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*This paper presents the paleoenvironmental reconstruction of a mire sequence near the village Blatuša, with a focus on changes in vegetation composition, hydrological regime and fire history of the Banovina/Kordun area during the last two millennia. For this purpose, pollen, non-pollen and charcoal analysis were done. By the application of CONISS statistical analysis three different pollen assemblage (sub)zones could have been distinguished: a dominance of alder-beech/oaks from the 2nd to the middle of the 7th century, followed by a prevalence of grasses-beech/oaks till the end of the 13th century. Finally, an assemblage of grasses-hornbeam/oaks populated the area from the 14th to the beginning of the 20th century. The high abundance of peat mosses (*Sphagnum*) from the 11th to the end of the 14th century must indicate increased precipitation and higher frequencies of rainfall during the Medieval Climate Anomaly. Transition from an ombrotrophic to minerotrophic phase of mire evolution during the Little Ice Age is caused by changing in moisture level, with somewhat wetter period prevailing till the middle of the 17th century followed by drier conditions till the beginning of the 20th century. Although cereal pollen grains first appear from the layers dated to the late 14th century and the proportion of secondary anthropogenic indicators were low during the entire Middle Ages, a large number of charcoal particles suggests stronger anthropogenic activity than indicated by observed changes in vegetation composition. Still, a sharp rise of non-arboreal pollen during the Migration period most likely reflect a general natural succession process on mire surface than persuable proof of Avaric-Slavic impact on vegetation. Direct anthropogenic pressure indicated by weeds and cereal pollen can be tracked from the Late Middle Ages onwards.*

Keywords: the Balkans, palynology, peatland, Medieval Climate Anomaly, Little Ice Age, Antiquity, Middle Ages, Early Modern Period

*U ovome radu predstavljena je paleookolišna rekonstrukcija creta u blizini sela Blatuše, s naglaskom na promjene u strukturi i sastavu vegetacije, hidrološkoga režima i povijesti požara na području Banovine/Korduna tijekom posljednja dva tisućljeća. U svrhu paleookolišne interpretacije, napravljena je analiza akumuliranoga peluda, nepeludnih palinomorfa i pougljenjenih čestica. Upotrebom CONISS statističkoga modela mogu se razlučiti tri različite (pod)zone akumulacije: vegetacija „joha-bukva/hrastovi" dominanira razdobljem od 2. stoljeća do sredine 7. stoljeća, nakon čega slijedi dominacija vegetacije „trave-bukva/hrastovi" do kraja 13. stoljeća, te naposlijetku vegetacije „trave-grab/hrastovi" u razdoblju od 14. do početka 20. stoljeća. Obilje spora maha tresetara (*Sphagnum*) u razdoblju od 11. do kraja 14. stoljeća vjerojatno je utjecano povećanom količinom oborina i učestalijim padalinama tijekom srednjovjekovne klimatske anomalije. Prijelaz iz ombrotrofije u minerotrofiju same cretne površine, tijekom maloga ledenog doba, uzrokovan je promjenom zasićenosti supstrata vodom, s nešto vlažnijim razdobljem do sredine 17. stoljeća i djelomično sušnijim do početka 20. stoljeća. Iako se pelud žitarica ne pojavljuje do kraja 14. stoljeća i udjeli sekundarnih antropogenih indikatora su niski tijekom cijeloga razdoblja srednjeg vijeka, veliki broj pougljenjenih čestica ukazuje na jaču antropogenu aktivnost no što se to može iščitati iz promjenama u biljnome pokrovu. Ipak, snažan porast udjela peluda nedrvenastih vrsta tijekom Seobe naroda više je rezultat procesa sukcesije na površini samoga creta nego nepobitan dokaz avarsko-slavenskoga utjecaja na sastav i strukturu vegetacije. Izravni antropogeni pritisak, koji se očituje učestalom pojavom peluda korovnih vrsta i žitarica, može se pratiti tek od razdoblja kasnoga srednjeg vijeka nadalje.*

Ključne riječi: Balkan, palinologija, cret, srednjovjekovna klimatska anomalija, malo ledeno doba, antika, srednji vijek, novi vijek

