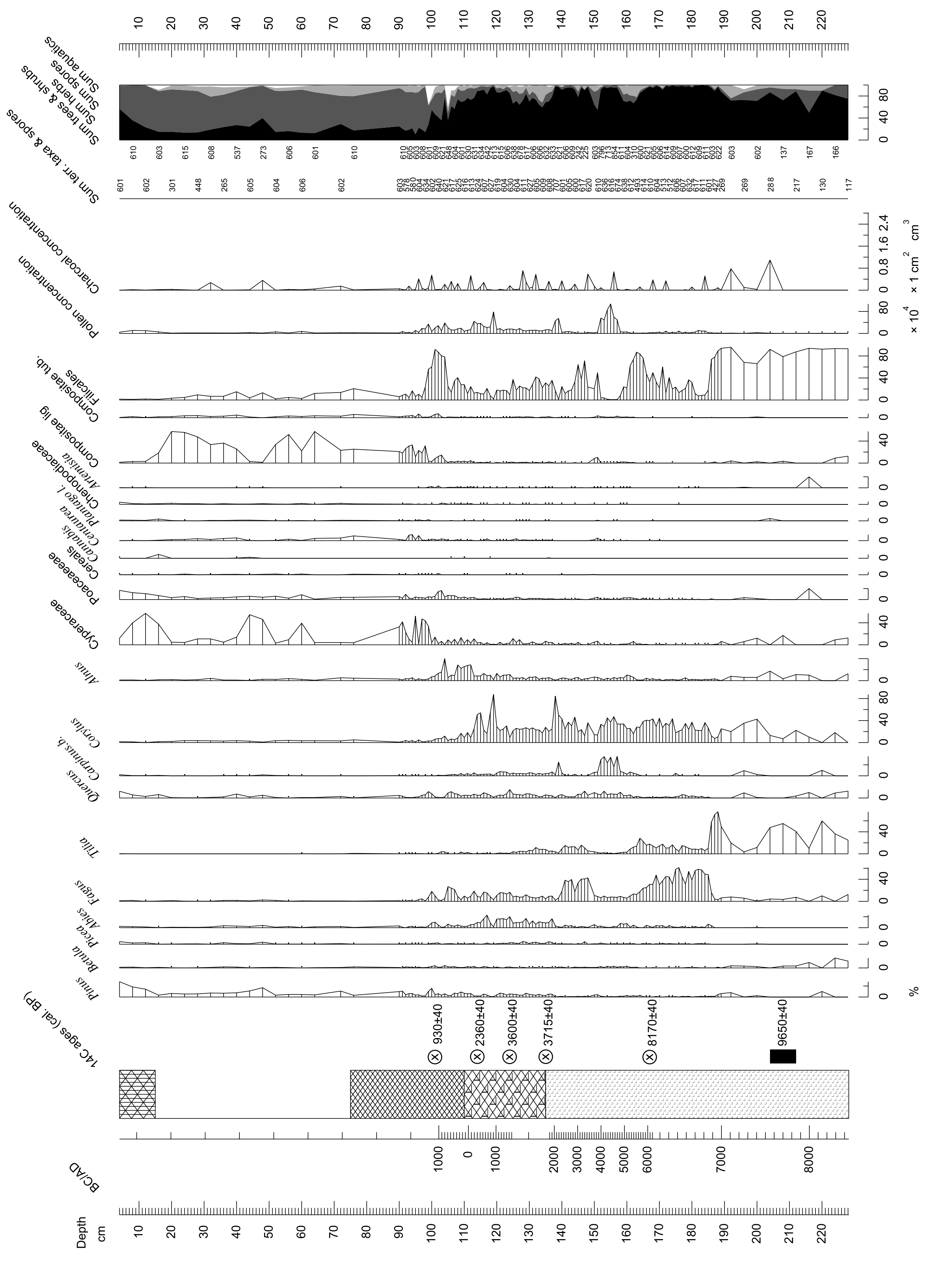
Poleg podatkov grenlandskih vrtin pa se za opis bronastodobne klime v Evropi še vedno pogosto uporablja tudi Blytt-Sernanderjev klimatski sistem z začetka 20. stoletja. Prvotni sistem je temeljil na stratigrafskem zaporedju pelodnega zapisa in stopnji humifikacije šote na najdiščih v Skandinaviji in je bronasto dobo uvrstil v toplo in suho obdobje, subboreal. Kasnejše raziskave so pokazale, da naj bi bila za subboreal značilna tudi izdatnejša nihanja vlažnosti (Magny 1982) z izrazitimi hladnimi in/ali vlažnimi fazami, datiranimi v sledeča obdobja: *ca.* 2000 pr. n. št., 1600-1500 pr. n. št., 1000 pr. n. št. (*e. g.* Lamb 1977; Coles, Harding 1983). Obdobja nestabilne klime tudi sovpadajo z arheološkimi podatki in pisanimi viri o sušnih klimatskih fazah in poplavah v Egiptu, na Bližnjem vzhodu, Kitajskem in v Grčiji (Lamb 1977; Bintliff 1982; Weiss 2000; deMenocal 2001), dendrokronološkimi podatki (Baille 1998), nekatera pa bi tudi lahko povezali z vulkanskimi izbruhi (n.pr. izbruh There (Santorini) ali Hekle (Island), Baillie 1998; Dincauze 2002; Eiríksson et al. 2000) ali celo roji meteoritov (Huntley et al. 2002). Vpliv teh katastrofalnih dogodkov na razvoj prazgodovinskih kultur v vzhodnem Sredozemlju in Aziji je bil pomemben in, kot poročajo pisni viri, so mnoge od teh kratkih faz spremenjene klime povzročile precejšnje opustošenje pokrajine in vegetacije, čeprav nedavne palinološke raziskave na Kreti kažejo, da do večjih sprememb vegetacije ob izbruhu There verjetno ni prišlo (Bottema, Sarpaki 2003). Morebitni vpliv teh kratkotrajnih klimatskih faz na razvoj srednjeevropske vegetacije še ni bil ocenjen in na dosedanjih pelodnih diagramih ni viden.

