Holocenske paleoekološke in paleohidrološke razmere na Ljubljanskem barju – prispevek k diskusiji

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Izvleček

Ljubljansko barje je izjemna pokrajina. Vlažne hidrološke razmere omogočajo dobro ohranjenost arheoloških najdišč in paleoekološkega zapisa. Vendar pa je Ljubljansko barje za paleoekološke raziskave hkrati tudi izjemno zahtevna regija. Razvoj holocenske pokrajine in vegetacije je bil namreč zelo dinamičen, posledica tega pa spremenljive tafonomske razmere in, zaradi kompleksne hidrološke mreže in človekovega vpliva (rezanje šote), pogosto fragmentiran paleoekološki zapis. Kljub številnim raziskavam v zadnjih desetletjih, podrobne raziskave nekdanje hidrologije niso bile opravljene, čeprav je za arheologijo in paleoekologijo to očitno pomembna tema, saj se je v zadnjih letih razvila živahna diskusija o tem, ali je območje Ljubljanskega barja nekoč pokrivalo jezero ali rečna poplavna ravnica. S tem prispevkom se želim vključiti v razpravo in predstaviti svoj pogled na hidrološko problematiko. Moje mnenje je, da so bile paleoekološke razmere na področju Ljubljanskega barja preveč kompleksne, da bi jih lahko zreducirali samo na polemiko *"jezero ali poplavna ravnica?"*, moj glavni očitek raziskovalcem, ki so dozdaj razpravljali o tej temi pa, da je njihova interpretacija hidrološkega dogajanja preveč ambiciozna, ker temelji na rezultatih premalo obsežnih paleoekoloških raziskav, pa najsi gre za rezultate njihovih lastnih raziskav ali interpretiranje rezultatov drugih raziskovalcev.

Ključne besede: paleohidrologija, Ljubljansko barje, holocen, paleoekologija, palinologija

Abstract

The Ljubljansko barje is a remarkable landscape. Due to wet hydrological conditions the palaeoecological record and archaeological sites in the area are very well preserved. Yet, it is also a very demanding landscape for studying the past environment. The environmental changes and vegetation development throughout the Holocene were very dynamic, which led to changeable taphonomic conditions and, because of the complex hydrological network and human impact (peat cutting), the palaeoecological record is often fragmented. Past hydrological conditions at Ljubljansko barje are a very important topic for archaeologists and palaeoecologists alike and in the last few years there has been an intensive debate about whether Ljubljansko barje was covered by a floodplain or a lake. However, despite intensive research in the area in the last decades, no detailed study of palaeohydrology was carried out. With this paper I would like to join the discussion and present my opinion regarding past hydrological conditions in the area. In my opinion this question is too complex to limit ourselves to the *"lake or floodplain?"* dilemma. In most studies to date of the past hydrology, the interpretation that has been suggested was too ambitious, because it was based on insufficient data, no matter whether researchers were presenting their own data or interpreting other researcher's results.

Key words: palaeohydrology, Ljubljansko barje, the Holocene, palaeoecology, palynology

UVOD

Paleoekologija je omejena na preučevanje zapisa preteklega dogajanja, ki je zaradi tafonomskih procesov pogosto fragmentiran in preoblikovan. Palinologi, na primer, analiziramo pelodne ostaline v jezerskih in močvirskih sedimentih, da bi lahko rekonstruirali zgodovino razvoja vegetacije, na razvoj vegetacije in hidrologijo v neki pokrajini pa, poleg drugih dejavnikov, bistveno vplivata klima in človek. Vendar pa vpliva nekdanje klime ne moremo meriti neposredno; opazujemo lahko le spremembe zapisov v "paleoekoloških arhivih" (npr. v sedimentu). Čim več različnih paleoekoloških raziskav naredimo (z velikim številom analiziranih vzorcev, čim boljšo kronološko kontrolo in koordinacijo med raziskovalci), tem podrobnejša bo naša informacija o nekdanjem okolju. Z na-

predovanjem raziskovalnega dela si interpretacije različnih raziskav pogosto med seboj navidezno nasprotujejo in odpira se vse več novih problemov, ampak nič hudega, to je davek, ki ga plačujemo za napredek in specializacijo paleoekoloških ved. Dobra paleoekologija je multidisciplinarna in osebno imam raje "diskusijo" kot pa "sintezo", s katero bi se vsi strinjali, kar bi nam dajalo navidezno varen občutek, da so vsi problemi rešeni (pa morda sploh niso bili odprti, ker smo jih varno "pometli pod preprogo").

Tudi tako zahtevnega raziskovalnega problema, kot je preučevanje nekdanjih hidroloških razmer v pokrajini, se lahko lotimo na več načinov. Raziskave, ki se ukvarjajo s preučevanjem nihanja vodne gladine v jezerih in močvirjih, pogosto vključujejo geomorfološke raziskave, analize sprememb fizičnih in kemičnih lastnosti sedimenta in proučevanje rastlinskih in živalskih mikro- in makrofosilov (Dearing, Foster 1986; Moore 1986). Vendar pa se je treba zavedati, da vse prej omenjene spremembe niso dobro vidne v vseh tipih bazenov (pomembno je, ali je jezero/močvirje majhno ali veliko, s površinskimi pritoki/odtoki vode ali brez njih) in niso nujno povezane z nihanjem višine vode. Lahko so povezane tudi z drugimi dogodki v okolju, kot so spremembe v povodju (npr. odlaganje debelejših frakcij minerogenega sedimenta zaradi erozije, ki jo je povzročilo izsekavanje gozda) ali naravno zasipavanje in sukcesijsko zaraščanje bazena (Digerfeldt 1986, 129–130). Skratka, "čarobne palčke" in samo ene "prave metode" za proučevanje hidrologije ni, analogije z dogajanjem v primerljivih modernih jezerih so lahko zavajajoče (Dearing, Foster 1986, 70), pogosto pa se je okolje do danes že tako močno spremenilo, da tudi moderne analogije niso več na voljo. Ko končno ugotovimo, kako se je višina vode v jezeru spreminjala skozi čas, se seveda odpre nov problem in postavi novo vprašanje: Zakaj je do teh sprememb okolja sploh prišlo? In tudi odgovor na to vprašanje ni enostaven: na nihanje gladine vode lahko vplivajo tektonika, geološka podlaga, klima (temperatura in količina padavin), dotok/odtok vode, okoliška vegetacija in človek (Dearing, Foster 1986, 68, 71). Vsako od omenjenih vprašanj pa potrebuje svojo, podrobno raziskavo. Skratka: preučevanje hidrologije je zapletena in dolgotrajna multidisciplinarna paleoekološka raziskava.

V hidrološko tako kompleksnih bazenih, kot je (bilo) Ljubljansko barje, so podrobne in dolgotrajne paleoekološke raziskave še toliko bolj pomembne. V preteklih letih je bilo na Ljubljanskem barju opravljenega kar nekaj raziskovalnega dela, ki se posredno ali neposredno dotika hidrološke problematike. V tem prispevku bom najprej na kratko predstavila nekaj najbolj tipičnih pogledov na hidrologijo Ljubljanskega barja in se kritično opredelila do argumentacije posameznih raziskovalcev, na koncu pa predstavila še svoj pogled na hidrološko problematiko, ki temelji na rezultatih multidisciplinarne paleoekološke raziskave vrtine z vzhodnega dela Ljubljanskega barja. V razpravi se ne bom omejila samo na za arheologijo najzanimivejše obdobje prazgodovinske poselitve barja, ampak bom, zaradi lažjega razumevanja dogajanja v pokrajini, obravnavala celoten holocen (z izjemo zadnjih nekaj tisočletij, ko je bil paleokeološki zapis zaradi rezanja šote uničen).

JEZERO ALI POPLAVNA RAVNICA? Kritičen pregled argumentov, ki so bili uporabljeni v dosedanji polemiki

Jezero

Prvi model hidrološkega razvoja Ljubljanskega barja, ki temelji na geomorfoloških in sedimentoloških podatkih predvideva, da je področje Ljubljanskega barja v poznem glacialu ter zgodnjem in srednjem holocenu prekrivalo jezero (Melik 1946). Do ojezeritve naj bi bilo prišlo zaradi tektonike in mehanične zajezeritve zaradi rečnega zasipanja Save. Melik je na osnovi geomorfoloških podatkov (lega in nadmorske višine obrežnih teras) menil, da je bilo v prvi, poznoglacialni fazi jezero globoko 13–14 m, kasneje, ko je jezero postalo plitvejše (10–11 m), je zaradi nasipanja potokov obrežni pas že pogledal iz vode, medtem ko je bilo v zadnji fazi, ki jo postavlja v koliščarsko obdobje, jezero že zelo plitvo in le v najglobljih predelih globoko preko 3 m (Melik 1946, 60–66). Jezero naj bi v barje prešlo nekje v obdobju med "koliščarsko" in rimsko dobo; sredi šotne plasti za Babno Gorico pri Škofljici so namreč našli ostanke rimske ceste, ki je domnevno potekala na relaciji Škofljica–Ig–Bloke (Melik 1946, 99–100; Velušček 2006, 43, sl. 24).