1. INTRODUCTION

Environmental history is the interdisciplinary study of the relations of culture, technology and nature through time (Damodaran 2015: 747–755) highlighting relationships between human societies and their natural environment (McNeill 2010: 347). Environmental history traditionally focuses on three major aspects: 1) ecological – features and functions of an ecosystem that includes biotic and abiotic constituents; 2) productional – interrelationships of socioeconomic activity and the environment; 3) ideological – features and changes in people's understanding of the natural environment (Ekohistorija 2019). As a new field of study mostly concerned with environmental problems, it emerged during the second half of the 20th century (Delort, Walter 2002; Simmons 2010; Hughest 2011) and soon became a global political agenda (Barry 2010). In Croatia, great progress has been made in this field since the beginning of the 21st century (Roksandić 2002; Fürst-Bjeliš et al. 2011), mainly from the side of scientists or scholars belonging to

1. UVOD

Povijest okoliša može se definirati kao interdisciplinarno proučavanje odnosa kulture, tehnologije i prirode kroz vrijeme (Damodaran 2015: 747–755), ističući u prvi plan odnos između ljudskoga društva i prirode u kojoj ljudi obitavaju i o kojoj ovise (McNeill 2010: 347). Povijest okoliša tradicionalno ispituje svoj predmet na tri razine: 1) ekološkoj – značajke i funkcije nekoga ekosustava koji uključuje biotičke i abiotičke sastavnice; 2) proizvodnoj – međuodnosi društveno-ekonomske aktivnosti i prirodne sredine; 3) ideološkoj – značajke i promjene u razumijevanju prirodne sredine od strane čovjeka (Ekohistorija 2019). Kao novo područje proučavanja, temeljeno uglavnom na zabrinutosti društva stanjem okoliša, ono se počelo ubrzano razvijati tijekom druge polovice 20. stoljeća (Delort, Walter 2002; Simmons 2010; Hughest 2011) te je uskoro postalo globalnim političkim programom (Barry 2010). U Hrvatskoj se značajni napredak u promišljanju promjena prirodne sredine može uočiti početkom 21. stoljeća (Roksandić 2002; Fürst-Bjeliš et al. 2011), uz značajan doprinos znanstvenika koji pripadaju social or humanistic fields (Fürst-Bjeliš et al. 2011). Collecting and analysing data from the literature, geographical maps as well as other records gained wider and wider attention and appreciation also promoting interdisciplinary research with natural scientists from the fields of Biology and Geosciences, including archaeology (Šoštarić et. al. 2015; 2017; Karavanić et al. 2016; Essert et al. 2018; Dubolnić Glavan, Šoštarić 2020; Reed et al. 2019; etc.). Palynology, a basic method used in our study for paleoenvironmental reconstruction, is an interdisciplinary field (eg. Mercuri 2015) and a subdiscipline of botanical ecology (Dawson, Mayes 2015). Originally, palynology was defined as the study of pollen grains and spores from higher plants and cryptograms and as such is widely adopted in palaeo-environmental reconstructions as well as modern biological research (Boyd, Hall 1998). As was stated by Edwards et al. (2015), palynology has for long been a major contributor to archaeology too; mostly in helping to reconstruct dietary, medical use of plants, deciphering the season of death and funerary rituals (Kvavadze, Kakhiani 2010; Piombino-Masacali et al. 2013; Iriarte-Chiapusso et al. 2015; Reinhard et al. 2018; Slepchenko et al. 2019; Weber et al. 2020). Its potential in other scientific fields, eg. plant taxonomy (Ulrich et al. 2012) conservation biology (Bessega et al. 2017; Marrero et al. 2019), forensic (Mildenhall 2006; Wiltshire 2009) or human health (Puljak et al. 2016; McInnes et al. 2017; Damialis et al. 2019; Vucić et al. 2019) is also recognised. Results of pollen analysis can be used for different purposes. In our research pollen and spores were used, together with non-pollen palynomorphs and charcoal particles, for describing environmental conditions in the past (eg. Lamentowicz et al. 2015; Expsito, Burjachs 2016; Tunno, Mensing 2017; Blaus et al. 2019; Dendievel et al. 2019; Marcisz et al. 2019; Wojewódka, Hruševar 2020). To understand whether or not past environmental changes are climate or human-induced or both, the analysis of several lines of information; i.e. a multi-proxy reconstruction provides the best approach (eg. Andrič et al. 2009; Chodorowski et al. 2013; Dietre et al. 2014; Karpińska-Kołaczek et al. 2018; Kołaczek et al. 2018). The aim of our work is to highlight the potential causes of human and/or climate-induced environmental changes for the area between the Kupa and Una rivers, recognised under toponims Kordun and Banovina (Fig. 1) using palynological data. As paleoenvironmental data is generally lacking for the area, especially for the period of Late Antiquity, and the Middle Ages, our goal was to establish a framework for understanding vegetation dynamics, paleohydrology and changes in the trophic status of a mires for the period of the last two millennia. This is a much-needed step because the last palynological research for continental biogeographical region of Croatia was conducted more than fifty years ago. Although Gigov and Nikolić (1960: 4–10) made a significant contribution with their palynological work, in their research analysis of non-pollen palynomorphs and charcoal completely lack and pollen analysis was focused only on arboreal pollen, so comparison with local (mire and wetland) taxa is