Blytt-Sernanderjev klimatski sistem se torej ujema s podatki grenlandskih vrtin v tem, da za začetek bronaste dobe predvideva zelo vlažno klimo (2000

←

Tab. 3: Holocenska klima (kompilacija podatkov iz: Dansgaard et al. 1993, Dahl-Jensen et al. 1998, Meese et al. 1994, Alley et al. 1993, O'Brien et al. 1995, Blunier et al. 1995, Sirocko et al. 1993, Stager et al. 1997, Bond et al. 1997, COHMAP Members 1988, , P-D označuje današnjim podobne klimatske razmere.

Table 3: The Holocene climate. Compiled from Dansgaard et al. 1993, Dahl-Jensen et al. 1998, Meese et al. 1994, Alley et al. 1993, O'Brien et al. 1995, Blunier et al. 1995, Sirocko et al. 1993, Stager et al. 1997, Bond et al. 1997, COHMAP Members 1988, , P-D indicates present-day conditions



Sl. 4: Mlaka. Procentni pelodni diagram za izbrane taksone.
Fig. 4: Mlaka. Percentage pollen diagram (selected taxa).

pr. n. št. je domnevno tudi obdobje z najvišjim postglacialnim nivojem morja), po letu 1000 pr. n. št. pa naj bi klima postala zelo hladna (Lamb 1977), kar se ujema tudi z nedavno objavljenimi paleoklimatskimi podatki jadranske vrtine RF 93-30 (Oldfield et. al. 2003). Glavni problem Blytt-Sernanderjeve klimatske sheme je, da se v arheološki literaturi pogosto uporablja zelo nekritično, kot splošno sprejet stereotip za evropsko klimo v celoti, čeprav temelji pretežno le na paleoekoloških podatkih za Skandinavijo. V zadnjem času vse več paleoekoloških raziskav kaže, da je bila holocenska klima (še zlasti količina padavin) v različnih delih Evrope zelo raznolika (Huntley et al. 2002) in da, na primer, paleoklimatski podatki za Nemčijo in švicarske Alpe, ki se na splošno sicer ujemajo s klimatskimi fazami grenlandskih vrtin, hkrati tudi nakazujejo, da mnoge od teh klimatskih faz niso bile globalne ali sočasne, ampak gre pogosto tudi za regionalne fenomene ter vplive mikroklime (Haas et al. 1998; Zolitschka et. al. 2003; Kalis et al. 2003; Tinner, Ammann 2001). Raziskave paleoklimatskega zapisa v stalagmitih nakazujejo, da, po 4000 cal. BC, hladna obdobja v severnem Atlantiku verjetno sovpadajo s suhimi zimami v srednji Evropi (Niggerman et al. 2003). Paleoekološki podatki za zgodnejša obdobja tudi nakazujejo, da klimatska nihanja niso bila sočasna; nastanek današnji podobne, manj kontinentalne klime kot v zgodnjem holocenu, je v južnih Alpah datiran *ca*. 7100 pr. n. št., v severnih Alpah in srednji Evropi pa ta klimatska sprememba domnevno nastopi šele okrog 6200 pr. n. št. (Tinner, Ammann 2001).