Poleg geomorfološke Melik uporablja tudi sedimentološko argumentacijo. Svetlo siva karbonatna meljasta glina (polžarica), ki pokriva večji del Ljubljanskega barja, je bila opredeljena kot jezerski sediment na osnovi geokemičnih lastnosti sedimenta: vsebuje veliko karbonatov, ki so se odlagali tako s kemičnim kot biogenim izločanjem apnenca zaradi fotosinteze vodnih rastlin, in

vsebnosti vodnih polžev (konhilij). "Rjavo blato" in šoto nad polžarico je označil kot "močvirski sediment", pri čemer naj bi bila črna šota značilna za nizko (travniško) barje, rjava šota pa za visoko barje (v katerem so prevladovali mahovi iz rodu *Sphagnum*), vendar pa Melik opisa okolja, v katerem naj bi se bile odlagale posamezne plasti, ni podrobno argumentiral, hkrati pa tudi opozarja na pomembne krajevne razlike glede razvoja močvirja in potrebo po nadaljnjem raziskovanju (Melik 1946, 51–52, 90–98). Melikovo argumentacijo so sprejeli in s svojimi raziskavami dopolnili tudi raziskovalci v naslednjih desetletjih. Tako je bila v naslednjih letih opravljena palinološka analiza sedimenta z opažanjem odtisov haracej v polžarici (Šercelj 1965; Šercelj 1966), analiza mehkužcev (Pavlovec 1967; Pavlovec 1982), kemična analiza, sedimentološki in pedološki opis polžarice in nad njo ležečih plasti (e. g. Grimšičar, Ocepek 1967; Tancik 1965; Turk 2006).

Kje so glavne prednosti in pomanjkljivosti "jezerske" razlage? Ena od prednosti zgoraj predstavljene hipoteze je kombinirana uporaba geomorfoloških in sedimentoloških podatkov, glavna pomanjkljivost pa odsotnost ustrezne kronološke kontrole, slaba resolucija vzorčenja in nenatančen opis preiskovanih profilov. Slabo je proučen tudi razvoj okolja v fazi izsuševanja jezera, pa čeprav se v literaturi že zelo dolgo pojavlja opis razvoja jezera, ki ga povzema sledeča trditev: "*V obdobju vsaj od koliščarske dobe naprej je namreč dokazano, da je Ljubljansko barje prešlo več razvojnih stopenj – od umikanja jezera, sočasnega napredovanja močvirja, do rasti nizkega barja in na nekaterih območjih v visoko barje (glej in prim. npr. Šercelj, 1966, 443; Peterlin 1970-71; 1987; Pavšič 1989, 9; Mencej 1992, 264; Turk 2006, 94).*" (Velušček 2007, 428). Na katerih podatkih temelji ta trditev? Melikov (Melik 1946, 91–92) opis sprememb vegetacije, do katerih običajno prihaja v plahnečem, zaraščajočem se jezeru – gre za splošen ekološki koncept naravnega razvoja jezera v nizko in visoko barje (Tansley 1939, "*hydroseral succession*" = hidrološka sukcesija) – so v prejšnjem stavku citirani avtorji le povzemali in ponavljali. Vendar pa, z izjemo nekaj zelo splošnih opisov šotnih plasti (brez predstavitve metodologije, točne lokacije in podrobnega opisa profilov, npr. Tancik 1965) in podatka iz 19. stoletja, ki v šotni plasti nad gyttjo omenja ostanke trsta (*Phragmites*) in različnih vrst iz rodov *Carex* (šaš) in listnatih mahov *Hypnum* (Martinčič 1987), podrobna raziskava, ki bi ugotovila, kaj se je dejansko dogajalo in kako točno je to sosledje potekalo, na Ljubljanskem barju ni bila opravljena. Velika večina šote je bila uničena, še preden je bilo mogoče opraviti ustrezne (paleo) ekološke raziskave (Martinčič 2003).

Osnovni koncept hidrološke sukcesije (Clements 1916; Tansley 1939; Charman 2002, 146, fig. 7.3a) predvideva postopno zaraščanje vseh jezer po vnaprej točno določenih vegetacijskih fazah. Na začetku hidrološke sukcesije prevladujejo vodne rastline globlje vode (*Myriophyllum, Potamogeton* – rmanec in dristavec), ki jih kasneje, ko voda zaradi zasipavanja bazena postaja vse plitvejša, nadomestijo rastline plitve vode (*Nymphaea, Nuphar*, lokvanj in blatnik), čemur sledi razširitev trstičja (*Phragmites*, pelod tipa "Poaceae"), šašev (Cyperaceae), v končni fazi pa področje prekrije visoko barje in/ali gozd. Vendar pa raziskave modernih rastlinskih združb kažejo, da je ta idealiziran koncept hidrološke sukcesije potrebno jemati z rezervo in le kot splošen koncept, ne pa kot "recept", po katerem se bodo zaraščala vsa jezera (Charman 2002, 146).

Kaj o vegetacijskih sukcesijskih stopnjah zaraščajočega se jezera pravi paleoekologija? Na kakšen način so se zaraščala jezera v preteklosti? Primerjava modernega dogajanja s fosilnim zapisom kaže, da v različnih delih bazena lahko poteka različno vegetacijsko zaporedje, na katerega vplivajo tudi zunanji vplivi: klima, spremembe hidrologije, človek (Birks 1980, 29–30). Primerjava holocenskih zapisov na paleoekoloških najdiščih v Veliki Britaniji (Walker 1970) pa tudi kaže, da se klasična sukcesija ne pojavlja na vseh najdiščih, pogosto so nekatere faze izpuščene ali pa prihaja celo do razvoja v obratni smeri (Birks, Birks 1980, 59–60). Stratigrafske spremembe, ki kažejo tipično hidrološko sukcesijsko zaporedje, se običajno pojavljajo samo v jezerih, ki imajo dovolj majhno zaledje, da je nivo vode odvisen pretežno od talnice (Dearing, Foster 1986, 71). Ljubljansko barje je, v nasprotju s tem, velik bazen s številnimi pritoki in odtokom vode, zaradi česar lahko pričakujemo bolj zapleteno zaraščanje bazena in upoštevanje zgolj sukcesijskih razvojnih stopenj je verjetno preveč poenostavljen opis dogajanja. Zato ne preseneča, da pelodni diagram vrtine "na mahu" (Andrič et al. 2008), na primer, ne kaže klasične hidrološke sukcesije vodnih in močvirskih rastlin. Morda je bila na tem mestu kakšna sukcesijska faza izpuščena ali pa razvoj tako hiter, da ga pelodni diagram ne zazna. Vsekakor bi, kljub slabi ohranjenosti makrofosilov, nekaj več informacij o "in situ" hidrološki sukcesiji morda lahko dale podrobnejše analize rastlinskih makrofosilov.

Ali "jezerska" teorija predvideva, kdaj je jezero na celotnem Ljubljanskem barju prešlo v močvirje? Velušček (Velušček 2005, 77–78) na osnovi Šifrerjevega radiokarbonskega datuma za *"rjavo organogeno ilovico neposredno nad polžarico v Črni vasi"* (2850 ± 100 BP, Šifrer 1984, 43) domneva, da se je to zgodilo v 2. tisočletju pr. n. št. Verjetno res, vendar je škoda, da za področje pri Črni vasi nimamo podrobnejših paleoekoloških podatkov (npr. podrobnega opisa celotnega profila, večjega števila radiokarbonskih datumov in drugih paleoekoloških raziskav). Z organskimi snovmi bogat sediment se lahko odlaga v hidrološko zelo raznolikih okoljih, lahko tudi v plitvem jezeru (Birks, Birks 1980, 50) ali v hidrološko bolj suhih razmerah. Samo na osnovi barve in starosti organskih snovi, ki jih sediment vsebuje, si nekdanjih okoljskih razmer bolj podrobno nikakor ne bi upala interepretirati, pa čeprav se je v arheološki literaturi v zadnjem času precej razširilo interpretiranje okoljskih razmer na osnovi iz konteksta iztrganih radiokarbonskih datumov, tako pri zagovornikih "jezerske" kot "rečne" (npr. Budja, Mlakuž 2008a; Budja, Mlekuž 2008b) hipoteze, ampak več o tem nekoliko kasneje.

Poplavna ravnica

Drugi model hidrološkega razvoja Ljubljanskega barja, ki, podobno kot "jezerski" model, temelji na geomorfoloških in sedimentoloških podatkih, domneva, da na Ljubljanskem barju v holocenu nikoli ni bilo stalne ojezeritve (Šifrer 1984). Zaradi izdatnega fluvioperiglacialnega nasipanja potokov in rek naj bi na Ljubljanskem barju ne bilo pogojev za zastajanje vode, prav tako pa ni opaziti deltaste sedimentacije in debelejših plasti sedimenta, ki bi se morale odlagati ob izlivih potokov in rek v mirno stoječo vodo nekdanjega jezera. Šifrer (1984, 42–43) tudi domneva, da heterogenost polžarice kaže na to, da je nastajala v zelo raznolikem okolju in je verjetno fluvialnega porekla, velika količina apnenca, ki jo vsebuje, pa bolj klimatski (holocenska otoplitev) kot pa jezerski indikator. Do zastajanja vode, obsežnih poplav in zaraščanja z mahom naj bi bilo prišlo šele kasneje (v času koliščarjev) zaradi vlažnejše klime, izsekavanja gozda in erozije tal (Šifrer 1984, 40–41, 49).

