Paleoekološki podatki o človekovem vplivu ob gozdni meji na planini Klek v Julijskih Alpah

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Izvleček

Planina Klek sodi med najstarejša pašna področja na Pokljuki, v regiji pa so bila najdena tudi rimska, poznoantična in zgodnjesrednjeveška arheološka najdišča. V tem članku predstavljamo rezultate palinoloških in pedoloških raziskav, ki kažejo na razmeroma zgoden vpliv človeka na okolje alpskih habitatov, kar je – morda že v bronasti dobi – povzročilo erozijo tal in spremembo v sestavi vegetacije. Pelod, značilen za travnike, pašnike in ruderalna območja se pojavi že po pribl. 4000 cal. BC, prva pelodna zrna žitaric pa nekoliko kasneje, verjetno v pozni prazgodovini, pred pribl. 500 cal. BC (točno starost je težko določiti).

Ključne besede: Slovenija, Klek, Pokljuka, palinologija, pedologija, arheologija, bronasta doba, uporaba pokrajine ob zgornji gozdni meji

Abstract

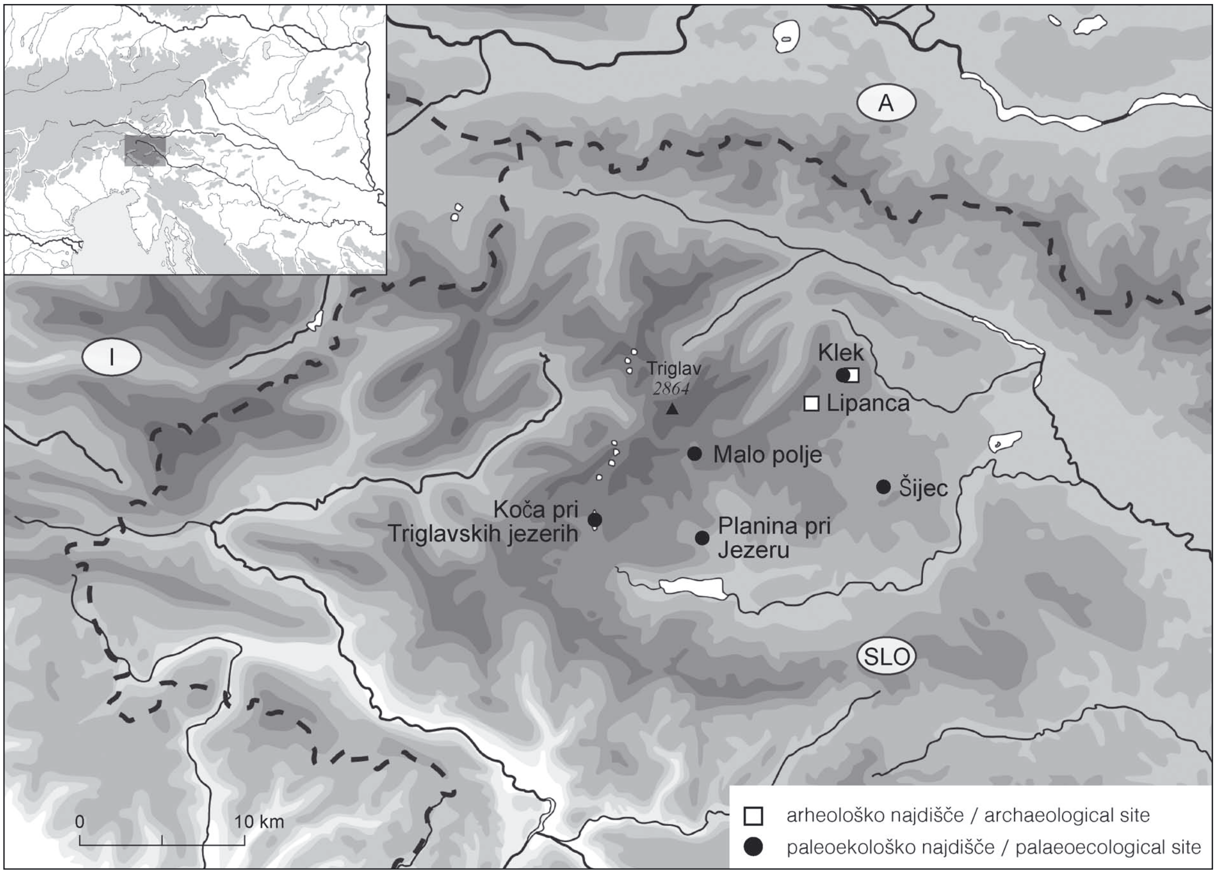
Klek is one of the oldest alpine grazing areas on the Pokljuka Plateau in Slovenia, with archaeological sites dating to the Roman, Late Antiquity and Early Medieval periods. The results of palynological and pedological research presented in this paper suggest that human impact on the alpine habitats started relatively early (possibly as early as the Bronze Age), which led to soil erosion and changes in the vegetation composition. Pollen taxa characteristic for meadows, pastures and ruderal areas occur after ca. 4000 cal. BC, whereas the exact age of the first cereal type pollen grains is uncertain (late prehistory, earlier than ca. 500 cal. BC).

Keywords: Slovenia, Klek, Pokljuka, palynology, pedology, archaeology, Bronze Age, land-use at forest line

UVOD

Alpski habitati ob zgornji gozdni meji so zelo občutljivi na klimatska nihanja in človekov vpliv na okolje (npr. pašo, gozdarstvo). V Sloveniji so bila ta območja gospodarsko zelo pomembna od srednjega veka dalje (npr. Melik 1960; Kos 1960; Novak 1970; Pleterski 1986; Petek 2005; Andrič et al. 2010), medtem ko raziskav o izrabi prostora in nihanjih zgornje gozdne meje v starejših arheoloških obdobjih praktično nimamo. Arheološke najdbe pričajo o tem, da so ljudje Pokljuko v vzhodnih Julijskih Alpah obiskovali vsaj od pozne bronaste dobe dalje (Ogrin 2006; Horvat 2006), vendar pa so arheološki in paleoekološki podatki o nekdanjem okolju in ekonomiji v visokogorju izjemno skopi. Tako, na primer, ni jasno, kdaj se je pojavila prva paša v visokogorju in kdaj so na Pokljuški planoti začeli s kopanjem rude (Mohorič 1969).

Palinološki podatki s paleoekoloških najdišč, ki ležijo v bližini ali nad današnjo gozdno mejo (npr. Koča pri Triglavskih jezerih in Malo polje, na pribl. 1700–1800 m nadmorske višine; *sl. 1*), kažejo na to, da je bila v zgodnjem holocenu gozdna meja verjetno na večji nadmorski višini kot danes (Šercelj 1961; Šercelj 1965). Vendar pa so podatki o razvoju holocenske vegetacije le splošni: omenjeni pelodni diagrami namreč niso bili radiokarbonsko datirani, rastlinski makrofosili pa pogosto niso bili ohranjeni ali analizirani. Na drugi strani imajo številni pelodni diagrami z nekoliko nižje ležečih najdišč (pribl. 1200–1450 m n. m.) mnogo boljšo resolucijo vzorčenja in kronološko kontrolo (npr. Planina pri Jezeru: Culiberg 2002; Šijec: Šercelj 1971; Andrič et al. 2010), vendar pa večina pokriva le krajša časovna obdobja, npr. zadnjih 200–300 let. V alpski regiji zato zelo potrebujemo podroben pelodni diagram za celoten holocen.