Lahko omenjene globalne in regionalne klimatske in mikroklimatske spremembe opazimo tudi v Sloveniji? Vsa tri paleoekološka najdišča, Prapoče, Gorenje jezero in Mlaka, ležijo v nižinah, kjer, za razliko od višinskih ekotonov, klimatske spremembe verjetno niso bile tako intenzivne, da bi imele drastičen učinek na vegetacijo. Edina večja sprememba v sestavi gozda okrog 2000 pr. n. št., ko na najdiščih Prapoče in Mlaka naraste količina jelke (*Abies*), je domnevno posledica vlažnejše klime. To spremembo vegetacije verjetno lahko povežemo s srednjeevropsko hladno klimatsko oscilacijo (CE-7, Löbben, Haas et al. 1998), datirano *ca.* 1800-1400 pr. n. št. Vendar pa je tudi v tem primeru možno, da je na spremembo v sestavi gozda, ki sovpada z razvojem metalurgije, vplival tudi človek z domnevnim sekanjem bukve za potrebe metalurgije in s spremenjeno kmetijsko dejavnostjo. Če drži, da je bila v Sloveniji, podobno kot drugje v srednji Evropi, zaradi poslabšanja klime ob prehodu v bronasto dobo, živina čez zimo stalno nastanjena v hlevu (Behre 1998), je bil njen vpliv na okolje zaradi gozdne paše manjši. To bi tudi lahko prispevalo k širitvi jelke, ki je zelo občutljiva na gozdno pašo. Jelka pa je občutljiva tudi na pogosto požiganje gozda (Tinner et al. 1999; Tinner et al. 2000), zato bi pojav stalnih polj in domnevna opustitev ekstenzivnega požigalništva (Clark et al. 1989; Rösch 1993; Rösch 1996) prav tako lahko olajšala njeno širjenje.

ZAKLJUČEK

Primerjava palinoloških in paleoklimatskih podatkov kaže, da so bili vzroki za nastanek raznolikega paleookolja na področju Slovenije in severne Istre kompleksni. Različna klima, mikroklima, geološka podlaga in relief v posameznih fitogeografskih regijah Slovenije so vsekakor vplivali na razvoj vegetacije (Wraber 1969), verjetno pa ne morejo biti edini razlog za vegetacijsko pestrost (Andrič, Willis, 2003). V srednjem in poznem holocenu je na povečanje razlik med vegetacijo posameznih regij in porast biodiverzitete močno vplival tudi človek z izsekavanjem in požiganjem gozda za naraščajoče potrebe kmetijstva in metalurgije. Vloga klimatskih dejavnikov, ki je trenutno še zelo slabo raziskana, verjetno prav tako ni bila zanemarljiva in je, skupaj s človekom, vplivala na spremembe v sestavi gozda.

Na koncu dolgujem še odgovor na zadnje, najtežje raziskovalno vprašanje: so neenotna kultura, poselitveni vzorec in paleookolje Slovenije v pozni prazgodovini med seboj vzročno povezani? Človekov vpliv na okolje je bil zelo izrazit še zlasti na območju Prapoč (Čičarija), kjer se je današnji zelo podobna pokrajina pojavila že v pozni bronasti dobi (*ca.* 1200 pr. n. št.). Drugje je nastanek današnje pokrajine datiran nekaj stoletij ali celo tisočletij kasneje. Lahko zaradi tega domnevamo, da je bil na področju Istre človekov vpliv na okolje (sekanje in požiganje gozda, poljedelstvo, pašništvo, metalurgija, gradbena dejavnost) v času kaštelirske kulture intenzivnejši kot drugje? Ali pa je bila vegetacija na področju Istre bolj občutljiva na človekov poseg kot drugje in je zato današnja pokrajina (ob enakem človekovem pritisku na okolje po vsej Sloveniji) tukaj nastala prej? So na širjenje (krčenje) področij, ki so jih izkoriščali za potrebe kmetijstva, vplivala tudi klimatska nihanja, kar nekateri raziskovalci domnevajo za alpsko področje v času med 2300 pr. n. št. in 800 n. št. (Tinner et al. 2003)?