Glavne prednosti in pomanjkljivosti "rečne" razlage so podobne kot pri prej omenjeni "jezerski" hipotezi: kombinirana uporaba geomorfoloških in sedimentoloških podatkov je vsekakor prednost, pomanjkljivost pa odsotnost ustrezne kronološke kontrole in nenatančen opis preiskovanih profilov. Tudi trditev, da gre pri polžarici za "fluvialni" sediment, je vprašljiva. Ne glede na heterogenost tega sedimenta se svetlo siva karbonatna meljasta glina pojavlja skoraj povsod po Ljubljanskem barju, od Resnikovega prekopa na vzhodu (npr. Andrič 2006; Turk 2006) do Zaloga pri Verdu na zahodu (npr. Verbič 2006) in ni videti, da bi bila omejena samo na manjše kotanje. Veliko količino karbonatov, ki naj bi se bili odlagali v poplavni ravnici, Šifrer (1984, 42) utemeljuje z modernimi analogijami: kreda, ki se danes odlaga na Cerkniškem polju, je močno podobna tisti z Ljubljanskega barja. Vendar pa je ob tem treba dodati, da je bil na Cerkniškem jezeru analiziran sediment z najvlažnejšega dela polja (Zadnji kraj), kjer so poleg trstičja prisotne tudi alge, pa še tam vsi vzorci ne vsebujejo enake količine karbonatov (Tancik 1965, 68).

V zadnjih letih je bila na vzhodnem delu Ljubljanskega barja opravljena podrobnejša geomorfološka analiza (meritve LiDAR in izdelava digitalnih modelov površine), s katero so avtorji razpoznali nekdanje rečne struge, opazovali spremembe rečne mreže in te podatke primerjali z arheološkim poselitvenim vzorcem (Budja, Mlekuž 2001; Mlekuž et al. 2006). Na osnovi relativne stratigrafije opuščenih rečnih korit (dokumentirali so štiri faze paleokanalov) in radiokarbonskega datiranja lesenih kolov z arheološke naselbine Maharski prekop, ki leži neposredno ob rečnem kanalu iz prve faze rečnega preoblikovanja, je bila postavljena domneva, da so koliščarska naselja na Ljubljanskem barju ležala na poplavni ravnici (ki se je izoblikovala že v poznem mezolitiku), na obrežnih nasipih, ki so bili večinoma suhi in jih visoke poplavne vode niso dosegle (Budja, Mlekuž, 2001).

Glavna prednost zgoraj predstavljene hipoteze je zelo dobra in podrobna rekonstrukcija nekdanje hidrološke mreže, glavni problem pa predstavlja slaba kronološka kontrola, čeprav sta Budja in Mlekuž v zadnjem času opravila tudi radiokarbonsko datiranje organskega sedimenta v opuščenih rečnih koritih in tako odpravila glavno šibko točko svoje prvotne (Mlekuž et al. 2006) hipoteze (Budja, Mlekuž 2008a; Budja, Mlekuž 2008b). Na osnovi teh radiokarbonskih datumov poplavno ravnico datirata v čas pred pribl. 5500 cal. BP, zato sklepata, da so eneolitska in bronastodobna najdišča na tem delu Ljubljanskega barja stala na poplavni ravnici (Budja, Mlekuž 2008a). Vendar tudi v tem primeru ostaja moj

očitek podoben kot pri "jezerski" hipotezi – gre za iz konteksta iztrgane radiokarbonske datume in vse prej omenjene probleme v zvezi s tem. Previdnejši raziskovalni pristop in podrobnejši opis sedimenta z večjim številom radiokarbonskih datumov na vrtino bi bil koristen, še zlasti v tem delu Ljubljanskega barja, kjer lahko pričakujemo fragmentiran paleoekološki zapis (e. g. hiatuse in presedimentiranje sedimenta).

Moj drugi pomislek se nanaša na trditev, da so koliščarska naselja ležala na večinoma suhih obrežnih nasipih. Opis vlažnosti terena je vedno subjektiven in relativen, tudi na osnovi multidisciplinarnih raziskav (kot je npr. Andrič et al. 2008) se absolutne globine vode ne da točno določiti. Vseeno pa se je treba zavedati nečesa: pelod je v kulturnih plasteh arheoloških najdišč (npr. Maharski prekop, Blatna Brezovica, Stare Gmajne) ohranjen, kar pomeni, da hidrološke razmere niso mogle biti pretirano sušne, ampak moramo računati na visok nivo talnice ali stoječo vodo.

JEZERO IN POPLAVNA RAVNICA

Uvod

Skratka: dosedanje raziskave hidrologije na Ljubljanskem barju so bile usmerjene predvsem v sedimentološke in geomorfološke analize, močno pa nam manjkajo podrobne multidisciplinarne raziskave celotne holocenske sekvence, da bi lahko bolje razumeli, v kakšnem okolju so se odlagale posamezne vrste sedimenta. Menim namreč, da hidrološke problematike ne more reševati le ena stroka (npr. geologija), ampak morajo to biti usklajene, multidisciplinarne raziskave. Zato smo s kolegi opravili podrobno paleoekološko raziskavo (analiza diatomej, stabilnih izotopov, geokemičnega in pelodnega zapisa) vrtine "na mahu", ki leži na vzhodnem delu Ljubljanskega barja. Vrtino smo leta 2003 zvrtali v bližini arheoloških najdišč (pribl. 1 km severno od Maharskega prekopa), vendar ne neposredno na arheološkem najdišču ali v bližini reke ali nekdanjega rečnega korita, ker smo se želeli izogniti premešanju sedimenta zaradi človekove dejavnosti ali delovanja tekoče vode in raziskavo opraviti v sedimentacijsko čim bolj mirnem okolju. Rezultati te raziskave so bili že objavljeni (Andrič et al. 2008), v tej razpravi pa jih želim postaviti v kontekst dosedanje hidrološke polemike in predstaviti svoj pogled na holocenske spremembe vegetacije in hidrologije.

Naj takoj na začetku poudarim, da si ne domišljamo, da smo dokazali, kakšne so bile nekdanje hidrološke razmere na Ljubljanskem barju, lotili smo se le "vršička ledene gore" celotnega hidrološkega problema, ki bi ga lahko bolje raziskal le team specialistov paleoekologov (ki ga nimamo) in ki bi v okviru dobro financiranega paleoekološkega inštituta (ki ga v Sloveniji najverjetneje ne bomo nikoli imeli) deloval več desetletij.

Jezero in poplavna ravnica

Vrnimo se k vprašanju, ki je bilo v dosedanji diskusiji zelo izpostavljeno: Ali je bilo Ljubljansko barje nekoč jezero ali poplavna ravnica? To je pravzaprav zelo nenatančno vprašanje, ki hidrološke razmere reducira samo na dve možnosti, brez podrobnejše definicije razlik med obema hidrološkima režimoma. Enako se lahko vprašamo, ali je današnje Cerkniško jezero jezero ali poplavna ravnica? Pa tega ne omenjam zato, ker bi hotela reči, da so bile hidrološke razmere na Ljubljanskem barju nekoč podobne tistim na Cerkniškem jezeru. Želim le opozoriti, da moderni človek v današnji hidrološko umetno regulirani pokrajini vidi le jezera in reke, ki skoraj ne poplavljajo več, pa mu je predstava, da bi arheološko naselje (npr. Maharski prekop) lahko stalo nekje ob jezeru, v bližini izliva reke v jezero (torej, če hočete, ob jezeru in na poplavni ravnici hkrati), očitno tuje. Zato, ker takega okolja danes v Sloveniji praktično ni več in si ga ne znamo predstavljati. Zato mislim, da je mnogo pomembnejše vprašanje, kdaj in kje je prišlo do sprememb okolja, kaj točno se je zgodilo in, seveda, zakaj. In na ta vprašanja bom poskusila odgovoriti v nadaljevanju. Podrobnejša utemeljitev je bila že predstavljena v prvotni objavi (Andrič et al. 2008) in je v tem tekstu ne bom v celoti ponavljala.

Pozni glacial (ca. 15000–11500 cal. BP)

Rezultati raziskav vrtine "na mahu" (Andrič et al. 2008) kažejo, da je bilo Ljubljansko barje v poznem glacialu verjetno prekrito z globokim, oligotrofnim jezerom (prisotnost planktonskih diatomej), v katero je dotekalo kar precej kopenskega materiala (stabilni izotopi, geokemizem), domnevno zaradi erozije tal ob hladni klimi in razmeroma odprti vegetaciji (pelod). Čisto na dnu (650 cm) je vrtina zadela na plast zbitega, organskega sedimenta, na osnovi

česar domnevamo, da je do ojezeritve verjetno res prišlo šele v poznem glacialu, medtem ko je bilo v najhladnejših obdobjih, na primer v zadnjem višku poledenitve (ca. 20000 cal. BP), Ljubljansko barje verjetno občasno poplavljeno polje, kar je v skladu z rezultati dosedanjih raziskav (Šercelj 1965). Ti rezultati se tudi ujemajo z raziskavami na zahodnem delu Ljubljanskega barja (Zalog pri Verdu), kjer spodnji del profila pripada jezerski kredi, za katero Verbič (Verbič 2006) domneva, da ni holocenske, ampak pleistocenske starosti. Poznoglacialna jezerska kreda vsebuje nekoliko manj karbonatov kot holocenska, verjetno zaradi hladnejše klime in šibkejše bioprodukcije v oligotrofnem jezeru. Na razvoj okolja v poznem glacialu je močno vplivala klima. Nekoliko toplejša in vlažnejša klima v poznem glacialu je omogočila ojezeritev, o drugih, geomorfoloških vzrokih za ojezeritev (npr. rečno zasipavanje Save, tektonika) pa si ne bi upala soditi.