društvenome ili humanističkome području (Fürst-Bjeliš et al. 2011). Prikupljanje i analiza podataka iz literature, zemljopisnih karata i drugih oblika zapisa zadobiva sve širu pažnju i uvažavanje, uz promicanje interdisciplinarnih istraživanja između prirodoslovaca iz područja biologije i geoznanosti s humanistima iz područja arheologije (Šoštarić et. al. 2015; 2017; Karavanić et al. 2016; Essert et al. 2018; Dubolnić Glavan, Šoštarić 2020; Reed et al. 2019). Palinologija, osnovna metoda za razumijevanje i interpretaciju paleookoliša, korištena uostalom i u ovome našem istraživanju, transdisciplinarna je znanost (npr. Mercuri 2015) kao i poddisciplina botaničke ekologije (Dawson, Mayes 2015). Originalno, palinologija se interpretira kao znanost o palinomorfima, tj. peludu viših biljaka i sporama kriptogama te se kao takva koristi u paleookoloških rekonstrukcijama, ali i suvremenim biološkim istraživanjima (Boyd, Hall 1998). Kao što su utvrdili Edwards et al. (2015), palinologija već odavna dopunjuje i pridonosi arheologiji, uglavnom u pitanjima prehrane, medicinske upotrebe biljaka, razumijevanju sezone smrti i pogrebnih rituala (Kvavadze, Kakhiani 2010; Piombino-Masacali et al. 2013; Iriarte-Chiapusso et al. 2015; Reinhard et al. 2018; Slepchenko et al. 2019; Weber et al. 2020), iako je potencijal iste u drugim znanstvenim područjima, npr. biljnoj taksonomiji (Ulrichet al. 2012), konzervacijskoj biologiji (Bessega et al. 2017; Marrero et al. 2019), forenzici (Mildenhall 2006; Wiltshire 2009) ili pitanju ljudskoga zdravlja (Puljak et al. 2016; McInnes et al. 2017; Damialis et al. 2019; Vucić et al. 2019) također prepoznat. Dakle, rezultati peludnih analiza mogu se koristiti u različite svrhe, međutim u našem istraživanju pelud i spore su korišteni, zajedno s nepeludnim palinomorfima te pougljenjenim česticama, za opis paleookolišnih promjena (npr. Lamentowicz et al. 2015; Expsito, Burjachs 2016; Tunno, Mensing 2017; Blaus et al. 2019; Dendievel et al. 2019; Marcisz et al. 2019; Wojewódka, Hruševar 2020). Upotreba različitih indikatora je općenito najbolji pristup (npr. Andrič et al. 2009; Chodorowski et al. 2013; Dietre et al. 2014; Karpińska-Kołaczek et al. 2018; Kołaczek et al. 2018) razumijevanju čimbenika koji dovode do promjena u prirodnoj sredini (posredovanih klimom ili ljudskim utjecajem). Svrha našega rada je istaknuti potencijalni utjecaj antropogenoga pritiska i/ili klimatskih promjena u okolišu na području između Kupe i Une, geografski znanim kao Kordun i Banovina (sl. 1), upotrebom palinoloških podataka. Kako paleoekološki podaci općenito nedostaju za to područje, posebno u razdobljima kasne antike i većega dijela srednjega vijeka, nadamo se kako će predstavljeni rezultati dati okvir za razumijevanje dinamike vegetacijskih promjena kao i hidrologije i trofije samoga područja istraživanja tijekom posljednjih dva tisućljeća. Ovo je prijeko potreban korak budući da su posljednja palinološka istraživanja za kontinentalnu biogeografsku regiju Hrvatske provedena prije više od pedeset godina. Premda su Gigov i Nikolić (1960: 4–10) dali značajan doprinos paleookolišnim interpretacijama, u njihovim istraživanjima nedostaju analize nepeludnih palinomorfa i pougljenjenih čestica, a peludna analiza je usredotočena na pelud drvenastih vrsta, pa usporedba s lokalnim svojtama (cretne i močvarne vrste) nedostaje. Također, oni u svojoj publikaciji ne datiraju starost jezgre upotrebom ^{14}C metode što postaje standardna kronološka metoda tek desetljeće nakon njihova istraživanja.