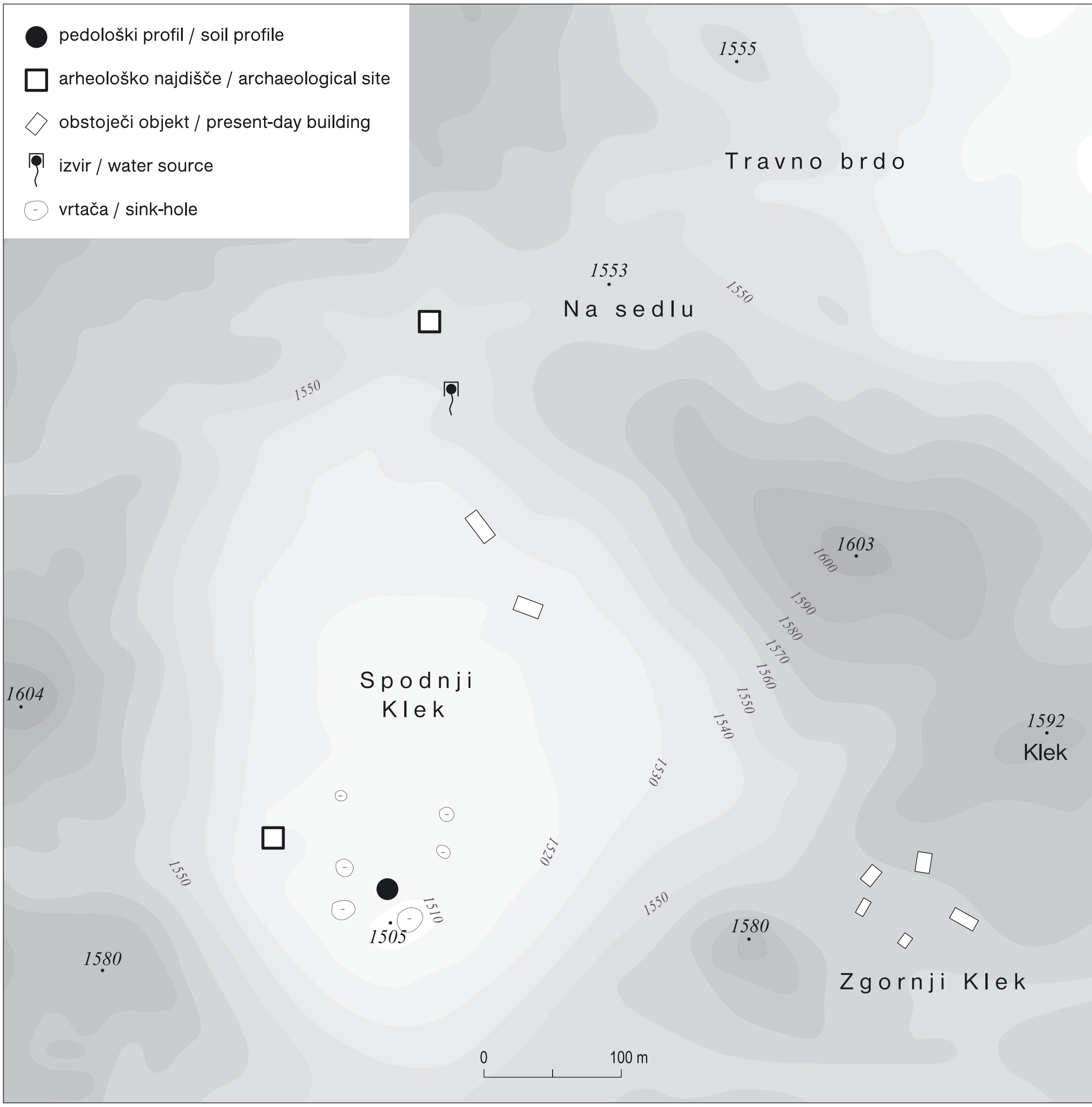
Sl. 1: Pokljuška planota s planino Klek.
Fig. 1: Pokljuka plateau and the location of Klek alpine grazing area.

Na osnovi zgodovinskih podatkov lahko sklepamo, da je bila planina Klek ena od najstarejših pašnih planin na Pokljuki (Pleterski 1986, 114–118). Arheološka izkopavanja na Kleku kažejo na človekovo prisotnost v rimskem obdobju (1. in 2. st. n. št.), pozni antiki (5. in 6. st. n. št.) in zgodnjem srednjem veku (7.–10. st. n. št.) (Ogrin 2006). Kljub arheološkim podatkom pa ni jasno, v katerem časovnem obdobju so se pojavili prvi pašniki in ali človekovo prisotnost lahko povežemo z metalurškimi ali kakšnimi drugimi aktivnostmi. V članku analiziramo palinološke dokaze za spremembe holocenskega okolja ob gozdni meji, v bližini arheoloških najdišč na planini Klek (Pokljuka, Slovenija).

OPIS REGIJE IN NAJDIŠČ

Planina Klek leži v Julijskih Alpah (severozahodna Slovenija), na Pokljuški planoti na 1550 m nadmorske višine (*sl. 1*), v bližini gorske steze, ki povezuje Bohinj z dolino zgornje Save. Planino sestavljajo trije deli: Spodnji Klek, Zgornji Klek in Pekel (*sl. 2*). V osrednjem območju Spodnjega Kleka leži večja kotlina (pribl. 550 × 420 m). Izvir vode je na severnem pobočju. Spodnji Klek je porasel s suhimi travniki z bogato floro, ki pokrivajo pribl. 20 ha in so obdani z macesni (*Larix decidua*) in smrekovim (*Picea abies*) gozdom (Dakskobler et al. 2010). Klima na območju Alp je zmerna z dolgoletnim januarskim temperaturnim povprečjem 0–3 °C in julijskim povprečjem med 15 in 20 °C. Najnižje ležeča točka Spodnjega Kleka leži na 1505 m nadmorske višine, kar je precej nižje od Zgornjega Kleka (1565 m) in Travnega brda (1553 m). Ta del (mrazišče) je zato pozimi hladnejši kot okolica, kar vpliva na sestavo vegetacije. Povprečna letna količina padavin na širšem območju je pribl. 1300–2800 mm (Ogrin 1996).

Na pobočjih Spodnjega Kleka sta bili odkriti dve arheološki najdišči (*sl. 2*). Ostanki poznoantične stavbe (5.–6. st. n. št.) so bili izkopani na zahodnem pobočju (*sl. 3*). Na sedlu, ki leži nad izvirom v severnem delu Spodnjega Kleka, so arheologi izkopali drobne predmete, ki sodijo



Sl. 2: Planina Klek. Lega arheoloških najdišč in pedološkega profila (vir: TTN 10, Bled 3, © Geodetska uprava RS).
Fig. 2: Klek. The position of archaeological sites and soil profile (source: TTN 10, Bled 3, © Geodetska uprava RS).

v zgodnjerimsko (1.–2. st. n. št.), poznoantično (5.–6. st. n. št.) in zgodnjesrednjeveško (9.–10. st. n. št.) obdobje. Našli so tudi ostanke železove rude (*sl. 2;* Ogrin 2006, 103–104; Ogrin 2010, 203–203; Bizjak 2004, 133–134).

Zgodovinski viri omenjajo Klek kot eno najstarejših planin na Pokljuki; v 10. st. n. št. so jo morda že uporabljali prebivalci severnega Blejskega kota (Pleterski 1986, 114–118; Štular 2006). Na planini Klek so našli tudi različno velike rudniške jame. Rudarjenje ni dobro datirano, večina jam verjetno izvira is srednjega veka in kasnejših obdobij (Bizjak 2004, 133–134).

METODE

Vzorci za paleoekološke raziskave so bili pobrani iz plitve (50 cm globoke) sonde, ki je bila izkopana v južnem, najvlažnejšem delu planine Klek (*sl. 2, 3*). Sediment je bil pobran s pomočjo kovinskih profilov. Vzorci so bili zaviti v tanko folijo za shranjevanje živil, aluminijasto folijo in še eno plast debelega polivinila in shranjeni v hladilnici pri +4 °C. Ker na planini Klek ni močvirij, ki bi bila bolj primerna za palinološko raziskavo, smo se odločili, da na teh vzorcih opravimo pelodno analizo.

Sl. 3: Planina Klek. Mesto vzorčenja pedološkega profila (na levi) in lega arheološke sonde (na desni, glej *sl. 2*).
Fig. 3: Klek. The position of soil profile (on left) and archaeological trench (on right, see *fig. 2*).

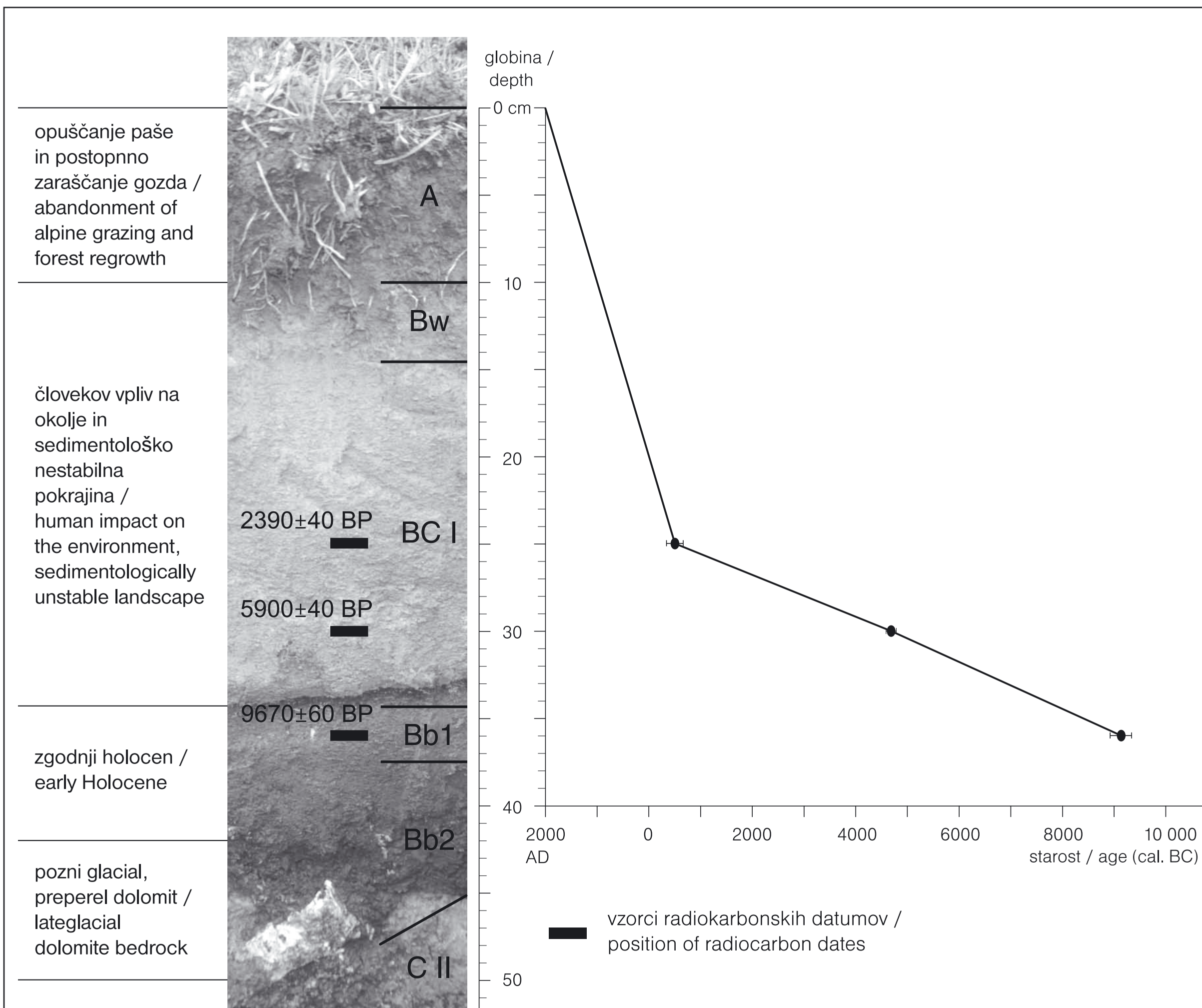
Starost sekvence je bila določena s pomočjo AMS-radiokarbonskega datiranja organskega ogljika iz vzorcev, ki so bili pobrani na treh različnih globinah (*tab. 1; sl. 4*). Pedološki procesi so vplivali na kemično sestavo tal. Zaradi znakov premeščanja železa (lise in konkrecije na stiku današnjih in pokopanih tal na globini 34 cm; glej poglavje *Rezultati, Pedološki profil, sl. 4* in *tab. 2*) smo se odločili, da se fulvo in huminske kisline odstranijo s pomočjo izpiranja s kislinami, bazami in kislinami, nato pa se radiokarbonsko datira samo preostala huminska frakcija vzorca tal (*tab. 1*). Vzorec na globini 25 cm (Beta-227136), ki je bil drobnozrnat melj in ni vseboval ostankov rastlin ali šote, je vseboval premalo huminskega materiala, zato je bilo pri predpripravi vzorca za radiokarbonsko datiranje uporabljeno samo spiranje s kislino, dobljeni rezultat pa predstavlja "najmanjšo možno starost". Konvencionalni radiokarbonski datumi so bili kalibrirani s pomočjo računalniškega programa CALIB Rev 5.0.1 (CALIB 5.0 Website; Stuiver and Reimer 1993) in podatkovne baze IntCal 04 (Reimer et al. 2004). Za oceno starosti sedimenta (linearna interpolacija; *sl. 4*) so bile uporabljane mediane (kot priporočajo Telford et al. 2004). Položaj radiokarbonskih datumov je prikazan na pelodnem diagramu (*sl. 5*).