Zgodnji holocen (ca. 11500–6750 cal. BP)

Na prehodu poznega glaciala v holocen je količina hranilnih snovi v bazenu narasla, jezero pa je verjetno postalo plitvejše (diatomeje, stabilni izotopi). Avtohtona biogena produkcija v jezeru je narasla, alohtona pa upadla (geokemizem in stabilni izotopi), verjetno zaradi toplejše klime in stabiliziranja (manj erozije) z gostejšim gozdom pokrite pokrajine (pelod). Jezero, ki je verjetno prekrivalo večji del Ljubljanskega barja, je bilo obdano s pretežno bukovimi gozdovi, porast količine jelke okrog 9200 cal. BP, ki sovpada z dvigom nivoja jezera in erozijo tal, pa verjetno lahko povežemo z vlažnejšo klimo. Zakaj domnevam, da gre za večje jezero in ne več manjših jezerc, podobnih retjem? Seveda je treba priznati, da paleoekološki zapis v vrtini "na mahu" odraža tako lokalno dogajanje kot dogajanje v celotnem bazenu, zato je ločevanje, kdaj gre za lokalne in kdaj regionalne dogodke, lahko težavno. Vendar pa je polžarica – zgodnjeholocenski karbonatni sediment z visoko koncentracijo in zelo dobro ohranjenostjo peloda – prisoten tudi na drugih delih Ljubljanskega barja (Andrič, neobjavljeno) in zato domnevam, da gre v vseh primerih za jezerski sediment, vrtina "na mahu" pa beleži dogajanje v širši regiji, ne samo na mestu vrtanja. Na razvoj vegetacije in hidrologijo je v zgodnjem holocenu pomembno vplivala toplejša in vlažnejša klima.

Srednji holocen (ca. 6750–4600 cal. BP)

Hidrološke in vegetacijske razmere na Ljubljanskem barju med 6750–6000 cal. BP je najtežje razložiti. Diatomeje kažejo povratek oligotrofnih razmer, pojavljajo se vrste, značilne za tekoče in stoječe vode in močvirja, medtem ko stabilni izotopi nakazujejo večji dotok "kopenskih" snovi (erozija tal). Možno je, da je ta okoljska sprememba povezana z znižanjem gladine vode v celotnem bazenu in je mesto vrtine ležalo v bližini izliva reke v jezero, kar pojasnjuje prisotnost indikatorjev za bolj "pretočne" razmere. Zelo zanimivo je, da se hkrati s hidrološko spremembo pojavi tudi sprememba v sestavi vegetacije. Količina bukve in jelke upade, hrast, leska in jelša pa narastejo, kar bi lahko bila posledica človekovega vpliva na okolje (izsekavanje gozda in pašništvo) in bolj suhe klime ter znižanja gladine jezera (hrast in jelša zaraščajo na novo izsušene, ampak še vedno vlažne površine). Zelo kratko in zelo suho obdobje je datirano v čas okrog 6000 cal. BP, ko se je odlagal z organskimi snovmi bogat sediment, količina hranilnih snovi je spet narastla, kalcijevega oksida pa upadla.

V kasnejših stoletjih se je na mestu vzorčenja odlagal pretežno glinen sediment, z malo manj organskih snovi kot okrog 6000 cal. BP, količina jelke in bukve pa je spet začela naraščati okrog 5500 cal. BP, kar nakazuje vlažnejše klimatske (in verjetno tudi hidrološke) razmere. Hidrološke razmere v 6. tisočletju cal. BP je težko podrobneje opredeliti. Če bi imela možnost, da se usedem v "časovni stroj" in potujem nazaj na Ljubljansko barje, bi si prav gotovo izbrala 7. in 6. tisočletje in šla pogledat globino vode ter lego jezera, rek in arheoloških najdišč. Organska glina se lahko odlaga v različnih okoljih, takratna sestava gozda je bila podobna tisti v času odlaganja jezerske krede (med ca. 11500–6750 cal. BP), samo odprtih površin in erozije tal je bilo zaradi človekovega vpliva več. Voda je bila spet bogata s hranilnimi snovmi, vendar pa je sediment, ki se je odlagal, vseboval več organskih snovi in manj karbonatov kot med 11500 in 6750 cal. BP, vrednosti $\delta^{13}C$ pa so višje, kar govori za hidrološko plitvejše razmere.

Morda so paleoestruge, ki jih Budja in Mlekuž (Budja, Mlekuž 2008a) postavljata v čas pred 5500 cal. BP, nastale v kratki suhi fazi okrog 6000 cal. BP ali pa okrog 5200 cal. BP, ko se je "na mahu" začela odlagati šota, čeprav so bile hidrološke razmere pri Maharskem prekopu verjetno manj suhe kot "na mahu". Kaj pa se je dogajalo po nastanku paleostrug in kakšen material se je odlagal v njih?

Se je sediment odlagal v mrtvicah z visokim nivojem talnice? Ali pa je bilo poplavljanje samo občasno in razmere bolj suhe? Ali v spet vlažnejših razmerah, ker je morda prišlo do ponovnega dviga nivoja vode v celotnem bazenu? Ob trenutnem stanju raziskav si hidroloških razmer (pred poselitvijo lokacije, med njo in po njej) na arheološkem najdišču Maharski prekop ne bi upala podrobneje opredeliti. Gre za sedimentacijsko zelo nemiren del Ljubljanskega barja, kjer je paleoekološki zapis fragmentiran, tafonomski procesi izjemno kompleksni in slabo proučeni, podrobna kronološka kontrola pa težavna, zato nekdanjih hidroloških razmer verjetno ne bomo nikoli v celoti razumeli. Nekaj informacij, na osnovi katerih bi lahko sklepali o nekdanji hidrologiji, dajejo tudi rezultati palinoloških raziskav na Maharskem prekopu in v paleostrugi v neposredni bližini, ampak ker gre za še nedokončano raziskavo (Andrič, neobjavljeno), o tem le na kratko. Na arheološkem najdišču Maharski prekop vsebuje sediment neposredno pod kulturno plastjo ca. 30–38 % karbonatov, medtem ko kulturna plast samo še ca. 20 % (polnilo paleostruge v neposredni bližini vsebuje pribl. 9 % karbonatov), nad njo ležeče plasti pa manj kot ca. 8 % (Andrič, neobjavljeno). Pelodni in *"loss-on-ignition"* diagram (Andrič, neobjavljeno) kažeta, da so razmere na najdišču Maharski prekop po pribl. 6000 cal. BP postale malo bolj suhe (upad karbonatov in alg *Pediastrum*), kar je verjetno omogočilo naselitev človeka, vendar pa so bile razmere še vedno precej vlažne (še vedno 20 % karbonatov in dobra ohranjenost peloda). O tem, ali je bila na samem arheološkem najdišču stoječa voda ali pa gre le za zelo vlažen teren in visoko talnico, ob dosedanjem stanju raziskav ne morem soditi. A dovolj o teh preliminarnih rezultatih, na tem mestu ne morem podrobneje diskutirati o podatkih, iztrganih iz konteksta . Palinološke in druge raziskave so še v teku in več bo znanega, ko bodo rezultati izkopavanj na Maharskem prekopu v celoti objavljeni.

Vrnimo se k vrtini "na mahu". V času po ca. 5200–5100 cal. BP odsotnost diatomej, porast organskih snovi in $\delta^{15}N$ in $\delta^{13}C$ vrednosti govorijo o tem, da se je na mestu vzorčenja začela odlagati šota. Paleoekološki zapis za zadnjih ca. 4500 let je bil uničen zaradi rezanja in požiganja šote v 18. in 19. stoletju (Andrič et al. 2008).

Paleoekološki zapis vrtine "na mahu" kaže, da so bile spremembe holocenskega okolja na Ljubljanskem barju, kjer je potekalo več ekoloških procesov hkrati, zelo dinamične. Osnovni proces predstavlja zasipanje bazena, vendar pa, čeprav je bil ta proces pomemben, ne gre samo za preprosto, enakomerno hidrološko sukcesijo zaraščajočega se bazena. Pomembno vlogo pri uravnavanju ekoloških razmer v pokrajini sta igrala tudi klima in človek. Še zlasti nas je presenetilo, da je do sprememb vegetacije in hidrologije prihajalo sočasno, kar, poleg vpliva vegetacije na hidrologijo (in *vice versa*), lahko razložimo s tem, da je na vegetacijo in hidrologijo bistveno vplivala klima.

ARHEOLOGIJA IN PALEOEKOLOGIJA
Kako naprej?