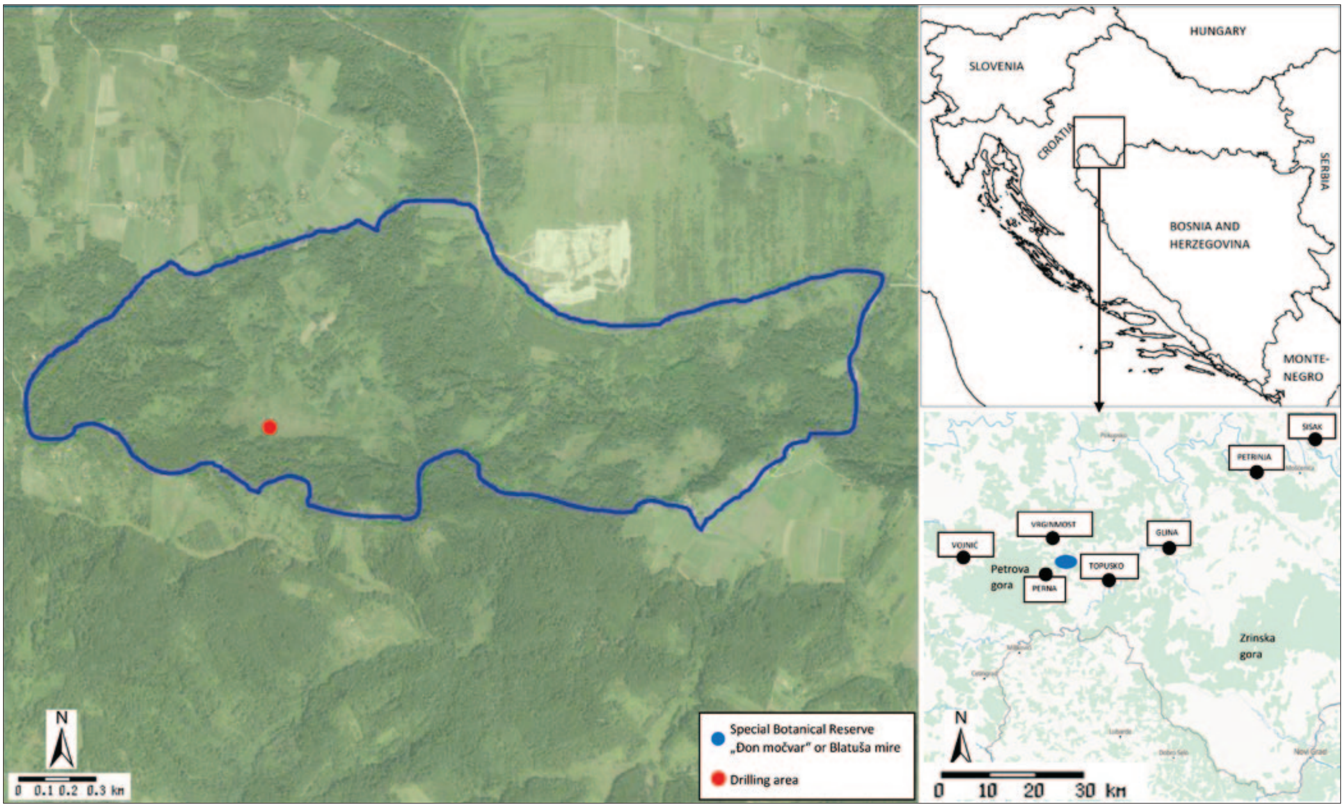

Fig. 1 Map of the "Đon močvar" protected site or Blatuša mire, located in Kordun/Banovina geographical region, Central Croatia (made by: D. Hruševar)

Sl. 1 Karta Posebnog botaničkog rezervata „Đon močvar" ili cret u Blatuši, na geografskom području Kordun/Banovina, središnja Hrvatska (izradio: D. Hruševar)

missing. Also, their core is not dated by using ^{14}C which only became standard analysis in decade after their publication. All this highlighted the necessity for new survey in sens of modern multidisciplinary approach, which we tried to conduct in this article.