Ta in podobna vprašanja bodo rdeča nit bodočih paleobotaničnih, arheoloških in paleoekoloških raziskav. Da bi ocenili vrsto in intenzivnost človekovega vpliva na okolje, namreč nujno potrebujemo podatke z arheoloških naselbin v različnih delih Slovenije. Prav tako pa potrebujemo tudi paleoklimatske raziskave. Le s pomočjo neodvisnih paleoklimatskih podatkov in boljšim poznavanjem človekove ekonomije v pozni prazgodovini bomo v prihodnosti lahko govorili ne samo o tem, kakšna je bila bronastodobna pokrajina, ampak tudi o tem, zakaj je bila takšna, na kakšen način je pogojevala človekovo poselitev, in pa tudi o tem, na kakšen način so človekove odločitve ter klimatske danosti vplivale na spremembe vegetacije in kulturne krajine.

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The vegetation of Slovenia and northern Istria in late prehistory

Translation

INTRODUCTION

Significant changes in the Bronze Age (2200-800 cal. BC) archaeological material culture, society and environment are associated with the transition to a predominantly farming economy and the introduction of metallurgy. Archaeological and palaeoecological research in Europe indicates that Bronze Age farmers used a wide range of plants and animals that were domesticated already in the Neolithic (wheat, barley, millett, oat, pulses and flax, Renfrew 1973; Zohary, Hopf 1993; Behre 1988; sheep, goat, pig, cattle; Bökönyi 1974; Gerrard et al. 1996; Legge 1996; Hole 1996). However, an increased dependence on domesticated plants and animals and use of their products ('secondary products revolution') - milk, cheese, wool, manure and the use of ard (simple plough) - are presumably Bronze Age phenomena (Sherratt 1981, 1997; Harding 2000). It is supposed that in central Europe during the Bronze Age the cattle were kept in stables, whereas the first permanent meadows did not occur before the Iron Age (*ca.* 800 cal. BC; Behre 1988; Behre, Jacomet 1991; Knörzer 1991; Behre 1998; Kalis et al. 2003). Human impact on the environment (forest clearance, intensification of agriculture, pottery production and metallurgy) was increasing, and Greek and Roman mining several centuries later already had global effects on the environment, as demonstrated by increased copper and lead concentrations discovered in Greenland ice cores (Hong et al. 1994, 1996).

What do we know about the palaeoenvironment of the Bronze Age inhabitants of Slovenia? The analysis of pollen, deposited in lake and marsh sediments indicates that, while in the late glacial the vegetation of Slovenia was predominantly pine-birch woodland, the warmer and presumably also more humid climate at the beginning of the Holocene (*ca.* 11000 cal. BP; Kutzbach et al. 1998) favoured the spread of broadleaved tree taxa. Oak, lime, hazel and elm replaced pine and birch (Culiberg 1991, Šercelj 1996). Another major change of vegetation occured at *ca.* 6800 cal. BC, when the most common tree taxa in Slovenia became beech and fir (e.g. Šercelj 1963, 1965, 1966, 1971, 1975, 1976, 1981-1982, 1988, 1996; Culiberg, Šercelj 1987; Culiberg, Šercelj 1980a, b; Culiberg 1991; Andrič 2001, 2002). This vegetation change (spread of shade-tolerant tree taxa) at the beginning of the 7^{th} millennium cal. BC might be a regional phenomenon, associated with the following climatic changes: decline of climatic continentality in the southern Alps, dated to *ca.* 7100 cal. BC (Tinner et al. 1999; Tinner, Ammann 2001), a Pasterze Glacier advance at *ca.* 6900 cal. BC (Nicolussi, Patzelt 2000) and maybe also a pluvial period on the Dalmatian coast, dated to 7000-4800 cal. BC (Schmidt et al. 2000). Later, in the middle and late Holocene, the growing human impact on the environment in Slovenia probably triggered an increase in oak and decline of beech and fir on many pollen diagrams (e.g. Šercelj 1988; Culiberg, Šercelj 1991; Šercelj 1996; Gardner 1997). At the Bronze Age settlement of Dolnji Lakoš (north-eastern Slovenia) for example, an increase in hazel can be associated with pastoralism (Šercelj 1987, 1996).