Cilj te razprave je bil opozoriti na to, da so bile holocenske paleoekološke razmere na Ljubljanskem barju kompleksne, zato iskanje odgovorov na raziskovalna vprašanja zahteva dolgotrajne raziskave. Zame znanost ni dokazovanje hipotez, ampak postavljanje raziskovalnih vprašanj in iskanje odgovorov nanje. Pri tem je dobro upoštevati dobro staro načelo: Bolj kot je raziskovalno vprašanje, ki si ga postavimo, ambiciozno, več raziskovalnega dela in podatkov potrebujemo za utemeljevanje trditev, ki jih postavljamo (Booth et al. 1995, 97–106), oziroma, z drugimi besedami, zelo podrobna interpretacija mora temeljiti na obsežnih podatkih. Tam, kjer je podatkov manj (in naravne danosti terena onemogočajo iskanje odgovorov na vsa vprašanja), naj bo interpretacija malo bolj zadržana. To velja za katerokoli raziskovalno področje, za paleoekologijo, ki je "delovno intenzivna panoga" in zato stalno v nevarnosti, da se razvije v "instant paleoekologijo" in "populizem", pa še prav posebej.

Za nobeno znanost tudi ni dobro, če se zapira v svoje lastne okvire in deluje samo v okolju, kjer se z istim raziskovalnim področjem ukvarja le malo ljudi. V slovenskem raziskovalnem prostoru veliko večino paleoekoloških prispevkov objavljamo v slovenskih arheoloških publikacijah, ki za paleoekološka vprašanja niso specializirana in imajo zato mnogo nižje standarde od uveljavljenih tujih revij s področja paleoekologije (podobno velja tudi za objavljanje arheoloških prispevkov v paleoekoloških revijah). Raziskovalci velikokrat žal popustimo pod vsako leto večjim pritiskom po "hitrih rezultatih" in naredimo tisto, kar je lažje, dokončamo in objavimo manj obsežno raziskavo v slovenskem raziskovalnem prostoru, kjer je konkurenčni boj za dostop do objave manj krut in bo razpravo bralo manj parov kritičnih oči in manj specialistov za področje paleoekologije.

Polemika okrog paleohidroloških razmer se je po mojem mnenju razvila zato, ker je Ljubljansko barje ena najtežjih regij v Evropi, kjer paleoekolog in arheolog lahko opravljata svoje raziskovalno delo, Slovenija pa je država, kjer na mnogih področjih nimamo močne, v mednarodno raziskovalno okolje odprte paleoekološke raziskovalne tradicije, trenutne razmere za organiziranje multidisciplinarnih paleoekoloških raziskav pa so zelo težavne. Zato bi bilo hudo krivično, če bi bil glavni cilj tega prispevka kritiziranje raziskovalcev, ki so z dosedanjim dolgoletnim delom veliko prispevali k vse večjemu uveljavljanju paleoekoloških in drugih naravoslovnih raziskav v Sloveniji in si vsak dan prizadevajo za boljšo znanost in odpiranje novih raziskovalnih tem.

Polemike sicer običajno dvignejo veliko prahu, ampak mnogo bolj resne stvari se dogajajo drugje (na različnih ravneh, od raziskovalnega dela na terenu do raziskovalne politike v pisarnah) in čisto po tihem, ker se o tem ne piše. Na prvem mestu gre za vprašanje, kako dobro poteka sodelovanje med paleoekologijo in arheologijo, pri čemer paleoekologi arheologe premalo intenzivno obveščamo o svojem raziskovalnem delu, medtem ko arheologi na paleoekologe pogosto gledajo kot na podrejene tehnične sodelavce, ne pa kot na raziskovalce in enakopravne partnerje, s katerimi bi se bilo o poteku raziskave potrebno posvetovati in naša mnenja upoštevati. Koliko arheoloških terenov se prekoplje, ne da bi se opravilo ustrezno paleoekološko vzorčenje in analize (e. g. arheozoološke, arheobotanične, palinološke, …), včasih pa si na terenu, kjer skušaš rešiti kakšne vzorce, celo nezaželen. A na srečo se razmere, sicer zelo počasi, pa vendarle, premikajo na bolje.

Drugi problem je mnogo bolj resen, zato ker se razmere ne premikajo na boljše, ampak na slabše. Gre za oblikovanje raziskovalne politike v Republiki Sloveniji in razvoj paleoekologije kot raziskovalne vede. Najprej je treba omeniti bibliografsko kvantiteto kot vstopnico za dostop do vira finančnih sredstev za raziskovalno dejavnost. To, da je znanstveni prispevek, objavljen v soavtorstvu v mednarodni reviji s področja paleoekologije, ki sodi v prvo četrtino SCI (npr. objave tipa Andrič et al., 2008), vreden trikrat manj kot članek enega avtorja v katerikoli slovenski reviji s spiska ARRS (kamor sodi tudi tale diskusija), ni samo neznanstveno in žaljivo, ampak tudi spodkopava možnosti za razvoj kvalitetne raziskovalne dejavnosti, vzpodbuja razvoj "instant paleoekologije" in "zaplankanost" v majhen slovenski raziskovalni prostor. Hkrati pa se bibliografska kvantiteta palinologov stalno primerja z drugimi vedami, kjer je v eno objavo pogosto vloženega mnogo manj dela. Različnih raziskovalnih področij se med seboj ne bi smelo primerjati (Sorčan et al. 2008, 70), vendar pa se v praksi to stalno počne, med drugim tudi zato, ker nas je v Sloveniji paleoekologov pač malo in nimamo niti vpliva niti "svoje" vede.

Problematično pa je tudi sodelovanje med raziskovalnimi inštitucijami. V Sloveniji nimamo posebnega inštituta/raziskovalne skupine, ki bi se ukvarjala samo s paleoekološkimi raziskavami, in specialistov za številna področja holocenske paleoekologije enostavno ni. Če želimo prijaviti skupni raziskovalni projekt v sodelovanju z drugimi raziskovalnimi organizacijami, vsaka raziskovalna institucija dobi manj finančnih sredstev, kot pa bi jih dobila, če bi projekt prijavila sama, ker se enaka vsota denarja pač razdeli na več partnerjev. Zato je zanimanja za takšno multidisciplinarno raziskovanje malo, naravoslovne inštitucije pa so pod stalnim pritiskom, da si morajo denar služiti z delom za industrijo in druge zunanje uporabnike. Članki tipa (Andrič et al. 2008) in (Andrič et al. 2009) zato niso nastali zaradi multidisciplinarnim raziskavam naklonjenih razmer, ampak zaradi tega, ker so imeli soavtorji veliko srce in so bili, kljub preobremenjenosti z drugim delom, v raziskavo pripravljeni vlagati svoj čas in v nekaterih primerih tudi pridobiti kar nekaj svojega raziskovalnega denarja, nikakor pa to ni recept, ki bi lahko veljal tudi za bodoče raziskave. Kljub vsemu se ne bom nehala truditi, ker smo palinologi in palinologinje že zaradi narave svojega dela zelo trmasti in potrpežljivi in bi zato prispevek rada zaključila bolj pozitivno. Nastajanje tega prispevka sta vodili dve želji. Prva želja je bila, da hidrološko problematiko Ljubljanskega barja osvetlim še s tretjega, *"multi-proxy"* paleoekološkega zornega kota. Hkrati pa sem si želela v reviji, ki jo bere veliko arheologov, na malo bolj "poljuden" način predstaviti možnosti in omejitve paleoekoloških raziskav. V upanju, da boste, tudi če še nikoli niste sodelovali s paleoekologi, ob iztekajočem se letu razmislili, ali bi takšno sodelovanje morda začeli naslednje leto.

Zahvala

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The Holocene palaeoecological and palaeohydrological conditions at Ljubljansko barje – a contribution to discussion

Translation

INTRODUCTION

Palaeoecologists study records of past environmental changes, which were altered by taphonomical processes and are very often incomplete. Palynologists, for example, analyse pollen grains, preserved in lake and marsh sediments, in order to reconstruct the vegetation history. The vegetation development in a landscape was affected by many factors, including climate and people. However, the impact of climate cannot be measured directly; we can only observe changes of "palaeoecological archives" (e.g. sediments). The more analyses of a different kind we perform (with high-resolution sampling, good chronological control and coordination among researchers), the more detailed will be our information about the past environment. With the advancement of science, many new research questions are opened and the explanations of different research disciplines often seem to contradict each other, but this is not a bad thing, it is a consequence of the progress and specialisation of palaeoecological research disciplines. Good palaeoecology is multidisciplinary palaeoecology and I like better "discussion" than "synthesis" that everyone would agree with, and which would give us the seemingly confident feeling that all problems had been solved (but in fact they were just avoided).

A research topic as demanding as past hydrology can be addressed by using several research techniques. Researchers studying past marsh or lake water level fluctuations very often study geomorphological features of the landscape or physical and chemical characteristics of sediments, as well as animal and plant micro- and macrofossils (Dearing, Foster 1986; Moore 1986). Yet, when we do this, we need to be aware of the fact that changes of all the above mentioned palaeoecological records cannot be seen in all types of basins (it is important whether we are studying a small or big lake/marsh, with or without water inflows/outflows) and were not always caused by water level fluctuations. Sometimes a change of the lake/marsh palaeoecological record can be associated also with other environmental events, for example changes in the catchment (e.g. deposition of more silty and sandy sediment due to soil erosion, which was triggered by forest cutting) or natural infilling of the basin and hydroseral succession (Digerfeldt 1986, 129–130). In short, there is no quick and just one "correct" method for studying past hydrology; comparisons with modern lakes can be misleading (Dearing, Foster 1986, 70) and very often the environment has changed so much that modern analogues are not available any more. Finally, when we do reconstruct water level fluctuations through time, a new research question emerges: "What was the reason for the observed environmental changes?" And it is not easy to answer to this question: water levels can be influenced by tectonics, bedrock, climate (temperatures and the amount of precipitation), water inflow/outflow, vegetation and people. To conclude, palaeohydrological studies involve complex multidisciplinary palaeoecological research of long standing.