1.1. STUDY AREA

1.1.1. Location

A Special Botanical Reserve "Đon močvar" or Blatuša mire (X=45019'4''N, Y=15054'24'' E; at 130 m a.s.l.) (Fig. 1) is located near the village of Blatuša in Central Croatia, close to the borderline with Bosnia and Herzegovina. Administratively, the study site belongs to Sisak-Moslavina County, lying between the Kupa and Una rivers, in Kordun and Banovina geographical regions.

1.1.2. Climate

According to Köppen's climatic classification, the broader area of Blatuša belongs to the climate type Cfb – a moderately hot humid climate with warm summers: the mean air temperature of the hottest month is lower than 22°C (Šegota, Filipčić 2003). The average annual precipitation amount in the period from 1965 to 1990 is ~1079 mm and the mean annual air temperature for Topusko is 10.3°C. The coldest month is January with a mean monthly temperature of

Sve to naglašava potrebu za novom paleookolišnom interpretacijom upotrebom suvremenoga multidisciplinarnog pristupa koju smo pokušali provesti u našem istraživanju.

1.1. PODRUČJE ISTRAŽIVANJA

1.1.1. Lokacija

Posebni botanički rezervat „Đon močvar" ili cret Blatuša (X=45019'4''N, Y=15054'24'' E; na 130 m n.v.) (sl.1), kako se obično naziva zbog blizine sela Blatuše, smješten je na području središnje Hrvatske, u blizini pograničnoga područja s Bosnom i Hercegovinom. Administrativno, područje istraživanja pripada Sisačko-moslavačkoj županiji, a nalazi se između rijeka Kupe i Une, tj. na granici dviju zemljopisnih regija: Korduna i Banovine.

1.1.2. Klima

Prema Köppenovoj klimatskoj klasifikaciji, šire područje Blatuše pripada klimatskome tipu Cfb – umjereno vrućoj vlažnoj klimi s toplim ljetima: prosječna temperatura zraka najtoplijega mjeseca je niža od 22°C (Šegota, Filipčić 2003). Prosječni godišnja količina padalina u razdoblju od 1965. do 1990. iznosi ~1079 mm, a prosječna godišnja temperatura zraka utvrđena za Topusko iznosi 10,3°C. Najhladniji mjesec je siječanj, s prosječnom mjesečnom temperaturom od −0,4°C (Mesić 2000). Tijekom zimske sezone bilježi se u prosjeku 5 do 10 dana sa snježnim pojasom iznad 30 cm (Posa-

–0.4°C (Mesić 2000). During winter season, an average of 5 to 10 days with snow belt above 30 cm is recorded (Posavec-Vukelić et al. 2010). The hottest month is July with a mean monthly temperature of 20°C (Mesić 2000).

1.1.3. Geomorfology and Vegetation Cover of the Broader Area

Steep slopes of small hills sourround the mire area. These are Šabica Brdo (199 m a.s.l.), Oštri Vrh (188 m a.s.l.) and Čubanovac (171 m a.s.l.) on the west and south sides, with slopes of Toplička kosa (Modrić-Surina 2011) in the east. The stream Čemernica flows through the northeastern part of the protected area (Posavec-Vukelić et al. 2010). The steep hills are mostly covered by oaks (eg. *Quercus petraea* and *Q. cerris*) and hornbeam (*Carpinus betulus*) assigned to the Erythronio-Carpinion and Carpinion betuli woodland assemblage (Alegro, Šegota 2009). Conversely, a Quercion robori-petraeae and Aremonio-Fagion (NN 88/14) assemblage developed on the neighboring mountains just a few kilometers away from the study site: Petrova gora (highest paeak Priseka at 616 m a.s.l.) is only 4 km away from study site and Zrinska gora (highest peak Mali Petrovac at 512 m a.s.l.) is about 10 km from "Đon močvar". Consequently, other arboreal taxa like birch (*Betula pendula*), lime (*Tilia* spp.), chestnut (*Castanea sativa*), beech (*Fagus sylvatica*) and fir (*Abies alba*) may have a strong influence on the regional pollen spectrum besides oaks and hornbeam.