However, was similar vegetation typical also for other phytogeographic regions of Slovenia, and what were the main changes in the vegetation associated with the introduction of metallurgy? How did the landscape in the Bronze Age differ from the Neolithic/Eneolithic and Iron Age landscape? What was the influence of presumable Bronze Age climatic fluctuations (cooling and supposed dry and warm climatic phase in the Late Bronze Age, e.g. Lamb 1977; Jockenhövel 1998; Baillie 1998; Ložek 1998; Behre 1998) on the vegetation and economy? Is there a causal link between diverse culture (Dular 1999; Teržan 1999) and the palaeoenvironment? The Holocene vegetation development in three study sites will be compared in order to address these research questions.

STUDY SITES AND METHODOLOGY

Study sites (*Tab. 1; Fig. 1*) - Prapoče (south-western Croatia, submediterranean phytogeographic region), Gorenje jezero (Cerknica lake, dinaric phytogeographic region) and Mlaka (predinaric phytogeographic region) were selected in areas with various climates, from a predominantly submediterranean climate in south-western Slovenia to a predominantly subpannonian (continental) climate in south-eastern Slovenia (Ogrin 1996). The topography, bedrock and vegetation at selected study sites are also diverse (Wraber 1969) and the pollen record indicates that the vegetation history at each study site was different. At each site sedimentary cores were collected by a Livingstone piston corer, and the results of pollen and charcoal analysis, together with radiocarbon dates (AMS dated organic carbon, extracted from the sediment), are presented in the pollen diagrams (*Figs. 2-4*). Linear interpolation between dates was used for the age modelling, and selected tree and herb taxa are presented as percentage data. Research methodology and results of pollen analysis have already been presented elsewhere (Andrič 2001, 2002, Andrič, Willis 2003); however, this time additional radiocarbon dates of all three cores allow us to concentrate on vegetation development in the late prehistory.

THE HOLOCENE AND BRONZE AGE VEGETATION

Firstly, I will shortly summarize the Holocene vegetation development at four selected study sites (Andrič 2002, Andrič, Willis 2003). In the early Holocene (*ca.* 8000-6800 cal. BC) the vegetation of Slovenia was relatively uniform - broadleaved woodland of oak (*Quercus*), hazel (*Corylus*), lime (*Tilia*) and elm (*Ulmus*) was growing in all four phytogeographic regions. At 6800 cal. BC the forest composition suddenly changed - shade tolerant tree taxa spread - fir (*Abies*) and beech (*Fagus*) became the most important tree taxa in central Slovenia, whereas in south-western and north-eastern Slovenia the most important tree taxon probably became lime (*Tilia*). This vegetation change was presumably triggered by climatic fluctuation - an increase in precipitation. Biodiversity increased, and growing human impact probably also contributed to the formation of phytogeographic regions of Slovenia (Andrič, Willis 2003) and led to the formation of the present-day landscape several millennia later.

The Bronze Age vegetation of Slovenia was therefore very diverse. In the 3^{rd} millennium cal. BC predominantly lime forest was growing at Prapoče site (Čičarija, north-western Croatia). The pollen record indicates that, besides lime (*Tilia*), the main tree taxa growing in the region were oak (*Quercus*), hornbeam (*Carpinus betulus*), hazel (*Corylus*), fir (*Abies*) and beech (*Fagus*). Alder (*Alnus*) was probably growing in marshy areas at the bottom of the valley. At the beginning of the 2^{nd} millenium BC the landscape became more open, the percentage of tree pollen declined, whereas herb pollen increased (*Fig. 2*). The first cereal type pollen grains appeared at *ca.* 2100 cal. BC. Since cereal pollen does not spread far from the plant (Behre 1988; Rösch 2000), the Bronze Age fields must have been located in the vicinity of Prapoče village. The pollen record indicates that in the Bronze Age (2000-1400 cal. BC), forest composition changed - the percentage of fir (*Abies*) pollen increased. Due to human impact on the environment in the 2^{nd} millennium BC, the present-day landscape was being formed already in the late Bronze Age around 1200 cal. BC. It is possible that increased biodiversity in the Iron Age (increased number of plant taxa, Andrič 2002, Fig. 15) is associated with forest clearance.