In hydrologically complicated basins, such as Ljubljansko barje, detailed and lasting palaeoecological research is even more important. Quite a few papers, directly or indirectly associated with the hydrology of Ljubljansko barje, were published over the years and in this paper a few most typical viewpoints will be reviewed. I will also present my opinion about this subject, which is based on the results of multi proxy analysis of the sedimentary core, collected in the eastern part of the basin. In order to better understand environmental changes, the entire Holocene sequence will be presented (but with the exception of the last few millennia, because the more recent pollen record was destroyed by peat cutting) and discussion will not be limited only to Prehistory, which is a most interesting time period for the archaeologists.

LAKE OR FLOODPLAIN?
A review of arguments, used in discussion hitherto

Lake

According to the first hydrological model, which is based on geomorphological and sedimentological data, the area of Ljubljansko barje was covered by a Lateglacial and early / middle Holocene freshwater lake (Melik 1946). The main reasons for the formation of a lake include tectonics and mechanical damming by alluvial sediments of the Sava river. Melik used geomorphological data (the position and altitude of lake terraces) to suggest that the first, Lateglacial lake at Ljubljansko barje, was ca. 13–14 m deep, later it became shallower (10–11 m) and the littoral belt was already rising above water level due to stream discharge, while in the last lake phase, which is dated to the archaeological pile-dwelling time period, the lake was already very shallow and only in deepest parts did water depth exceed 3 m (Melik 1946, 60–66). The transition of

a lake to a bog is dated in the time period between "pile-dwelling" and the Roman Age; a Roman road (presumably in Škofljica–Ig–Bloke direction) was, namely, discovered in the middle of a peat layer at Babna Gorica near Škofljica (Melik 1946, 99–100; Velušček 2006, 43, Sl. 24).

Melik uses also sedimentological argumentation. Light grey calcareous silty clay ("polžarica"), which covers most of the Ljubljansko barje, was declared as a lake sediment because of its geochemical characteristics: it contains a lot of carbonates, which were deposited by chemical and biogenic processes due to photosynthesis of water plants and it also contains shells of water snails ("konhilije"). "Brown mud" and "peat" lying above "polžarica" are presumably "marsh sediment", with black peat being characteristic of minerotrophic peatlands (grassland), whereas brown peat belongs to an ombrotrophic peat bog (with *Sphagnum* mosses). However, description of environmental conditions in which different types of peat formed was not substantiated in much detail and, at the same time, Melik points out that there are significant differences between peat occurring in different parts of Ljubljansko barje and that further research is needed (Melik 1946, 51–52, 90–98). Melik's model was accepted and complemented by other researchers in the subsequent decades. The following analyses have been carried out: pollen analysis with description of imprints of charophyte stems in "polžarica" (Šercelj 1965; Šercelj 1966), analysis of molluscs (Pavlovec 1967; Pavlovec 1982), chemical, sedimentological and pedological description of "polžarica" and the sediment above it (e.g. Grimšičar, Ocepek 1967; Tancik 1965; Turk 2006).

What are the main advantages and drawbacks of the "lake" model? One of the advantages of the above presented hypothesis is a combined use of geomorphological and sedimentological data, whereas the main disadvantage is the lack of sufficient chronological control, low sampling resolution and inaccurate description of studied profiles. Environmental changes at the time of drying out of the lake are not precisely investigated, even though in the literature the following description of environmental changes is very common: *"In the period at least from the pile-dwelling age onwards it has been proven that the Ljubljansko barje passed through several developmental stages – from the withdrawal of the lake, the simultaneous advance of the swamp, to the formation of low marshes and in several regions high marshes (see and cf. e.g. Šercelj, 1966, 443; Peterlin 1970-71; 1987; Pavšič 1989, 9; Mencej 1992, 264; Turk 2006, 94)."* (Velušček 2007, 433). On what data is the above assumption based? Melik's (Melik 1946, 91–92) description of vegetation changes, characteristic for an infilling lake, which follow the general ecological concept of natural lake development into minerotrophic marsh and peat bog (hydroseral succession, Tansley 1939) was only resumed and reiterated by the above cited authors. However, with the exception of a few very general descriptions of peat layers (without description of research methodology, exact location of studied sediments or detailed description of trench profiles, e.g. Tancik 1965) and the 19th century information, talking about the remains of reeds (*Phragmites*) and *Hypnum* mosses (Martinčič 1987), a detailed research was never carried out into what exactly happened and what type of hydroseral sucession took place. Most of the peaty layers were destroyed even before it was possible to perform proper (paleo)ecological research (Martinčič 2003).

The basic concept of hydroseral succession (Clements 1916; Tansley 1939; Charman 2002, 146, Fig. 7.3a) assumed that all lakes are overgrown gradually, following certain vegetation phases, which can be predicted in advance. At the beginning of the hydroseral succession, water plants growing in deeper water (*Myriophyllum, Potamogeton* – water milfoil and pondweed) prevail, whereas later, due to infilling of the basin, these are replaced by plants characteristic of shallower water (*Nymphaea, Nuphar*, water lily and yellow water lily), and later also the spread of reedswams (*Phragmites*, pollen type "Poaceae"), and sedges (Cyperaceae). In the last phase the area is covered by peat bog and/or woodland. However, in contrast to this original concept, the investigations of modern plant associations suggest that hydroseral succession should be considered only as a general concept and not as an example that all the lakes will follow (Charman 2002, 146).

What is the palaeoecological viewpoint about hydroseral succession? How were lakes overgrown in the past? The comparison of modern with fossil vegetation shows that, in different parts of the basin, vegetation succession can be very dissimilar and is influenced also by external drivers such as climate, hydrological changes and human impact (Birks 1980, 29–30). A comparison of the Holocene palaeoecological sites in Great Britain (Walker 1970) also suggests that classical succession does not occur on all study sites, very often some phases are missing or there was even a reverse vegetation development (Birks, Birks 1980, 59–60). Stratigraphic changes, characteristic of typical hydroseral succession, usually occur only in lakes with a small catchment, where the water level depends mostly on groundwater (Dearing, Foster 1986, 71). In contrast to this, Ljubljansko barje is a big basin, with numerous water inflows and an outflow, therefore it would be an oversimplification to expect classical hydroseral succession; vegetation development was most probably more complex. Therefore it is not a surprise that the pollen record of the "na mahu" core (Andrič et al. 2008) does not show a classical hydroseral succession of lake and marsh plants. Maybe, at this part of the basin, some successional phases are missing or vegetation development was very fast and not detected on the pollen diagram. Anyhow, despite poor preservation of plant macrofossils, such an analysis could give us more information regarding "in situ" plant succession.

Does the "lake" model anticipate when the lake in the entire Ljubljansko barje was replaced by a marshy area? Velušček (Velušček 2005, 77–78), on the basis of Šifrer's radiocarbon date for *"brown organogenic loam above "polžarica" at Črna vas"* (2850 ± 100 BP, Šifrer 1984, 43) assumes that this happened in the 2nd millennium cal. BC. Probably this is true, but it is a pity that for the area near Črna vas village, no detailed paleoecological information is available (e.g. description of the entire profile, several radiocarbon dates and other paleoecological research). Sediment, rich in organic material can be deposited in hydrologically different environments, which include shallow lake (Birks, Birks 1980, 50) as well as hydrologically much drier conditions. Just on the basis of sediment colour and the age of the organic material it contains, I would not dare

to interpret past palaeoecological conditions in much detail. Despite the fact that recently in the archaeological literature it has become a habit to interpret palaeoenvironmental conditions just on the basis of radiocarbon dates without any palaeoecological context (e.g. additional analyses) by researchers in favour of the "lake" and "floodplain" model (e.g. Budja, Mlakuž 2008a; Budja, Mlekuž 2008b) alike. But I will talk more about this problem later.

Floodplain

The second model of hydrological development of Ljubljansko barje, which – similarly to the "lake" model – is based on geomorphological and sedimentological data, assumes that in the Holocene at Ljubljansko barje there was no permanent lake (Šifrer 1984). Due to intensive fluvioperiglacial discharge of streams and rivers, there were no conditions for stagnant water and in the area there is no deltaic sedimentation and thicker sediment layers, which are a characteristic geomorphological feature near river mouths, when river/stream water reaches stagnant water of a former lake. Šifrer (1984, 42–43) also assumes that "polžarica", which is quite a heterogeneous sediment, probably formed in a fluvial environment and in very diverse environmental conditions. The reasons for huge amounts of carbonates are rather a "climatic" (the Holocene warming) than a "lake" indicator. Stagnant water, widespread flooding and overgrowing by mosses at Ljubljansko barje presumably occurred only later (at the time of pile-dwellings) due to wetter climate, forest clearance and soil erosion (Šifrer 1984, 40–41, 49).