Nowadays Banovina and Kordun are sparsely populated. Within a radius of approximately 5 km two settlements with a population of 1000 or slightly above are found: the villages of Topusko and Vrginmost. The only town within a radius of approximately 15 km is Glina with almost 5000 inhabitats. However, during medieval period or earlier, inhabitants of some other important areas like Perna (Bali 2014: 21–22, 87), might have impacted the vegetation cover as well.

1.1.4. Mire Type and Local Vegetation

Blatuša is the largest mire in Croatia covering an area of 20 ha enjoying protection (Posavec-Vukelić et al. 2010). However, typical wetland and peatland vegetation covers only 11 ha. The average altitude of mire surface is 147 m a.s.l. Based on its hydrology, geochemistry and the level of nutrients, Blatuša mire today corresponds to a minerogenous oligotrophic peatland with relatively high concentrations of dissolved magnesium, manganese, sodium and iron in the soil, but a low level of nutrients. It has been developed on acid sandy cobblestone with inclusion of clay, and can be considered as soligenous minerotrophic peatland, with partly developed *Sphagnum*'s hummock (Modrić-Surina 2011). Moreover, this transition mire has the characteristics of a raised bog (Horvat 1962: 102), although *Sphagnum capillifolium* (including *S. rubellum*) and *S. paluste* are nowadays much more abundant than *S. magellanicum*. Also, *Polytrichum strictum* is replaced by *Polytrichum longisetum* on the study site (Alegro, Šegota 2008).

vec-Vukelić et al. 2010). Najtopliji mjesec je srpanj s prosječnom mjesečnom temperaturom zraka od 20°C (Mesić 2000).

1.1.3. Geomorfologija i vegetacijski pokrov širega područja

Strmi obronci niskih brežuljaka okružuju područje creta. Na zapadnoj i južnoj strani pružaju se Šabića brdo (199 m n.v.), Oštri vrh (188 m n.v.), Čubanovac (171 m n.v.), a s istočne strane prema cretu se spuštaju obronci Topličke kose (Modrić-Surina 2011). Potok Čemernica teče sjeveroistočnim dijelom zaštićenoga područja (Posavec-Vukelić et al. 2010). Okolna uzvišenja su uglavnom prekrivena hrastovima (npr. *Quercus petraea* i *Q. cerris*) i običnim grabom (*Carpinus betulus*) koji pripadaju šumskim savezima: Erythronio-Carpinion i Carpinion betuli (Alegro, Šegota 2009). Srednjoeuropske šume hrasta kitnjaka te obične breze (sveza Quercion robori-petraeae) i ilirske bukove i bukovo-jelove šume (sveza Aremonio-Fagion) (NN 88/14) čine pak prevladavajuću vegetaciju na obližnjim gorama: Petrova gora (najviši vrh Priseka, 616 m n.v.) udaljena je svega 4 km od lokacije istraživanja, a Zrinska gora (najviši vrh Mali Petrovac na 512 m a.s.l.) je oko 10 km udaljena od Posebnoga botaničkog rezervata „Đon močvar". Posljedično, i druge vrste drveća poput breze (*Betula pendula*), lipe (*Tilia* spp.), pitomoga kestena (*Castanea sativa*), bukve (*Fagus sylvatica*) i jele (*Abies alba*) značajno utječu na regionalni peludni spektar, uz već spomenute hrastove i grab.

Danas su Banovina i Kordun rijetko naseljeni. U polumjeru od oko 5 km od mjesta uzorkovanja jezgre sedimenta, samo naselja Topusko i Vrginmost dosežu populaciju od 1000 ili nešto više stanovnika, a jedini grad u polumjeru od otprilike 15 km je Glina, s manje od 5000 stanovnika. Međutim, tijekom srednjega vijeka ili ranije, stanovništvo nekih drugih, danas gotovo zaboravljenih mjesta, poput Perne (Bali 2014: 21–22, 87), također je moglo značajno utjecati na biljni pokrov.