Tla so bila opisana (*tab. 2; sl. 4*) in vzorčena (*tab. 3*) v Centru za pedologijo in varstvo okolja Biotehniške fakultete, Univerza v Ljubljani. Za določanje barve tal smo uporabili Munsellove barvne tablice. Vzorce za nadaljnjo analizo smo vzeli na sredini vsakega talnega horizonta, jih posušili na zraku in analizirali v skladu s standardnim postopkom ISO 11464 (1994). Velikost delcev je bila določena s sedimentacijsko metodo s pipetno analizo (ISO 11277, 1998). pH je bil izmerjen elektrometrično z uporabo 0.1 M $CaCl_2$ ekstrakcijske raztopine po standardnem postopku ISO 10390 (1994). Pri analizi "loss-on-ignition" smo 1 cm^3 suhega vzorca tal iz vsakega horizonta stehtali, osem ur žgali v žarilni peči pri 550 °C, nato pa spet stehtali, da bi določili izgubo organskega materiala pri žganju (izračunana kot odstotek suhe teže vzorca, *tab. 2*).

Za pelodno analizo so bili vzeti vzorci sedimenta (vsakič 1 cm^3) iz izbranih globin profila s pomočjo kovinske cevke za jemanje vzorcev. Pri laboratorijski pripravi vzorcev je bil uporabljen standardni laboratorijski postopek (7 % HCl, 10 % NaOH, 40 % HF, acetoliza, barvanje s safraninom, tertiar butilni alkohol, silikonsko olje; Bennett, Willis 2002). Na začetku postopka smo vsakemu vzorcu dodali dve tableti spor *Lycopodium* za določanje pelodne koncentracije (Stockmarr 1971). Za identifikacijo peloda smo uporabljali svetlobni mikroskop Nikon Eclipse E400 pri 400-kratni povečavi in ključe za določanje peloda: Moore et al. (1991) in Reille (1992, 1995). Ker je bila pelodna koncentracija v vzorcih razmeroma nizka (še zlasti pod 30 cm globine), je bilo preštetih le najmanj 300

Tab. 1: Planina Klek. Radiokarbonsko datiranje pedološkega profila.
Tab. 1: Klek. Radiocarbon dating of soil profile.

Št. vzorca / Sample no.	**Globina / Depth (cm)**	**Datirani material in laboratorijski postopek / Material dated and pretreatment**	**Standardni radiokarbonski datum / Conventional radiocarbon date**	**13C/12C Razmerje / 13C/12C ratio**	**2 sigma kalibrirani rezultati / 2 sigma calibrated results**	**Mediana / Median**
Beta-227136	25 cm	organski sediment (spiranje s kislino) / organic sediment (acid washes)	2390 ±40 BP	-25.1 ‰	747-389 cal. BC (= 2338-2696 cal. BP)	478 cal. BC (= 2428 cal. BP)
Beta-214342	30 cm	organski sediment – humin (spiranje kislina/baza/kislina) / organic sediment – humins (acid/alkali/acid)	5900 ±40 BP	-23.3 ‰	4893-4689 cal. BC (= 6638-6842 cal. BP)	4770 cal. BC (= 6720 cal. BP)
Beta-214343	36 cm	organski sediment – humin (spiranje kislina/baza/kislina) / organic sediment – humins (acid/alkali/acid)	9670 ±60 BP	-22.4 ‰	9266-8834 cal. BC (= 10783–11215 cal. BP)	9121 cal. BC (= 11071 cal. BP)



Sl. 4: Planina Klek. Opis pedološkega profila, časovni model in interpretacija tafonomskih procesov.
Fig. 4: Klek. Description of the soil profile, age-depth modelling and proposed taphonomical processes.

Tab. 2: Planina Klek. Pedološki opis profila in rezultati analize "loss-on-ignition" (odstotek izgube suhe teže sedimenta po žganju pri 550 °C).
Tab. 2: Klek. Pedological description of soil profile and loss-on-ignition analysis (the percentage of sediment dry weight lost after burning at 550°C).

Spodnja globina / Basal depth (cm)	**Barva (Munsellova barvna lestvica) / Color (Munsell Soil Chart)**	**Horizont / Horizon**	**Struktura / Structure**	**Konzistenca / Consistency**	**Količina organskih snovi / Organic matter**	**Prekoreninjenost / Roots**	**Pedološke značilnosti / Pedofeatures**	**Prehod med horizonti / Transition**
10	10 YR 4/2	A	poliedrična, slabo izražena / subangular blocky, weak	rahla / loose	srednja / medium	gosta / dense		jasen / clear
14.5	7.5 YR 5/5	Bw	poliedrična, slabo izražena / fine angular blocky, weak	rahla / loose	mineralno / mineral	brez / none	oranžne lise / orange mottles	postopen / gradual
34.5	10 YR 4.5/4	BCI	poliedrična, slabo izražena / angular blocky, weak	rahla / loose	mineralno / mineral	brez / none		oster / sharp
37.5	7.5 YR 3/2 (4/6)	Bb1	poliedrična / angular blocky	rahla / loose	mineralno / mineral	brez / none	črne in oranžne lise, konkrecije / black and orange mottles, concretions	postopen / gradual
49 (45)	7.5 YR 3/4	Bb2	poliedrična / angular blocky	rahla / loose	nizka / low	brez / none		neenakomeren / irregular
49 (45)+		C II						

Tab. 3: Planina Klek. Rezultati pedološke analize.
Tab. 3: Klek. Analytical data of soil samples.

Spodnja globina / Basal depth (cm)	**Globina vzorca / Sample depth (cm)**	**Talni horiziont / Soil horizon**	**pH_{CaCl2}**	**Tekstura / Texture**					
				Pesek / Sand	**Grobi melj / Coarse silt**	**Drobni melj / Fine silt**	**Melj skupno / Total silt**	**Glina / Clay**	**Tip / Class**
10	2.5-6.5	A	4.3	5.2	25.0	41.8	66.8	28.0	meljasto-glinena ilovica / silt clay loam
32	19.5-24.5	BCI	4.7	5.1	16.4	38.7	55.1	39.8	meljasto-glinena ilovica / silt clay loam
40	34.0-35.5	Bb1	5.2	20.4	33.9	25.0	58.9	20.7	meljasta ilovica / silt loam
50	42.0-46.0	Bb2	5.7	18.5	29.7	28.0	57.7	23.8	meljasta ilovica / silt loam

pelodnih zrn in spor kopenskih rastlin na vzorec. Podatki so bili analizirani s pomočjo računalniškega programa PSIMPOLL 3.00 (Bennett 1998; PSIMPOLL Website), s katerim je bil narisan tudi pelodni diagram. Pelodni diagram je bil razdeljen na tri pelodne cone (K1–K3) z metodo "binarnega razcepa po vsoti kvadratov" ("binary splitting by sum of squares").