The vegetation growing in the vicinity of Cerknica lake (Gorenje jezero site, *Fig. 3*) was completely different. The main tree taxa growing in the region were fir (*Abies*), beech (*Fagus*), spruce (*Picea*) and alder (*Alnus*). The pollen record indicates that in the late prehistory (2200-300 cal. BC) the percentage of alder (*Alnus*) declined and the landscape became more open (*Corylus, Poaceae* and *Compositae* increased), which could be a consequence of changes in hydrology of the basin and/or forest clearance and burning. Although the increased percentage of 'anthropogenic indicators' (such as *Artemisia, Centaurea* and *Chenopodiaceae*) after 1000 cal. BC indicates that agricultural activity was very intensive, the present-day landscape was formed several centuries later, in the Roman period (300 AD, Andrič 2002).

Mlaka site (*Fig. 4*) is specific for its high beech (*Fagus*) percentage. At 2200 cal. BC predominantly beech (*Fagus*) forest with lime (*Tilia*), oak (*Quercus*), hazel (*Corylus*) and hornbeam (*Carpinus betulus*) was growing in the vicinity of Mlaka site. The forest composition changed at 2000 cal. BC, when the percentage of fir (*Abies*) increased. A similar vegetation change was, at the same time, detected also at Prapoče site. The charcoal record at Mlaka site indicates that small scale burning of the landscape occurred throughout the Holocene. Pollen of 'anthropogenic indicators' (Cerealia, *Centaurea, Chenopodiaceae* and *Artemisia*) also suggest that prehistoric fields were located in the vicinity of Mlaka site. Major forest clearance and burning, which led to the formation of the present-day landscape, is dated much later, in the medieval period at *ca.* 1000 AD.

DISCUSSION

What were the reasons for such an interregional variety of vegetation in the late prehistory? Several factors, such as climate, human impact and internal vegetation dynamics (e.g. succession and competition between plants) can be considered. In the late glacial and early Holocene, for example, climatic impact was very important, whereas in the last few centuries (in some regions millennia) human impact on the vegetation was predominant. In the time period in between those two extremes (late prehistory) both climate and human impact were important, therefore it is very difficult to estimate the exact role of each of them.

The increasing trend of human pressure on the environment in the time period between *ca.* 2200 and 300 cal. BC was detected on all pollen diagrams. Intensification of agriculture, pottery production and metallurgy in this period were presumably the main reasons for forest clearance and burning and the increased percentage of domesticated plants (*sensu* Behre 1981, Cerealia pollen type, indicators of ruderal grounds and pasture: *Artemisia, Chenopodiaceae, Plantago lanceloata, Centaurea*, at Mlaka surprisingly also hemp (*Cannabis*)) indicate that the landscape became more open than in the Neolithic. At Prapoče, the very open present-day landscape emerged already in Late Bronze Age at ca. 1200 cal. BC, whereas elsewhere the present-day landscape was formed only several centuries or even millennia later.

Another change of vegetation at *ca.* 2000 cal. BC was an increase of fir at the Prapoče and Mlaka sites. A similar increase of fir was detected also on some Ljubljana marsh sites (Parte and Kamnik pod Krimom, Culiberg, Šercelj 1978, Šercelj 1955). Was this spread of fir triggered predominantly by climatic change or human impact? It is possible that forest composition was affected by the development of metallurgy, when cutting of beech for charcoal production would favour the spread of fir. Fir probably also started to grow on abandoned pasture areas (Culiberg, Šercelj 1978). On the other hand, however, the increased percentage of organic material in the Mlaka core (110-135 cm, section with increased fir percentage) indicates that the reasons for fir expansion might be climatic. Good preservation of organic material probably indicates anaerobic conditions in the sediment due to increased water level of the Mlaka marsh. Fir needs a humid climate and is sensitive to summer droughts (Ellenberg 1988; Mlakar 1990), therefore an increase of precipitation would favour the spread of fir.

What do we know about the Bronze Age climate in Slovenia? To date no research of local palaeoclimate has been conducted, and therefore paleoclimatic data from the Greenland ice cores and general circulation modelling (*Tab. 3*) will be used to address the global climate in late prehistory.