The main advantages and disadvantages of the "floodplain" model resemble those of the "lake" model: combined use of geomorphological and sedimentological data is certainly an advantage, but the main drawback is an absence of sufficient chronological control and inaccurate description of the studied sediment profiles. Also the statement that "polžarica" is fluvial sediment is questionable. Despite its heterogeneity, light grey calcareous silty clay ("polžarica") occurs almost everywhere at Ljubljansko barje, from Resnikov prekop in the east (e.g. Andrič 2006; Turk 2006) to Zalog pri Verdu in the west (e.g. Verbič 2006) and it does not seem that it would be limited only to smaller depressions. The significant amount of carbonates that were presumably deposited on a floodplain, Šifrer (1984, 42) explains by using modern analogues: marl, which is today deposited at Cerkniško jezero intermittent lake is very similar to the marl from Ljubljansko barje. However, one needs to add that the sediment that was analysed at Cerkniško jezero was collected in the wettest part of the polje (Zadnji kraj), where reeds and algae are present, and even these samples contain various amounts of carbonates (Tancik 1965, 68).

In recent years a detailed geomorphological study (LiDAR survey and development of digital surface models) was carried out in the eastern part of Ljubljansko barje in order to identify river palaeochannels, reconstruct changes of past hydrological networks and compare them with the archaeological settlement pattern (Budja, Mlekuž 2001; Mlekuž et al. 2006). On the basis of the relative stratigraphy of abandoned river channels (four phases of palaeochannels were documented) and radiocarbon dating of wooden piles from the archaeological site of Maharski prekop, which is located next to a palaeochannel from the first phase of river transformation, it was suggested that pile-dwelling archaeological sites were located on a floodplain (which formed already in the late Mesolithic), on mostly dry riverbanks, which were not reached by floodplain water (Budja, Mlekuž, 2001).

The main advantage of the above hypothesis is the very good and detailed reconstruction of the past hydrological network, but the main problem is insufficient chronological control, although later organic sediment infill of palaeochannels was radiocarbon dated and so the main weak point of the original hypothesis (Mlekuž et al. 2006) was eliminated (Budja, Mlekuž 2008a; Budja, Mlekuž 2008b). On the basis of these radiocarbon dates, Budja and Mlekuž date the floodplain at Ljubljansko barje before about 5500 cal. BP, therefore they assume that Eneolithic and Bronze Age archaeological sites at this part of Ljubljansko barje were located on a floodplain (Budja, Mlekuž 2008a). However, also in this case, my reproach stays the same as for the "lake" model – the palaeoenvironmental explanation is based on individual radiocarbon dates, without a context and hence with all with this associated problems as already mentioned above. A more careful research approach including more detailed description of the sediment with more radiocarbon dates would be useful, especially in this part of Ljubljansko barje, where the palaeoecological record is often fragmented (e.g. hiatuses, resedimentation).

My second reproach is associated with the assumption that archaeological settlements were located on mostly dry riverbanks. Description of dryness/wetness is, of course, always subjective and relative, and even on the basis of multi proxy research (such as Andrič et al, 2008), water depth cannot be precisely established. Nevertheless, we need to be aware of the fact that pollen in cultural layers of archaeological sites (e.g. Maharski prekop, Blatna Brezovica, Stare Gmajne) is preserved, which means that hydrological conditions could not have been excessively dry, but we do need to reckon with high groundwater level or standing water.

LAKE AND FLOODPLAIN

Introduction

To summarise: to date, hydrological research at Ljubljansko barje was focused on sedimentological and geomorphological analyses, but there has been no detailed multidisciplinary research on the entire Holocene sequence in order to better understand in which environmental conditions different types of sediments were deposited. In my opinion, past hydrological conditions cannot be studied by one discipline (e.g. geology) alone; it needs to be a harmonized, multidisciplinary activity. Therefore my colleagues and I performed a detailed multidisciplinary research on the "na mahu" sedimentary core (diatom, stable isotope, geochemical and pollen analysis), which was collected in the eastern part of the Ljubljansko barje. The palynological

core, which was collected in 2003, is located in the vicinity of archaeological sites (ca. 1 km north of Maharski prekop), but not directly on an archaeological site or near a river or palaeochannel in order to avoid sediment mixing due to human activities or hydrological disturbance. The results of this research have already been published (Andrič et al. 2008), but in this paper I would like to put them in the context of the hydrological polemics to date, and present my opinion about the Holocene changes of vegetation and hydrology.

Let me right at the beginning emphasize that we do not fancy that we have "proved" what exactly past hydrological conditions at Ljubljansko barje looked like, we have just touched the "tip of the iceberg" of the entire hydrological problem, which could be investigated in more detail by a group of specialists –palaeoecologists (which we do not have in Slovenia), working at a well-financed palaeoecological institute (which, I am afraid, will never exist in Slovenia) for decades.

Lake and floodplain

Let us go back to the question, which was very much emphasized in discussion to date: "Was Ljubljansko barje once covered by a lake or a floodplain?" This is actually a very inaccurate question. It reduces hydrological conditions to only two options, without defining in detail what would be the main differences between both hydrological regimes. Similarly, we could ask ourselves, is today's Cerkniško polje (intermittent lake) a lake or a floodplain? But, I do not mention this to say that hydrological conditions at Ljubljansko barje were once similar to those at present-day Cerkniško jezero. I would just like to stress that modern people in today's landscape, where hydrology is artificially regulated, hardly see any natural lakes and rivers which still overflow, so the idea that an archaeological site (e.g. Maharski prekop) could stand near a lake, close to a river outlet (so, if you wish, near a lake and on a floodplain at the same time) seems unusual, because such an environment hardly exists in the modern Slovenian landscape and it is difficult to imagine such an environment. Therefore I think that it is much more important to ask when and where environmental changes took place, what exactly happened and, of course, why. I will address these questions in the subsequent text. More detailed argumentation was already presented in the original paper (Andrič et al. 2008).

Lateglacial (ca. 15000–11500 cal. BP)

The results of palaeoecological research at the "na mahu" core (Andrič et al. 2008) suggest that, in the Lateglacial, Ljubljansko barje was probably covered by a deep, oligotrophic lake (planctonic diatoms), with significant terrestrial input (stable isotopes, geochemistry), presumably because of soil erosion due to cold climate and rather open vegetation (pollen). At the bottom (650 cm) the core hit hard, organic sediment, which suggests that the lake probably formed only in the Lateglacial, whereas in the coldest time periods, such as the Last Glacial Maximum (ca. 20 000 cal. BP), Ljubljansko barje was probably an occasionally flooded field, as already suggested in previous research (Šercelj 1965). These results are also in accordance with the results of sedimentological research in the western part of Ljubljansko barje (Zalog pri Verdu), where the lower part of the sedimentological profile consists of lake marl, for which Verbič (Verbič 2006) suggests that it is not of the Holocene, but Pleistocene age. Lateglacial lake marl contains less carbonates than the Holocene one, probably because of the colder climate and thus weaker bioproduction in an oligotrophic lake. Climate had a significant impact on environmental changes. Slightly warmer and wetter climate in the Lateglacial led to formation of a permanent lake; in addition to this, the role of other, geomorphological factors (e.g. deposition of alluvial sediment of the Sava river, tectonics) was probably also important, but I would not dare to be more detailed about it.

Early Holocene (ca. 11500–6750 cal. BP)

At the Lateglacial/Holocene transition the lake probably became shallower and the amount of nutrients increased (diatoms, stable isotopes). Autohygenic, biogene production in the lake increased, whereas allochtonous declined (geochemistry and stable isotopes), probably due to the warmer climate and stabilisation (less erosion) of more wooded landscape (pollen). The lake, which probably covered most of the area, was surrounded by predominantly beech forests. An increase of fir trees at about 9200 cal. BP coincides with an increase in lake level and soil erosion, which can be most probably associated with a wetter climate. Why do I suggest that there was only one bigger lake and not several smaller lakes, similar to present-day "karst springs" ("retja")? Of course, one needs to admit that the palaeoecological record of the "na mahu" core was affected by both local and wider, regional events, and very often it is difficult to tell whether palaeoecological change is a consequence of local or regional environmental changes. On the other hand, "polžarica" – early Holocene calcareous sediment with high concentrations of well preserved pollen grains (presumably lake sediment) – can be found also in other parts of Ljubljansko barje (Andrič, unpublished), therefore the "na mahu" pollen core probably reflects wider regional environmental conditions. Vegetation and hydrological conditions in the area were affected by the warmer and wetter early Holocene climate.

Middle Holocene (ca. 6750–4600 cal. BP)

Vegetation and hydrological conditions at Ljubljansko barje between 6750–6000 cal. BP are most difficult to understand. The diatom record suggests a return of oligotrophic conditions, taxa characteristic of running and standing water and marsh areas occur, whereas the stable isotope record suggests stronger "terrestrial" input (soil erosion). It is possible that this environmental change is associated with lowering of lake level in the entire basin and the sedimentary core being located in the vicinity of a river outlet, which would explain why indicators for running water are present. It

is very interesting that this hydrological change coincides with change in vegetation composition. The amount of beech and fir trees declines, whereas oak, hazel and alder increase, which could be a consequence of human impact on the environment (forest cutting and pasture) and drier climate and thus lowering of lake levels (oak and alder start to grow on newly dried out, but still damp surfaces). A very short and very dry time period is dated around 6000 cal. BP, when sediment, very rich in organic material was deposited, and the amount of nutrients increased again, whereas calcium oxide declined.