REZULTATI

Radiokarbonsko datiranje

Ocena starosti kaže, da pedološki profil pokriva celotno obdobje holocena (*tab. 1; sl. 4*). Sedimentacija v zgodnjem in srednjem holocenu (36–25 cm) je bila zelo počasna (pribl. 0,001 cm na leto), proti vrhu profila pa je narasla na pribl. 0,01 cm na leto.

Pedološki profil

Zgornji del pedološkega profila (horizonti A, Bw in BC I) smo opredelili kot *Epileptic Cambisol, siltic* (*tab. 2; tab. 3; sl. 4*). Ta horizont (= nad 34 cm) leži nad B–horizontom pokopanega in v zgodnjem holocenu erodiranega *Cambisola* (horizonti Bb1, Bb2 in C II). Zgornji del profila vsebuje veliko gline, kar prispeva k slabemu odtoku vode. Črne in oranžne lise in konkrecije v spodnjem delu profila potrjujejo slabo drenažo in premeščanje železa na stiku pokopanih in današnjih tal.

Pelodna analiza *(sl. 5)*

Pelod v coni K1 in v spodnjem delu cone K2 (pribl. 48–30 cm) je zelo slabo ohranjen (>20 % degradiranih zrn) in v nizki koncentraciji (< 1000 pelodnih zrn na 1 cm^3). V nasprotju s tem je pelodni zapis v zgornjem delu profila (nad 30 cm) dobro ohranjen in zato bolj izpoveden.

Cona K1 (48–37 cm, pred pribl. 9500 cal. BC)

Odstotek degradiranih pelodnih zrn v coni K1 je visok (35–130 % pelodne vsote, v katero so bili vključeni vsi kopenski taksoni brez degradiranih zrn). Zaradi zelo nizke pelodne koncentracije ni bilo mogoče prešteti statistično zanesljivega števila pelodnih zrn (≥300 na vzorec). Kljub temu pa vzorec kaže na prisotnost sledečih drevesnih taksonov: *Picea* (smreka), *Alnus* (jelša), *Quercus* (hrast) in *Fagus* (bukev), med zelišči pa prevladuje pelod družine Poaceae (trave).

Cona K2
(36–12 cm, pribl. 9500 cal. BC–cal. AD 800)

V spodnjem delu cone K2 ostaja pelodna koncentracija nizka, z visokim odstotkom degradiranega peloda (pribl. 80 %). Delež peloda dreves upade s 35–50 % (na dnu cone) na pribl. 20 % na globini 29 cm, medtem ko zelišča narastejo (npr. Poaceae prek 40 %).

V zgornjem delu cone K2 (nad 32 cm, po pribl. 6200 cal. BC) pelodna koncentracija naraste na ca. 10000–15000 zrn na 1 cm^3, odstotek degradiranih pelodnih zrn pa upade na 10–20 %. Odstotek zelišč ostane visok (pribl. 50–60 %), prvo pelodno zrno tipa *Secale* (rž) in Cerealia (žitarice) se pojavita na 28 cm oziroma 27 cm. Tudi količina ostalih "antropogenih indikatorjev", taksonov, značilnih za pašnike, travnike in ruderalne površine in polja (npr. *Plantago lanceolata* – ozkolistni trpotec, *Centaurea* – glavinec, Chenopodiaceae – metlikovke, *Artemisia* – pelin, *Ranunculus* – zlatice, Compositae – radičevke in *Campanula* – zvončnica), se poveča.

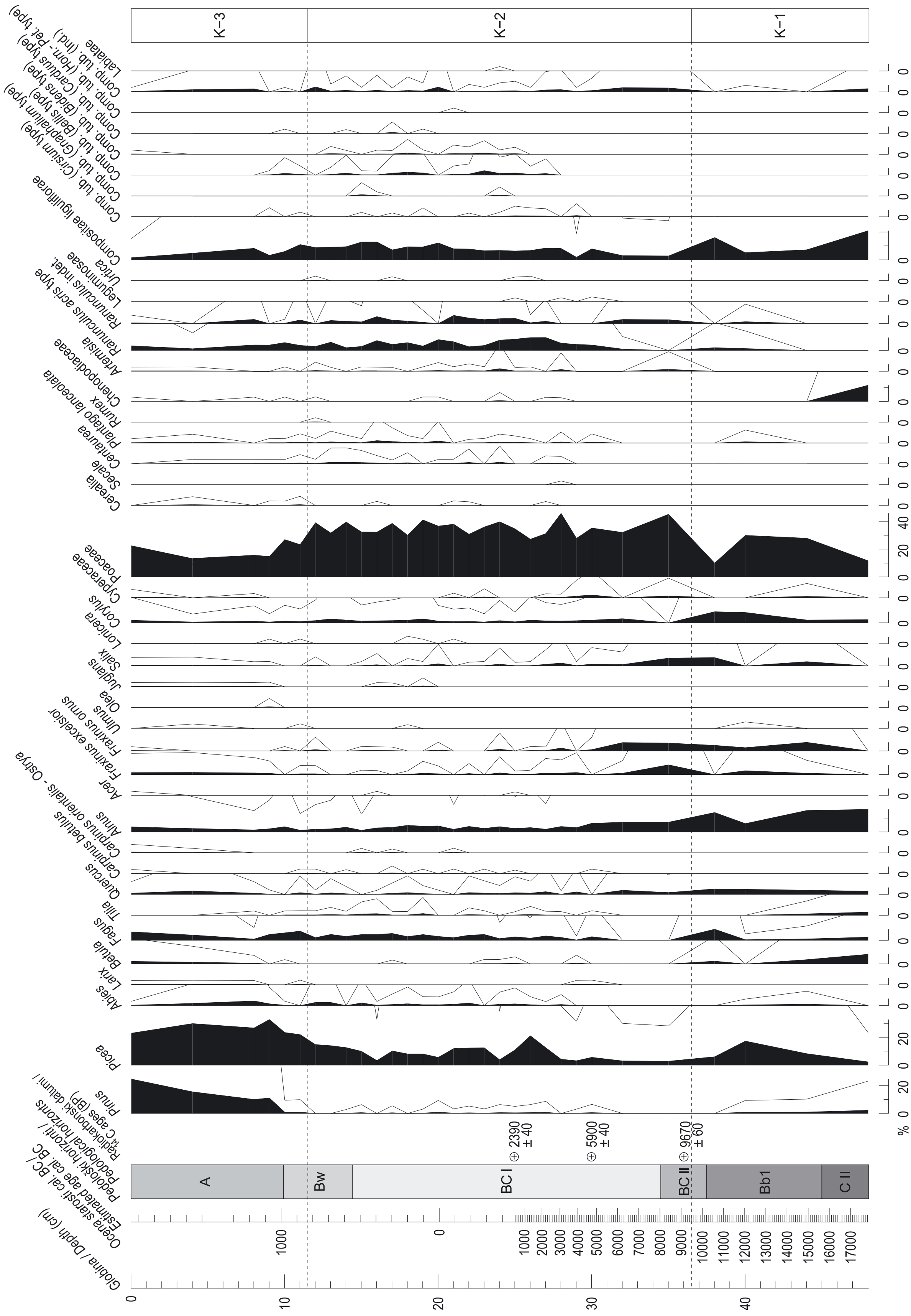
Cona K3 (12–0 cm, cal. AD 800–2005)

Glavna značilnost cone K3 je porast odstotka peloda dreves na pribl. 60 % (20 % *Pinus* – bor in 25 % *Picea*), medtem ko odstotek zelišč upade na 35 % (20 % Poaceae).