1.1.4. Tip creta i lokalna vegetacija

Blatuša je najveći cret u Hrvatskoj, sa zaštićenim područjem veličine 20 ha (Posavec-Vukelić et al. 2010). Međutim, tipična cretna vegetacija pokriva površinu od svega 11 ha. Prosječna nadmorska visina creta je 147 m n.v. Na temelju hidrologije, geokemije i trofije, cret u Blatuši pripada skupini minerogenih cretova s relativno visokim koncentracijama otopljenoga magnezija, mangana, natrija i željeza u tlu, ali siromašnih hranjivih tvari (oligotrofija). Tresetište je razvijeno na kiselim pjescima i šljuncima s proslojcima gline te se može smatrati soligenim minerotrofnim cretom, s gdjegdje razvijenim sfagnumskim humcima (Modrić-Surina 2011). Štoviše, ovaj prijelazni cret ima obilježja uzdignutoga creta (Horvat 1962: 102), premda su *Sphagnum capillifolium* (uključujući *S. rubellum*) i *S. paluste* u današnje vrijeme prisutniji na staništu od, za uzdigniti cret tipičnije vrste, *S. magellanicum*. Također, za uzdignute cretove tipična mahovina *Polytrichum strictum* na području Blatuše zamijenjena je svojtom *Polytrichum longisetum* (Alegro, Šegota 2008).

Tipična cretna vegetacija na Blatuši uključuje: zajednicu

The typical vegetation covering the mire surface includes different associations: Rhynchosporetum albae, Drosero-Caricetum stellulatae, Caricetum lasiocarpae and stands with *Eriophorum angustifolium.* Eight different *Sphagnum* mosses (if *S. capillifolium* and S. *rubellum* are treated like the same taxon) are noticed on the mire surface, with the most abundant *Sphagnum palustre* (Alegro, Šegota 2009). Contrary, in some parts of the mire typical wetland vegetation prevailes, eg. Magnocaricion, Typhaetum latifoliae and stands with *Phragmites australis*. Woodlands representing the Alnion glutinose assemblage are best developed along the marginal areas (Alegro, Šegota 2009 and our own observation).

1.2. ARCHAEOLOGICAL AND HISTORICAL CONTEXTS

Romans invaded the areas of Kordun and Banovina (Central Croatia) during the 2nd century BC. However Roman dominance in the area that would include Blatuša mire was the result of Octavian's military campaign in the 1st century BC who, by occupying Segestica (Siscia or present-day Sisak), subdued the inhabitans of Segestica (Škiljan 2007: 6). Octavian's troops mostl likely approached Segestica via Slunj, Veljun, Kolarić, Vojnić and Gvozd (Vrginmost). An alternative route along the valley of Mrežnica and Kupa is also possible. With the exception of Siscia, Roman monuments are especially numerous in the Topusko area (Škiljan 2007: 6), found adjacent to the study site.

Siscia is last mentioned in records dated to the first half of the 6th century AD (Škiljan 2007: 7) enjoying prosperity under Ostrogothic rule (Gračanin 2011: 247). Another period of general growth was Frankish supremacy during the 8th century (Gračanin 2011: 247) after succeeding waves of occupation by the Langobards, Avars and Slavs. Although Siscia is almost 40 km away from the study site it probably reflects the situation on the Kordun and Banovina region as well. Generally, findings from the Early Middle Ages are rare with the exception of the town of Kirin, where graves are traced between the 9th to the 11th centuries AD (Škiljan 2007: 7). It seems that Croatian domination can be traced from the 10th century (Gračanin 2011: 253). The great historical battle between the last Croatian king Petar Svačić and the Hungarian king Koloman Arpadović at the end of the 11th century could also have taken place not far from Blatuša, although Petrova gora, as a traditional battlefield, is nowadays mostly replaced with sites such as Zrinska gora (Škiljan 2007: 7; Goldstein 2008: 112) or Velika and Mala Kapela (Škiljan 2007: 7) which are quite far away.