In the subsequent centuries mostly clay sediment with somewhat less organic material than at 6000 cal. BP was deposited, whereas fir and beech start to increase again around 5500 cal. BP, which indicates wetter climatic (probably also hydrological) conditions. Hydrological conditions in the 6th millennium cal. BP are difficult to describe. If I had a chance to sit into a "time machine" to travel back in time, I would certainly decide to visit the 7th and 6th millennium and have a look at water depth and the position of lake, river and archaeological settlements. Clay, rich in organic material could be deposited in different types of environments, forest composition was similar to forest composition at the time when lake marl ("polžarica") was deposited (between ca. 11500–6750 cal. BP), but there were more open surfaces and soil erosion due to human impact. Water was rich in nutrients again, but the sediment contains more organic material and less carbonates than between 11500 and 7650 cal. BP, whereas $\delta^{13}C$ values are higher, which suggests hydrologically shallower conditions.

Maybe palaeochannels, which were dated by Budja and Mlekuž before 5500 cal. BP (Budja, Mlekuž 2008a) formed in a short dry period around ca. 6000 cal. BP or around 5200 cal. BP, when peat started to grow at the "na mahu" location, although hydrological conditions at Maharski prekop were probably wetter than at the "na mahu" location. However, what happened after the formation of palaeochannels and what kind of sediment was deposited? Were there oxbow lakes with high levels of groundwater? Or were hydrological conditions drier and flooding was only periodical? Or, were hydrological conditions in the entire basin wetter (again)? At the present state of research, I would not like to define more precisely hydrological conditions at Maharski prekop (before, during and after archaeological settlement). This part of Ljubljansko barje was sedimentologically very dynamic and the palaeoecological record can be fragmented; taphonomic processes were very complex and poorly investigated, consequently detailed chronological control is difficult to obtain, and it is possible that past hydrological conditions will never be completely understood. The results of palynological research at Maharski prekop and the palaeochannel in the vicinity (Andrič, unpublished) can give us some information about past hydrology, but, because this is still unfinished and unpublished research, I would present it only briefly. At Maharski prekop the sediment directly below the cultural layer contains ca. 30–38 % of carbonates, while in the cultural layer there is only 20 % of carbonates (infill of the palaeochannel nearby consists of 9 % of carbonates), whereas in the layers above cultural layer there is only 8 % of carbonates (Andrič, unpublished). Pollen and *"loss-on-ignition"* diagrams (Andrič, unpublished) show that hydrological conditions at Maharski prekop after 6000 cal. BP became slightly drier (decrease of carbonates and *Pediastrum* algae), which probably enabled people to settle at the location, but conditions were probably still very wet (still 20 % of carbonates, good pollen preservation). At the present state of research, I would not wish to discuss the question of whether at the archaeological site of Maharski prekop there was permanently standing water or whether it was just wet soils with a high level of groundwater. Palynological and other research at Maharski prekop is still in progress (and the above palaeoecological information is without a wider context); more information will be available after the research is finished and published.

Let us go back to the "na mahu" palynological core. After ca. 5200–5100 cal. BP an absence of diatoms, an increase of organic material and $\delta^{15}N$ and $\delta^{13}C$ values suggest that peat started to grow at the coring location. The palaeoecological record for the last 4500 years was destroyed due to peat cutting and burning in the 18th and 19th century AD (Andrič et al. 2008).

To summarise, the palaeoecological record, preserved in the "na mahu" core, shows that changes to the Holocene environment at Ljubljansko barje, where several ecological processes took place at the same time, were very dynamic. Although the basic process – infilling of the basin – was important, we should not see it as a simple, gradual hydrological succession of infilling lake. Climatic fluctuations and human impact on the landscape were also important. In particular, we were surprised that changes of past vegetation and hydrology were synchronous. This can be – in addition to the interpretation that hydrological conditions in the basin were affected by vegetation composition (and *vice versa)* – explained by the suggestion that the climate was the main, most important driving force, affecting both vegetation and hydrology.

ARCHAEOLOGY AND PALAEOECOLOGY: HOW TO PROCEED?

The main aim of this discussion was to remind us that the Holocene palaeoecological conditions at Ljubljansko barje were complex, therefore long-term research is needed to address palaeoecological research questions. For me, science is not about "proving" anything, I see it as a discipline, which poses research questions and seeks answers to these questions. By doing this, it is advisable to stick to an old principle: The more ambitious the research question is, the more research and data are needed to substantiate the claims that we make (Booth et al. 1995, 97–106). Or, in other words, very detailed interpretation must be based on extensive data. When such an extensive dataset is not available (and natural environmental conditions do not allow one to address all research questions), interpretation of data must be more careful. This is true for any field of research, but especially for palaeoecology, where a huge amount of work is needed and researchers are under constant pressure to get quick results, which could lead to the development of "instant" palaeoecology and "populism".

It is not a good practice when science is limited to its own field of research and operates in an environment where only few people are working within the same field of research. Within the Slovenian research community, most papers addressing palaeoecological issues are published in Slovenian archaeological publications. These are not specialised in publishing palaeoecological papers and therefore have much lower standards than foreign periodicals specialised in palaeoecology (the same is true also for publishing archaeological papers in paleoecological periodicals). The pressure for getting quick results is growing every year, and researchers very often give up and do the easiest thing: finish and publish less detailed research in the Slovenian research environment, where competition to publish is less severe and papers will be read by a smaller number of critical scientists and specialists in palaeoecology.

Discussion concerning past hydrological conditions at Ljubljansko barje is most probably a consequence of several factors. Firstly, Ljubljansko barje is one of the most difficult regions in Europe, where an archaeologist and palaeoecologist can do their research. At the same time, in Slovenia there is no strong tradition of internationally competitive, multidisciplinary palaeoecological research, and at the moment conditions for organising multidisciplinary palaeoecological research are very unfavourable. Therefore it would be unfair, if the main goal of this paper would be to criticise researchers, who, over the years, have significantly contributed to the development of palaeoecology and other natural sciences and are constantly opening up new research topics.

Polemics usually create a great sensation, but more serious events happen elsewhere (on several levels, from fieldwork to research policy in the office) and quietly, because nobody problematizes them. Firstly, it is a question of cooperation between palaeoecologists and archaeologists, when, on the one hand, archaeologists are very often insufficiently informed about palaeoecological research, whereas, on the other, archaeologists often treat palaeoecologists as subordinate "technical staff" and would not consider them as an equal partner, whom they should consult and whose opinion should be considered. How many archaeological sites were excavated without taking appropriate palaeoecological samples and without performing an analysis (e.g archaeozoological, archaeobotanical, palynological, etc.)? Sometimes a palaeoecologist trying to rescue samples at an archaeological site can be even unwelcome. But luckily – although very slowly – circumstances are improving.

The second problem is much more serious, because the circumstances are not improving, but changing for the worse. This problem refers to research policy of the Republic of Slovenia and development of palaeoecological science. First, it must be mentioned that bibliographic quantity is one of the most important criteria for qualifying for research financial sources. These criteria include an estimation that a paper, published by several authors in an international palaeoecological periodical ranking among the best quarter according to SCI (e.g. papers like Andrič et al., 2008), gets three times less bibliographic points than a paper (e.g. also this discussion), published by a single author in any periodical from the list of the Slovenian Research Agency. This criterion is not just unscientific and insulting, it undermines all the efforts to ensure development of high quality palaeoecological research and promotes "instant palaeoecology" and confinement to the small Slovenian research community. At the same time, the bibliographic quantity of palynologists is constantly compared with other fields of research, where very often it takes much less time to finish research and publish a paper. Different research disciplines should not be compared with each other (Sorčan et al. 2008, 70), but in practice it happens all the time; also, because there are not many palaeoecologists in Slovenia, we are not influential and do not have our own research discipline and evaluation panel.

Furthermore, cooperation between research institutions is very difficult. In Slovenia there is no special institute or research group which would be specialised for palaeoecological research, and there are no specialists for many research disciplines of the Holocene palaeoecology. If several research institutions would like to apply for a joint research project, the total amount of money would be divided between partners, so each research organisation would get less funding than if applying alone. Therefore, research institutes are not interested in applying for joint projects, and natural scientists are under constant pressure to earn money by working for industry or external, non-academic customers. Papers like "Andrič et al., 2008" and "Andrič et al., 2009" are therefore not a consequence of circumstances, which might be very favourable for multidisciplinary research. It was possible to publish these papers only because the co-authors were kindhearted and, despite, being overburdened with their own work, were willing to invest time and some research money; but this is not an example of how such multi-proxy research should be conducted also in the future. However, despite all these problems I will not give up on trying to fight for good palaeoecological research, because I am palynologist and we are, due to the nature of our activity, very patient and stubborn researchers. Therefore I would like to finish this discussion on a more positive note. My goals in writing this discussion were two-fold. Firstly, I wanted to present a third, multi-proxy palaeoecological point of view about palaeohydrological conditions at Ljubljansko barje. Secondly, I wanted to elucidate the possibilities and limitations of palaeoecological research also in a periodical which is read by many archaeologists. I hope that, even if you have never worked in cooperation with palaeoecologists, you will consider starting such a research project next year.

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