DISKUSIJA

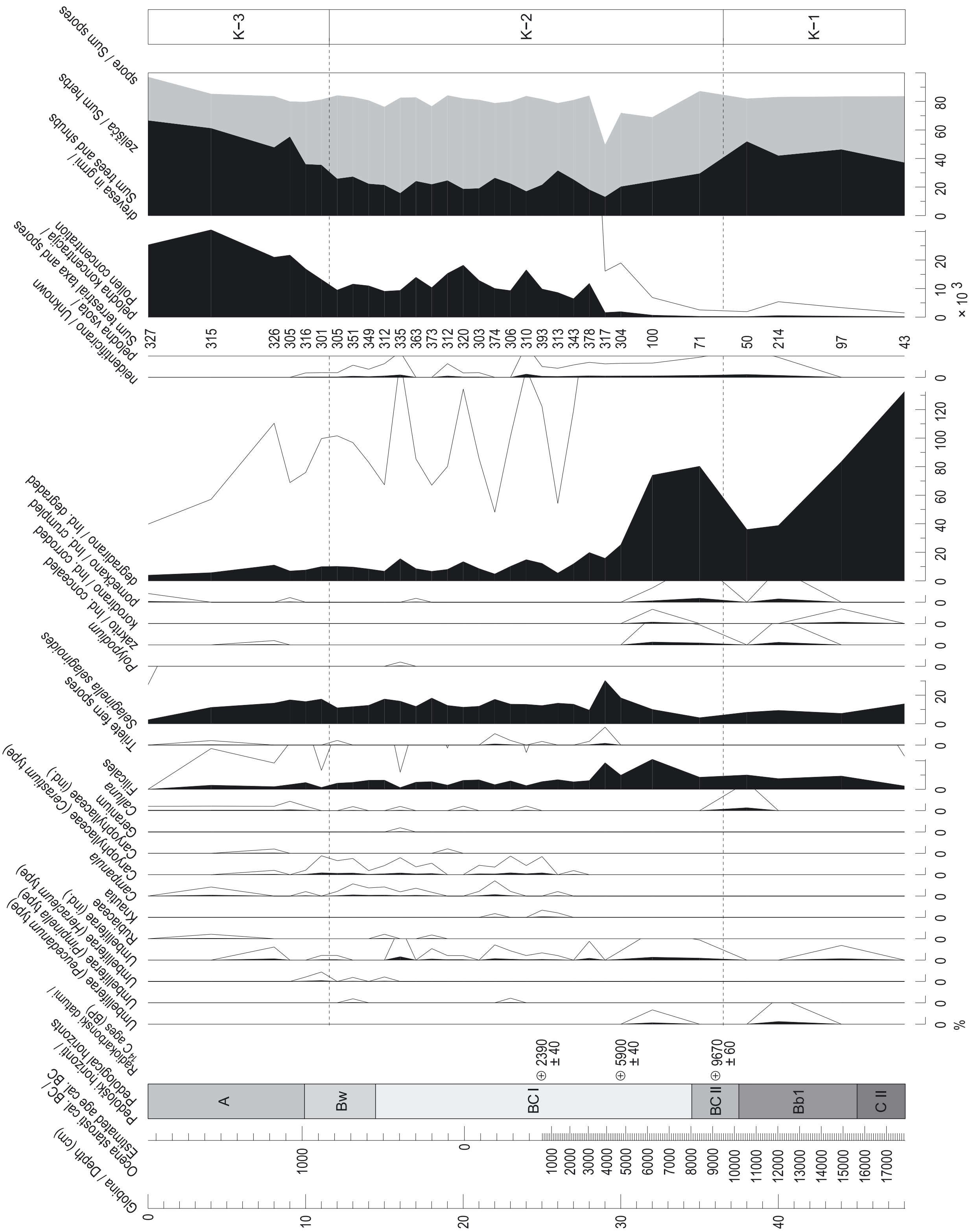
Tafonomski procesi ter časovna točnost in natančnost analiziranega profila

Pedološki procesi so pomembno vplivali na nastajanje paleoekološkega zapisa na planini Klek. Pelod se je na mestu vzorčenja najverjetneje ohranil zaradi razlik v teksturi talnega profila (glineno-ilovnate plasti nad meljasto-ilovnatimi pedološkimi horizonti) in posledično počasnega vertikalnega pretoka in zadrževanja vode, k ohranjenosti peloda pa so prispevale tudi razmeroma nizke pH vrednosti v današnjih tleh.


K–3
K–2
K–1
Labiatae
Comp. tub. (Ind.)
Comp. tub. (Hom. - Pet. type)
Comp. tub. (Carduus type)
Comp. tub. (Bidens type)
Comp. tub. (Bellis type)
Comp. tub. (Gnaphalium type)
Comp. tub. (Cirsium type)
Compositae liguliflorae
Urtica
Leguminosae indet.
Ranunculus acris type
Ranunculus
Artemisia
Chenopodiaceae
Rumex
Plantago lanceolata
Centaurea
Secale
Cerealia
Poaceae
Cyperaceae
Corylus
Lonicera
Salix
Juglans
Olea
Ulmus
Fraxinus ornus
Fraxinus excelsior
Acer
Carpinus orientalis - Ostrya
Alnus
Carpinus betulus
Quercus
Tilia
Fagus
Betula
Larix
Abies
Picea
Pinus
Radiokarbonski datumi / 14C ages (BP)
2390 ±40
5900 ±40
9670 ±60
Pedološki horizonti / Pedological horizons
A
Bw
BC I
BC II
Bb1
C II
Ocena starosti cal. BC / Estimated age cal. BC
Globina / Depth (cm)
%

Sl. / Fig. 5a

Sl. 5a in b: Planina Klek. Odstotni pelodni diagram. Tanka črna črta označuje 10-kratno povečavo pelodnih krivulj. (Za prevod latinskih imen za pelodne taksone glej dalje).
Fig. 5a and b: Klek. Percentage pollen diagram. Thin black line marks 10x exaggeration of pollen curves (translation for Latin names of pollen taxa see below).



Sl. / Fig. 5b

Prevod latinskih imen za pelodne taksone / Translation for Latin names of pollen taxa (*sl. / fig. 5*):
5a: *Pinus* (bor / pine), *Picea* (smreka / spruce), *Abies* (jelka / fir), *Larix* (macesen / larch), *Betula* (breza / birch), *Fagus* (bukev / beech), *Tilia* (lipa / lime), *Quercus* (hrast / oak), *Carpinus betulus* (navadni gaber / hornbeam), *Carpinus orientalis – Ostrya* (kraški ali črni gaber / oriental or hop hornbeam), *Alnus* (jelša / alder), *Acer* (javor / maple), *Fraxinus excelsior* (veliki jesen / common ash), *Fraxinus ornus* (mali jesen / manna ash), *Ulmus* (brest / elm), *Olea* (oljka / olive tree), *Juglans* (oreh / walnut tree), *Salix* (vrba / willow), *Lonicera* (koseničevje / honeysuckles), *Corylus* (leska / hazel), Cyperaceae (ostričevke / sedges), Poaceae (trave / grasses), Cerealia (žitarice / ceraeals), *Secale* (rž / rye), *Centaurea* (glavinec / knapweeds), *Plantago lanceolata* (ozkolistni trpotec / ribwort plantain), *Rumex* (kislica / sorrels), Chenopodiaceae (metlikovke / goosefoot), *Artemisia* (pelin / mugwort), *Ranunculus acris* type (tip ripeča zlatica / meadow buttercup type), *Ranunculus* indet. (zlatica / buttercups), Leguminosae (metuljnice / legume family), *Urtica* (kopriva / nettle), Compositae liguliflorae (radičevke / Asteraceae), Compositae tub. = Compositae tubuliflorae (nebinovke / Asteroideae), *Cirsium* (osat / thistles), *Gnaphalium* (griževec / cudweeds), *Bellis* (marjetica / daisy), *Bidens* (mrkač / beggarticks), *Carduus* (bodak / thistle), *Homogyne – Petasites* (planinšček, repuh / butterbur), Labiatae (ustnatice / mint family).
5b: Umbelliferae (kobulnice / umbellifers), *Peucedanum* (silj / marsley), *Pimpinella* (bedrenec / anise), *Heracleum* (dežen / hogweed), Rubiaceae (broščevke / bedstraw family), *Knautia* (grabljišče / widow flower), *Campanula* (zvončnica / bellflower), Caryophyllaceae (klinčnice / pink family), *Cerastium* (smiljka / mouse-ear chickweed), *Geranium* (krvomočnica / cranesbills), *Calluna* (vresa / common heather), Filicales (monoletne spore praproti / monolete fern spores), Trilete fern spores / triletne spore praproti), *Selaginella selaginoides* (alpska dresžica / spikemoss), *Polypodium* (sladka koreninica / common polypody).

Za pelodne zapise v talnih profilih pogosto velja, da so zaradi zapletenih pedoloških procesov (npr. vertikalnega premikanja in/ali mešanja sedimenta zaradi delovanja živali, npr. deževnikov) nezanesljivi, ohranjenost peloda pa je zelo slaba (Dimbleby 1985). V nasprotju s tem mnenjem pa so pedološke in palinološke raziskave pokazale, da vertikalno premeščanje peloda s pomočjo vode zaradi njegove velikosti (pribl. 20–180 μm) ni verjetno (van Mourik 1999). Študije mikromorfologije tal so namreč pokazale, da je pelod le v izločkih živali, ne pa tudi v praznih prostorih (voids) (van Mourik 1999; Davidson et al. 1999). Talna favna je zato zelo pomembna pri navpičnem mešanju in prerazporejanju peloda. Na našem profilu je zakisanje zgornjega dela analiziranega profila (0–34 cm), ki je skupaj s počasnim odtekanjem vode omogočilo ohranitev peloda, verjetno vplivalo tudi na živali v tleh. Ker je bilo talne favne malo, domnevamo, da je pelodni zapis na tem najdišču zanesljiv. Odsotnost vertikalnega premeščanja in/ali mešanja peloda podpirajo tudi rezultati radiokarbonskega datiranja (*tab. 1*) in krivulja pelodne koncentracija (*sl. 5*), ki v spodnjem delu profila ne narašča.

Pelodni zapis v zgornjem delu profila, ki je mlajši od pribl. 5000 cal. BC, kaže, da je bil človekov vpliv na pokrajino (paša) pomemben in je verjetno vplival na povečano hitrost sedimentacije. Vendar pa hitrost sedimentacije (pribl. 1 cm na 1000 let) ni bila dovolj velika, da bi na tem najdišču lahko nastal zapis razvoja vegetacije z visoko ločljivostjo, kar je potrebno upoštevati pri interpretaciji človekovega vpliva ob zgornji gozdni meji. Treba je tudi poudariti, da je ocena starosti sedimenta, ki temelji na linerani interpolaciji med posameznimi radiokarbonskimi datumi in predvideva enakomerno hitrost sedimentacije med dvema datiranima plastema, za talne profile zelo nezanesljiva. Nezanesljivost ocene starosti za ta profil je torej pomembna in lahko znaša več stoletij.