According to general circulation modelling, the climate at the late glacial - Holocene transition became warmer and wetter. During the climatic optimum between 9000 and 4000 cal. BC the seasonal contrasts increased, summers were warmer and drier and winters colder and wetter than today. It is supposed that in the late prehistory after 4000 cal. BC the climate was not significantly different from the present-day climate (COHMAP Members 1988; Huntley, Prentice 1993; Webb, Kutzbach 1998; Kutzbach, Guetter 1986; Kutzbach et al. 1998).

The geochemical record in Greenland ice cores, generally speaking, matches with circulation models and indicates that the climate at the late glacial - Holocene transition became warmer and wetter (GRIP Members 1993; Dansgaard et al. 1993). It is still unclear whether the temperature after 7200 cal. BC was similar to that of today and fairly constant (according to the δ^{18} O profile and ice accumulation rate, GRIP Members 1993; Dansgaard et al. 1993) or in the period between 6000 and 3000 cal. BC, when the temperature was *ca.* 2.5° K warmer than today (according to T profile, Alley et al. 1993; Meese et al. 1994; Dahl-Jensen et al. 1998, but also alpine palaeoecological data, Tinner, Ammann 2001; Tinner, Theurillat 2003). The researchers assume that the decline of methane concentration between 6200 and 3000 cal. BC was a consequence of a drier climate, whereas after 3000 cal. BC, the amount of precipitation increased (which does not match with ice accumulation data, Blunier et al. 1995; Chappellaz et al. 1993; Alley et al. 1997; Street-Perrot, Perrot 1990).

The results of palaeoclimatic research also indicate that the Holocene climate was probably more dynamic than previously thought. Some palaeoecological data - for example the δ^{18}O profile, ice accumulation rate, electric conductivity (O'Brien et al. 1995), terrestrial detritus in deep-sea marine cores (Bond et al. 1997), data on advances of alpine glaciers (Bray 1970; Denton, Karlén 1973) and the δ^{14}C concentration in wood samples (Stuvier, Reimer 1993) - suggest climatic cycles with the following phases of dry and cold climate: *ca.* 9300, 6800-5899, 4100-3000, 1100-400 cal. BC and 1340-1950 AD (Meese et al. 1994; Stuvier et al. 1995; Bond et al. 1997; Stager et al. 1997; Bianchi, McCave 1999; Chapman, Shackleton 2000; Eiríksson et al. 2000; Domack et al. 2001). These climatic cycles, detected in Greenland ice cores and deep-sea marine cores were presumably global. In late prehistory, according to these data the amount of precipitation after 3000 cal. BC increased and the climate between 1100 and 400 cal. BC was presumably dry and cold.

In order to the describe Bronze Age climate in Europe many researchers use also the Blytt-Sernander climatic scheme. The original scheme from the beginning of the 20th century was based on pollen record, peat stratigraphy and degree of peat humification on Scandinavian palaeoecological sites. According to this scheme the Bronze Age was described as a warm and dry period, subboreal. Later research suggested that during the subboreal strong fluctuations of humidity appeared (Magny 1982), with cold and/or wet phases, dated to ca. 2000, 1600-1500, 1000 cal. BC (e.g. Lamb 1977; Coles, Harding 1983). These phases of unstable climate match with archaeological data and written reports about dry phases and floods in Egypt, the Near East, China and Greece (Lamb 1977; Bintliff 1982; Weiss 2000; deMenocal 2001), and with dendrochronological data (Baillie 1998), some of which can be connected with volcanic eruptions (e.g. Thera (Santorini) or Hekla (Island), Baillie 1998; Dincauze 2002; Eiríksson et al. 2000) or even meteorites (Huntley et al. 2002). The influence of those catastrophic events was important and, according to written sources, many of them caused significant damage to landscape and vegetation, although recent palynological research on Crete, on the other hand, suggests that no major changes of vegetation took place (Bottema, Sarpaki 2003). The extent of environmental influence of these short-term climatic phases on vegetation development in central Europe is unknown and was not detected on pollen diagrams.