Zaradi slabe ohranjenosti peloda v zgodnjeholocenskih pokopanih tleh (pod 30 cm), ki so starejša od pribl. 5000 cal. BC, podrobna rekonstrukcija razvoja vegetacije ni možna, vseeno pa analiza daje informacije o nekaterih drevesnih in zeliščnih taksonih v pokrajini (*Picea* – smreka, *Alnus* – jelša, *Quercus* – hrast, *Fagus* – bukev in Poaceae – trave).

Spremembe vegetacije in človekov vpliv na okolje ob gozdni meji

Pozni glacial in zgodnji holocen

Na osnovi pelodnega diagrama s planine Klek ni mogoče rekonstruirati zgodovine razvoja vegetacije v tem obdobju. Odstotek peloda dreves je sicer precej visok, vendar pa se bomo, zaradi degradacije in nizke koncentracije peloda, odsotnosti rastlinskih makrofosilov ter možnosti resedimentacije in/ali transporta peloda na daljše razdalje raje odpovedali podrobnejši interpretaciji.

Po pribl. 5000 cal. BC

Pelodni zapis v zgornjem delu sekvence (med pribl. 30–29 cm in 12 cm), ki sodi v čas po pribl.

5000–4000 cal. BC, je bolje ohranjen in vsebuje nizek odstotek peloda dreves (15–30 %). To nam pove, da je bila v tem obdobju pokrajina manj pogozdena kot v zgornjem delu profila, ki odraža sestavo današnje vegetacije. Poleg rastlin, značilnih za travnike (npr. Poaceae – trave; Compositae liguliflorae – radičevke), je prisoten še pelod rastlin, ki so značilne za pašnike (npr. *Plantago lanceolata* – ozkolistni trpotec, *Campanula* – zvončnica, *Ranunculus* – zlatica) ter ruderalna področja in opuščena polja (*Centaurea* – glavinec, Chenopodiaceae – metlikovke, *Artemisia* – pelin). Ocenjujemo, da je starost prvih pelodnih zrn *Secale* (rži) na 28 cm in Cerealia (ostalih žitaric) na 27 cm med pribl. 4800 cal. BC in 500 cal. BC in zdi se, da pojav teh pelodnih zrn sovpada s hitrejšo sedimentacijo.

Tako zgoden pojav peloda žitaric na tej nadmorski višini je presenetljiv, tudi če upoštevamo negotovost ocene starosti analiziranega profila. Na planini Klek namreč niso bila odkrita bronastodobna (pribl. 2200–800 cal. BC) ali starejša arheološka najdišča, so pa bile drobne najdbe ali ostanki manjše poselitve odkriti na drugih visokogorskih najdiščih v Julijskih Alpah (npr. Horvat 2006; Horvat 2010; Ogrin 2006; Ogrin 2010). Bronasto bodalo (tipološko datirano v pozno bronasto dobo pribl. 1300–1100 cal. BC), ki je bilo odkrito na Lipanci pribl. 3,5 km jugozahodno od planine Klek, dokazuje, da so ljudje Pokljuko obiskovali že v bronasti dobi (Ogrin 2006; Horvat 2006).

Izvor peloda žitaric s Kleka je negotov. Morda je v klimatsko toplejših obdobjih na najdišče prišel z manjših polj v bližini. Druga razlaga je, da je pelod žitaric na Klek prišel z nižje ležečih območij z živino ali vetrom. Transport z vetrom je manj verjeten, ker žitarice niso vetrocvetke in se njihov pelod običajno ne širi na večje razdalje (Moore et al. 1991). Zgodovinski zemljevidi iz 19. stoletja kažejo, da so takrat polja na Pokljuki ležala na nadmorski višini pribl. 1000 m (Andrič et al. 2010, sl. 6a), ni pa zgodovinskih ali kakršnihkoli drugih dokazov (razen peloda) za obstoj polj na višjih nadmorskih višinah. Za razliko od Pokljuke zgodovinski dokumenti za območje Zgornjega Engadina v Švici pričajo o kultivaciji žitaric na terasah na nadmorski višini do pribl. 1800 m, vendar pa je točen čas nastanka teh teras nejasen (Gobet et al. 2003).

Človekove aktivnosti so pomembno vplivale na rastlinstvo. Ena najbolj podrobnih raziskav človekovega vpliva na okolje ob gozdni meji v Alpah je bila opravljena v Zgornjem Engadinu (pribl. 1780 m, vzhodna Švica, Gobet et al. 2003). Ta raziskava je razkrila, da se prvi sledovi človekovih aktivnosti (bolj odprta vegetacija, požiganje gozda in porast *Alnus viridis* – zelene jelše) pojavijo po pribl. 3550 cal. BC, medtem ko je začetek bolj intenzivnega človekovega vpliva datiran v zgodnjo bronasto dobo (pribl. 1950 cal. BC), ko nastane kulturna krajina, v kateri prevladujejo antropogeni travniki z macesnom (*Larix*) in grmičevje zelene jelše (*Alnus viridis*).

Tudi raziskave v Avstriji (Visoke Ture in Dachstein, na nadmorski višini 2100 in 1690 m) kažejo, da je imela paša pomemben vpliv na alpsko vegetacijo vse od bronaste dobe dalje (pribl. 1900–1300 cal. BC), tudi v poznorimskem in srednjeveškem obdobju (Drescher-Schneider 2010). Zanimivo je, da številna arheološka najdišča v alpskem visokogorju v Sloveniji sodijo ravno v ta tri arheološka obdobja (Horvat 2002, 120–122), ko je bil, po palinoloških podatkih domnevno zaradi toplejše klime, človekov vpliv na okolje južno in severno od Alp intenzivnejši (Tinner et al. 2003). Morda ta obdobja lahko povežemo s fazami umikov ledenikov pribl. 2900–2450 cal. BC, 2100–1650 cal. BC, cal. AD 0–300, cal. AD 700–900 in cal. AD 1300–1500 (Grosjean et al. 2007).

Človekov pritisk na okolje na planini Klek se je verjetno nadaljeval tudi v arheoloških obdobjih, ki so sledila bronasti dobi, z izjemo kratkotrajnega porasta smreke (*Picea*) v drugem tisočletju pr. n. št., ki kaže na nekoliko manj intenzivno človekovo aktivnost. Za razliko od Švice (Gobet et al. 2003), na Kleku nismo opazili faz intenzivnega požiganja vegetacije, ki bi jim sledila razširitev zelene jelše (*Alnus viridis*). Začetek današnjega zaraščanje gozda, ki je viden v zgornjem delu pelodnega diagrama (porast smreke – *Picea,* bora – *Pinus* in bukve – *Fagus;sl. 5*), je na diagramu postavljen v čas okrog cal. AD 1000. Vendar pa ocena starosti v tem delu diagrama ni natančna in je zato zaraščanje gozda verjetno nekoliko mlajše, kot predlaga naš časovni model.

ZAKLJUČEK

Na osnovi rezultatov paleoekoloških raziskav, ki so predstavljeni v tem članku, lahko sklepamo, da sta bili Pokljuka in planina Klek gospodarsko pomembni od bronaste dobe pa vse do danes. Palinološki rezultati kažejo na podobno uporabo alpskih habitatov kot v Švici in Avstriji (Gobet et al. 2003; Drescher-Schneider 2010), kar kaže, da je bila Slovenija del regionalnih trendov. Človekove dejavnosti na planini Klek so povzročile erozijo tal in sedimentacijo, kar je omogočilo ohranitev peloda. Zaradi kompleksne tafonomije, neugodnih pogojev za ohranitev peloda in počasne sedimentacije (in zato slabše časovne resolucije) v članku žal nismo mogli podati podrobnega opisa razvoja vegetacije. Za podrobnejšo rekonstrukcijo razvoja vegetacije in človekovega vpliva na okolje bo zato potrebno počakati na analizo za palinološko raziskavo primernejših paleoekoloških najdišč v regiji.

Zahvala

Stroške v tem članku predstavljenih arheoloških in palinoloških raziskav so krili Evropska skupnost, Ministrstvo za okolje in prostor, Triglavski narodni park in Občina Bohinj (projekt "Železna pot", 2005–2007, Interreg IIIB, Alpine Space). Slike sta pripravili Tamara Korošec in Lucija Lavrenčič. Za pomoč pri opisu najdišča se zahvaljujemo Tomažu Kralju, za podrobno recenzijo, ki je bistveno izboljšala članek, pa Pimu van der Knaapu in Heleni Grčman.

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Palaeoecological evidence for human impact at the forest line at Klek in the Julian Alps

Translation

INTRODUCTION

Alpine habitats at the forest line are very sensitive to climatic fluctuations and human impact (e.g. grazing, forestry). In Slovenia they were very important economic areas from the Middle Ages onwards (e.g. Melik 1960; Kos 1960; Novak 1970; Pleterski 1986; Petek 2005; Andrič et al. 2010), but the land-use and forest-line fluctuations in older archaeological time periods have not been investigated. Several archaeological finds testify that the Pokljuka Plateau in the eastern Julian Alps has been frequented from at least the Late Bronze Age onwards (Ogrin 2006; Horvat 2006), however archaeological and palaeoecological data about the past environment and the economy in these high altitude areas are very scarce. It is, for example, unclear when the first mountain grazing was established and when the first iron ore extraction took place on the Pokljuka Plateau (Mohorič 1969).

Palynological data from study sites located close to or above the present-day forest line (e.g. *Koča pri Triglavskih jezerih* and *Malo polje*, located at ca. 1700–1800 m a.s.l.; *fig. 1*) suggest that the forest line may have been higher than these locations during earlier parts of the Holocene (Šercelj 1961; Šercelj 1965). However, these pollen diagrams are not radiocarbon dated and plant macrofossils are often not preserved or analysed. We therefore have no more than very general information on the Holocene vegetation development. Many pollen diagrams from lower altitudes (ca. 1200–1450 m a.s.l.), on the other hand, have a much better sampling resolution and chronological control (e.g. Planina pri Jezeru: Culiberg 2002; Šijec: Šercelj 1971; Andrič et al. 2010), but most of them cover only short time periods, mostly the last ca.

200–300 years. Therefore a detailed analysis of a complete high altitude Holocene pollen sequence is very much needed in the area.

The Klek grazing area (ca. 1550 m a.s.l.) is, on the basis of historical data, presumed to be one of the oldest alpine grazing areas on the Pokljuka Plateau (Pleterski 1986, 114–118). Archaeological excavations at Klek suggest that it was frequented in the Roman period (1st and 2nd centuries AD), Late Antiquity (5th and 6th centuries AD), and Early Medieval time period (7th–10th century AD) (Ogrin 2006). However, it is not clear when the first grazing areas appeared and whether human presence was associated with metallurgical or any other activities. This paper discusses the palynological evidence for Holocene environmental changes at the forest line, near the archaeological sites in Klek on the Pokljuka Plateau in Slovenia.

STUDY AREA

The Klek Alpine grazing area is located in the Julian Alps (northwestern Slovenia), on the Pokljuka plateau at 1550 m a.s.l. (*fig. 1*), next to a mountain trail connecting the Bohinj area with the upper Sava valley. It consits of three parts: Spodnji Klek, Zgornji Klek and Pekel (*fig. 2*). The large depression of Spodnji Klek represents a central area (ca. 550 × 420 m). A water source is located in the Northern end of the depression. The depression has dry meadows with a rich flora, which cover about 20 ha and are surrounded by larch (*Larix decidua*) trees and spruce (*Picea abies*) forest (Dakskobler et al. 2010). The climate in the area is temperate with a long-term regional January average of 0–3°C and July average of 15–20°C. The deepest part of the Spodnji Klek depression lies at 1505 m a.s.l., which is rather lower than the surrounding areas of Zgornji Klek (1565 m a.s.l.) and Travno brdo (1553 m a.s.l.). The depression is therefore colder in winters (frost hollow) than its surroundings, which has an effect on the vegetation composition. Mean annual precipitation in the area is ca. 1300–2800 mm (Ogrin 1996).

Two archaeological sites were discovered on the slopes of Spodnji Klek (*fig. 2*). The location of a Late Antiquity (5th–6th century AD) building was found on the western slope (*fig. 3*). The site of Na sedlu, located above the spring in the northern end of Spodnji Klek, yielded no archaeological structures but only small objects originating from the Early Roman period (1st–2nd century AD), Late Antiquity (5th–6th cent. AD) and the Early Medieval period (9th–10th cent. AD). A deposit of iron ore was also excavated in the Na sedlu site (*fig. 2;* Ogrin 2006, 103–104; Ogrin 2010, 203–203; Bizjak 2004, 133–134).

According to written historical sources Klek is one of the oldest grazing areas on Pokljuka and it was possibly already utilized in the 10th century AD by peasants of the Northern Bled area (Pleterski 1986, 114–118; Štular 2006). Iron mining pits of different sizes have been found on the Pokljuka Plateau near the Klek grazing area. The mining is not well dated, but the largest part probably originates from the Medieval and Early Modern periods (Bizjak 2004, 133–134).

METHODS

Samples for palaeoecological research were collected from a shallow (50 cm deep) trench, which was dug in the southern, dampest part of the Klek depression (*figs. 2, 3*). The sediment was collected in metal boxes, wrapped into cling film, aluminium foil and thick plastic, and later stored in a cold room at +4°C. Since no marshy areas better suitable for palynological research were found at Klek, these samples were analysed for pollen.

The age of the sequence was determined by AMS radiocarbon dating of organic carbon, extracted from soil samples, collected at three different depths (*tab. 1; fig. 4*). The chemical composition of the soil profile was affected by pedological processes. Symptoms of iron translocation (mottles and concretions at the contact of the modern and a buried soil profile at 34 cm, see chapter *Results, Soil profile, fig. 4* and *tab. 2*) led to the decision to remove fulvic and humic acids using acid/alkali/acid pre-treatment prior to dating of the remaining humin fraction of the soil sample (*tab. 1*). The sample at 25 cm (Beta-227136) which was fine grained silt without any plant or peaty remains, did not yield a separable humin fraction, so only the acid washes were used for dating and the result is considered as a "minimum age" result. The conventional radiocarbon ages were calibrated using CALIB Rev 5.0.1 (CALIB 5.0 Website; Stuiver and Reimer 1993) on the IntCal 04 calibration dataset (Reimer et al. 2004). Median values (as recommended by Telford et al. 2004) were used for the age-depth modelling (linear interpolation; *fig. 4*) and the positions of the radiocarbon dates are plotted on the pollen diagram (*fig. 5*).

The soil profile was described (*tab. 2; fig. 4*) and sampled (*tab. 3*) at the Center for Soil and Environmental Science (CPVO) at the Biotechnical Faculty of the University of Ljubljana. A soil Munsell Chart was used to determine soil colour. Samples were collected from the middle of each identified soil horizon, air dried and analysed following the ISO 11464 (1994) standard procedure. Particle size was determined using a sedimentation method with pipette analysis (ISO 11277, 1998). pH was determined electrometrically using 0.1 M $CaCl_2$ extraction solution following the ISO 10390 (1994) standard procedure. For loss-in-ignition analysis, 1 cm^3 of dry soil sample from each horizon was weighted, burnt in a muffle furnace at 550°C for eight hours and weighted again to determine the loss of organic material (calculated as a percentage of sample dry weight and presented in *tab. 2*).

For pollen analysis, 1 cm^3 of the sediment was subsampled from selected levels using a metal volumetric subsampler. Standard laboratory procedures were used (7% HCl, 10% NaOH, 40% HF, acetolysis, staining with safranine, tertiary butyl alcohol, mounting in silicone oil; Bennett, Willis 2002). Two tablets with a known number of *Lycopodium* spores were added to each sample prior to laboratory preparation in order to determine the pollen concentrations (Stockmarr 1971). For pollen identification, a Nikon Eclipse E400 light microscope at x400 magnification, the pollen reference collection at the Institute of Archaeology ZRC SAZU in Ljubljana, and the pollen keys of Moore et al. (1991) and Reille (1992, 1995) were used. Because the pollen concentration in the samples was relatively low (especially below 30 cm), a minimum of 300 pollen grains of terrestrial plants and spores were counted. Data were analysed and plotted using PSIMPOLL 3.00 program software (Bennett 1998; PSIMPOLL Website). The pollen diagram was divided into three zones (K1–K3) using binary splitting by sum of squares.

RESULTS

Radiocarbon dating

The age-depth model suggests that the profile covers the entire Holocene sequence (*tab. 1; fig. 4*). The sedimentation rate in the early and middle Holocene was very slow (36–25 cm), and very low (ca. 0.001 cm yr^{-1}), but increased towards the top (ca. 0.01 cm yr^{-1}).

Soil profile

The upper part of the profile (A, Bw and BC I horizons) was classified as *Epileptic Cambisol, siltic* (*tabs. 2; 3; fig. 4*). It overlies a B horizon of a buried, early Holocene eroded *Cambisol* (Bb1, Bb2 and C II horizons) at ca. 34 cm. The upper part of the profile contains a significant amount of clay, which contributes to the slow drainage at the site. Black and orange mottles and concretions in the lower part of the profile attest to the impeded drainage and iron translocation along the contact of the buried and modern soil profile.

Pollen analysis *(fig. 5)*

The pollen in zone K1 and the lower part of K2 (ca. 48–30 cm) is poorly preserved (>20% degraded), with low concentration (< 1000 grains 1 cm^{-3}). The pollen record in the upper part (above 30 cm), on the other hand, is more informative due to good preservation.

Zone K1 (48–37 cm, before ca. 9500 cal. BC)

In the zone K1 the percentage of degraded pollen is high (35–130% of a pollen sum that includes all terrestrial taxa without degraded grains). The pollen concentration is very low, so we were unable to count a statistically significant number of pollen grains (≥ 300 per sample). Nevertheless, the grains that were counted indicate that the main tree taxa present were *Picea* (spruce), *Alnus* (alder), *Quercus* (oak), and *Fagus* (beech), with Poaceae (grass) pollen as the dominant herb taxon.

Zone K2 (36–12 cm, ca. 9500 cal. BC–cal. AD 800)

In the lower part of zone K2 the pollen concentration remains low, with a high (ca. 80%) percentage of degraded pollen. Tree pollen decreases from 35–50% at the base of the zone to ca. 20% at 29 cm, whereas herb pollen increases (e.g. Poaceae exceeds 40%).