The Blytt-Sernander climate scheme and palaeoecological data from Greenland ice cores both indicate that at the beginning of the Bronze Age the climate was very wet (at 2000 BC the postglacial sea level was presumably highest), whereas after 1000 cal. BC the climate also became colder (Lamb 1977). These data are in accordance with palaeoclimatic information from Adriatic core RF 93-30 (Oldfield et al. 2003). However, the main problem with the Blytt-Sernander scheme is that many archaeologists use it as a widely accepted stereotype for general European climate, although it was based mainly on palaeoecological data for Scandinavia. Recent palaeoclimatic research indicates that the Holocene climate in Europe (especially the amount of precipitation) varied between regions (Huntley et al. 2002). Palaeoclimatic data for Germany and the Swiss Alps, that are generally in accordance with Greenland ice cores data, also indicate that many Holocene climatic phases were regional phenomena (Haas et al. 1998; Zolitschka et al. 2003; Kalis et al. 2003, Tinner, Ammann 2001). Investigation of the stalagmite palaeoclimatic record, for example, suggests that after 4000 cal. BC, during cold phases in the northern Atlantic, the winters in central Europe were dry (Niggerman et al. 2003). Also for earlier periods, the palaeoecological data indicate that the transition from more continental to present-day climatic regimes (with warm and dry summers and cold winters) in the Alpine region was not synchronous; in the southern Alps a decrease in continentality is dated at *ca.* 7100 cal. BC, whereas this transition in the northern Alps and Central Europe took place only at 6200 cal. BC (Tinner, Ammann 2001).

Are the global and regional climatic changes described above visible also on Slovenian palaeoecological sites? All three palaeoecological sites (Prapoče, Gorenje jezero and Mlaka) are located in lowlands, where climatic changes were presumably less drastic than at the timberline. It is possible that Holocene climatic fluctuations in late prehistory were not strong enough to trigger significant changes in lowland vegetation. The only change of forest composition which might be associated with climatic fluctuations (increased precipitation) occurred at 2000 cal. BC, when the percentage of fir on pollen diagrams of the Prapoče and Mlaka sites increased. This vegetation change can be associated with central European cold climatic oscillation (CE-7, Löbben, Haas et al. 1998), dated to *ca.* 1800-1400 cal. BC. However, these changes of forest composition also coincide with the transition to metallurgy, and it is possible that, besides climatic changes, human activity (charcoal production) also altered the forest composition. Another - admittedly highly debatable - reason for the observed change in forest composition might be connected with the supposed alteration of farming economy. For central Europe it was suggested that at the transition to the Bronze Age the cattle were kept in stables because of colder winters. The influence of forest grazing was therefore reduced (Behre 1998). Fir is very sensitive to forest grazing and burning (Tinner et al. 1999; Tinner et al. 2000) and therefore the suggested formation of permanent fields and abandonment of extensive landscape burning (Clark et al. 1989; Rösch 1993, 1996) would also favour its spread.

CONCLUSIONS

The comparison between palynological and palaeoclimatic data indicates that the reasons for the palaeoenvironmental variability of Slovenia and northern Istria are complex. Various climatic, bedrock and topographical features of individual phytogeographic regions of Slovenia had a significant impact upon the vegetation development (Wraber 1969), but they might not be the only reason for biodiversity (Andrič, Willis 2003). In the late glacial and early Holocene, differences between regions were not yet significant, therefore we can assume that an increase of biodiversity in the middle and late Holocene can be associated with forest clearance and burning due to farming and metallurgy. The role of climatic fluctuations, which is poorly investigated, probably also had an effect on forest composition.

Finally, I still need to answer the last, most difficult research question: Is there a causal link between diverse culture and palaeoenvironment in the late prehistory? Human impact on the environment is most clearly seen on the Prapoče site, where the present-day landscape presumably occurred already in the late Bronze Age (ca. 1200 cal. BC). In other phytogeographic regions of Slovenia the present-day landscape occurred several centuries or even millennia later. Is this evidence for the assumption that in the northern Istria human impact (forest clearance and burning, agriculture, pastoralism, metallurgy and construction of fortified Bronze Age settlements) was more intensive than elsewhere? Or was the vegetation in Istria more sensitive to human impact? Were phases of expansion (and contraction) of cultivated land climatically driven, as suggested for the Alpine region between 2300 and 800 AD (Tinner et al. 2003)?

These research questions will be addressed in future palaeobotanical, archaeological and palaeoecological research projects. In order to assess the type and intensivity of human impact we urgently need more data from archaeological settlements. We also need more regional and local palaeoclimatic data. Only then will it be easier to discuss not only how the Slovenian landscape in late prehistory appeared, but also what were the reasons for vegetation changes and how climatic changes and human activity led to the formation of the present-day cultural landscape.

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