In the upper part of zone K2 (above 32 cm, after 6200 cal. BC) the pollen concentration increases to ca. 10000–15000 grains cm^{-3} and degraded pollen declines to 10–20%. Herb pollen remains abundant (ca. 50–60%), and the first *Secale* (rye) and Cerealia type pollen grains occur at 28 cm and 27 cm respectively. Also other "anthropogenic indicator taxa", characteristic for pastures, meadows, ruderal areas and fields, increase (*e.g. Plantago lanceolata* – ribwort plantain, *Centaurea* – knapweeds, Chenopodiaceae – goosefoot, *Artemisia* – mugwort, *Ranunculus* – buttercups, Compositae – daisy family and *Campanula* – bellflower).

Zone K3 (12–0 cm, cal. AD 800–2005)

The main characteristic of zone K3 is an increase of tree pollen to ca. 60% (20% of *Pinus* – pine and 25% of *Picea*), whereas herbs decline to 35% (20% of Poaceae).

DISCUSSION

Taphonomic processes and temporal precision of the analysed profile

The paleoecological record at Klek grazing area was significantly shaped by pedological processes. The slow drainage at the sampling site caused by the textural contrast within the soil profile (clay-loam horizons overlying silt-loam horizons) in combination with a relatively low pH in the modern part of the profile likely enabled the preservation of pollen.

Pollen records from soil profiles are often considered unreliable due to complex pedological processes (e.g. vertical movement and/or mixing of the sediment by soil animals, e.g. earthworms) and poor pollen preservation (Dimbleby 1985). In contrast to this opinion, pedological and palynological studies of soil profiles suggested that vertical movement of pollen grains by water is not likely, presumably due to the larger pollen grain size (ca. 20–180 μm; van Mourik 1999). This is demonstrated by soil micromorphological studies showing that pollen is regularly present only in the excrements, but not in voids (van Mourik 1999; Davidson et al. 1999). Soil fauna plays therefore a key role in vertical mixing and redistribution of pollen. Acidification of the upper part of the studied soil profile (0–34 cm) combined with slow drainage, which enabled pollen preservation, may have led to lessened soil fauna activity, so we consider the pollen record of this profile to be reliable. Absence of vertical pollen movement and/or mixing is also supported by the results of radiocarbon dating (*tab. 1*) and of the pollen concentration curve (*fig. 5*), as it does not increase downwards.

The pollen record in the upper part of the profile younger than ca. 5000 cal. BC suggests that human impact on the landscape (grazing) was significant, and likely contributed to increased sedimentation rates. However, the sedimentation rate (ca. 1 cm per 1000 years) was not high enough to provide a high-resolution vegetation record, which needs to be taken into account when interpreting human impact at the forest line. It also needs to be stressed that the age-depth model based on linear interpolation (which assumes a constant sedimentation rate between two dated levels) is highly uncertain for soil profiles. Uncertainty of age estimation for this profile is therefore significant (several centuries).

The poor pollen preservation in the buried early Holocene part of the profile (below 30 cm), dated to older than ca. 5000 cal. BC, does not allow for a detailed reconstruction of the vegetation development, but it does provide some information on tree and herb taxa (*Picea* – spruce, *Alnus* – alder, *Quercus* – oak, and *Fagus* – beech, with *Poaceae* – grass).

Changes of vegetation and human impact on the environment at the forest line

Late glacial and early Holocene

On the basis of the Klek pollen diagram we can not reconstruct the vegetation composition of this time period. The percentage of tree pollen is rather high, but we refrain from any further interpretation because of the degradation and low concentrations of the pollen, the lack of plant macrofossils, and the possibility of resedimentation and/or long-distance pollen transport.

After ca. 5000 cal. BC

The pollen record in the upper part of the sequence (between ca. 30–29 cm and 12 cm), which is dated after ca. 5000–4000 cal. BC, is better preserved and contains a low percentage of tree pollen (15–30%). This suggests that the landscape was less forested than the top of the sequence representing the present-day vegetation composition. In addition to meadow plants (e.g. Poaceae – grasses; Compositae liguliflorae- daisy family, dandelion sub-family), the pollen record contains taxa characteristic for pastures (e.g. *Plantago lanceolata* – ribwort plantain, *Campanula* – bellflower, *Ranunculus* – buttercups), ruderal areas and abandoned fields (*Centaurea* –

knapweeds, Chenopodiaceae – goosefoot, *Artemisia* – mugwort). The age of first pollen of the cultivated *Secale* (rye) and Cerealia (at 28 and 27 cm respectively) is estimated to be younger than ca. 4800 cal. BC and older than ca. 500 cal. BC, which seems to coincide with an increased sedimentation rate.

Such an early occurrence of cereal pollen at this altitude seems to be unusual, even if we take into account dating uncertainties of the pollen profile. No archaeological sites dated to the Bronze Age (ca. 2200–800 cal. BC) or earlier time periods were discovered at Klek, but small settlement sites and individual bronze objects are often found at other high altitude sites in the Julian Alps (e.g. Horvat 2006; Horvat 2010; Ogrin 2006; Ogrin 2010). A bronze dagger (typologically dated to the Late Bronze Age, ca. 1300–1100 cal. BC) was found at Lipanca, ca. 3.5 km south west of Klek, suggesting that the Pokljuka Plateau was frequented already in the Bronze Age (Ogrin 2006; Horvat 2006).

The origin of cereal pollen at Klek is uncertain. In climatically favourable periods small agricultural fields may have been present. Alternatively, cereal pollen grains may have been brought to the study site from lower altitudes by cattle or wind. This is, however, a less likely option, since cereals are not wind-pollinated and most of their pollen does not spread far (Moore et al. 1991). Historical maps of the 19th century AD of the Pokljuka Plateau show agricultural fields at about 1000 m a.s.l. (Andrič et al. 2010, fig. 6a), but there is no historical nor any other evidence (apart from pollen) for fields at higher altitudes. However, historical documents from the Upper Engadine region (Switzerland) testify that cereals were cultivated on terraces up to ca. 1800 m a.s.l., but the age of these presumably medieval terraces is uncertain (Gobet et al. 2003).

Various human activities must have had an important impact on the vegetation. One of most detailed studies of the Holocene environment near the timberline in the Alps was carried out in the Upper Engadine (ca. 1780 m a.s.l., eastern Switzerland, Gobet et al. 2003). This study suggests that the first signal of anthropogenic activities (more open vegetation, forest burning and increase of *Alnus viridis* – green alder) can be dated to after ca. 3550 cal. BC, but strong anthropogenic activities began only during the Early Bronze Age at ca. 1950 cal. BC, with the formation of a cultural landscape dominated by anthropogenic *Larix* (larch) meadows and *Alnus viridis* shrubs.

Similarly, research in Austria (Hohe Tauern and Dachstein, 2100 and 1690 m a.s.l. respectively) suggests that grazing activities had a significant impact on the Alpine vegetation starting in the Bronze Age (ca. 1900–1300 cal. BC), and continuing to the Late Roman and Medieval time periods (Drescher-Schneider 2010). It is interesting that many of the archaeological sites that were discovered in high altitude Alpine areas of Slovenia were dated into these three archaeological time periods (Horvat 2002, 120–122), when human impact on the environment was intensive because of warmer conditions as suggested by pollen records both north and south of the Alps (Tinner et al. 2003). It is possible that they can be associated with maximum glacier retreat phases dated to 2900–2450 cal. BC, 2100–1650 cal. BC, cal. AD 0–300, cal. AD 700–900 and cal. AD 1300–1500 (Grosjean et al. 2007).

At Klek anthropogenic pressure on the environment may have remained constant in archaeological time periods following the Bronze Age, with the exception of a slight short-term increase of *Picea* (spruce) in the 2nd millennium BC, indicating less intensive human impact. In contrast to Switzerland (Gobet et al. 2003), no intensive landscape burning followed by spread of green alder (*Alnus viridis*) was detected. The beginning of modern forest recovery towards the top of the sequence, when *Picea* (spruce), *Pinus* (pine) and *Fagus* (beech) increase (*fig. 5*), is estimated to be cal. AD 1000. However, the age estimates in this part of the pollen diagram are not very precise and it is not unlikely that the modern forest recovery is much younger than suggested by the age-depth model.

CONCLUSIONS

The results of palaeoecological research presented in this paper suggest that the Pokljuka Plateau in general and Klek in particular were important economic areas as far back as the Bronze Age to the present day. Palynological research has shown the same land use for alpine habitats in Switzerland and Austria (Gobet et al. 2003; Drescher-Schneider 2010), which suggests that the Slovenian territory was a part of regional trends. Human activities on Klek triggered erosion followed by sedimentation at the site, which enabled the preservation of the pollen record. Unfortunately, the complex taphonomy, unfavourable conditions for pollen preservation, and slow sedimentation rates resulting in limited temporal precision, meant that we were unable to produce a more detailed vegetation reconstruction. A detailed reconstruction of past vegetation and human impact on the environment might be derived from studies of palynologically more favourable locations in the area.

Acknowledgements

The archaeological and palynological research presented in this paper was funded by the "Iron Route" (2005–2007) "Interreg IIIb", "Alpine Space" research project funded by the European Union, local municipalities and the Ministry of the Environment and Spatial Planning of the Republic of Slovenia. Figures were prepared by Tamara Korošec and Lucija Lavrenčič. We are grateful to Tomaž Kralj for help with site description. We would like to thank Pim van der Knaap and Helena Grčman for their insightful comments which significantly improved the paper.

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