During the High Middle Ages, people in the municipalities of Gvozd and Topusko lived in Bović settlement (consacration of the Catholic Church in 1334), Perna (status of a free royal town from 1225) and Topusko (Cistercian abbey). The Pauline monastery in Veliki Petrovac was founded in 1303. Based on the privileges granted to the inhabitants of Perna, we know that they were allowed to plant vineyards on the hills of Gradišće and Žalac (Škiljan 2007: 91). Moreo-

bijele šiljkice (asocijacija Rhynchosporetum albae), zajednicu zvjezdastoga šaša i rosike (asocijacija Drosero-Caricetum stellulatae), zajednicu končastoga šaša (Caricetum lasiocarpae) te sastojine uskolisne suhoperke (*Eriophorum angustifolium).* Osam različitih vrsta maha tresetara (ako *Sphagnum capillifolium* i S. *rubellum* tretiramo kao identičnu svojtu) nastanjuju površinu creta s najobilnije zastupljenom svojtom *S. palustre* (Alegro, Šegota 2009). U nekim dijelovima posebnoga botaničkog rezervata prevladava tipična močvarna vegetacija, npr. visoki šaševi (sveza Magnocaricion), zajednica širokolisnoga rogoza (asocijacija Typhetum latifoliae) i sastojine obične trske (*Phragmites australis*). Močvarne šume crne johe (sveza Alnion glutinose) najbolje je razvijena na rubovima creta (Alegro, Šegota 2009 i naše vlastito opažanje).

1.2. ARHEOLOŠKI I POVIJESNI KONTEKSTI

Rimljani su već krajem 2. st. pr. Kr. prisutni na područjima Korduna i Banovine, međutim rimska dominacija na području koje uključuje i cret u Blatuši posljedica je Oktavijanovoga vojnog pohoda u 1. st. pr. Kr. Naime, zauzimajući Segestiku (Sisciju ili današnji Sisak), Oktavijan pokorava stanovnike Segestike (Škiljan 2007: 6). Vjerojatan smjer kretanja Oktavijanovih vojnih trupa prema Segestici bio je preko Slunja, Veljuna, Kolarića, Vojnića i Gvozda (Vrginmost), iako je moguć i alternativni smjer uz doline Mrežnice i Kupe. Osim Siska, posebno brojni rimski spomenici na području Topuskog (Škiljan 2007: 6) također ukazuju na prisutnost i značaj rimske kulture na istraživanome području.

Siscija se posljednji put spominje u prvoj polovici 6. stoljeća (Škiljan 2007: 7) kada je grad, pod ostrogotskom upravom, ponovno postao prosperitetan (Gračanin 2011: 247). Međutim, ubrzo slijedi okupacija od strane Langobarda, Avara i Slavena, da bi novi zamah življenja uslijedio tijekom 8. stoljeća pod franačkom upravom (Gračanin 2011: 247). Povijest Siska, grada udaljenoga oko 40 km od mjesta istraživanja, zasigurno u određenoj mjeri oslikava stanje političko-gospodarskih prilika na području Korduna i Banovine. Općenito govoreći, nalazi iz ranoga srednjeg vijeka su rijetki, s izuzetkom Kiringrada u kojem se grobni ukopi mogu pratiti od 9. do 11. stoljeća (Škiljan 2007: 7). Dominacija hrvatskoga življa može se pak pratiti od 10. stoljeća (Gračanin 2011: 253). Velika povijesna bitka između posljednjega hrvatskog kralja Petra Svačića i mađarskoga kralja Kolomana Arpadovića krajem 11. stoljeća mogla se odviti i u blizini Blatuše, premda je sve više razmišljanja da bi Petrovu goru, kao tradicionalnu lokaciju bitke, valjalo zamijeniti Zrinskom gorom (Škiljan 2007: 7; Goldstein 2008: 112) ili puno udaljenijom Velikom i Malom Kapelom (Škiljan 2007: 7).

Za vrijeme razvijenoga srednjeg vijeka na području današnjih općina Gvozd i Topusko nalazimo sljedeća naselja: Bović (katolička crkva posvećena je 1334.), Perna (status slobodnoga kraljevskog grada iz 1225.) i Topusko (cistercitska opatija). Pavlinski samostan u Velikom Petrovcu osnovan je 1303. Na osnovi povlastica koje su dane stanovnicima Perne, znamo da im je dozvoljeno saditi vinograde na brežuljcima Gradišće i Žalac (Škiljan 2007: 91). Štoviše, mogućem ver, anthropogenic pressure on nature was probably maintained by Cistercian monks who usually payed attention to logging or draining, thus preparing the land for economic exploitation (Bali 2014: 54).

During the Late Medieval and the New Age, the Ottoman threat over the entire territory of present-day Kordun, Banovina and Pokupsko prevaled. In 1548 the Ottomans invaded Perna and the Steničnjak estate, but on that occasion the town was not burned. However, ten years later the Ottomans, led by Malkoč-beg, burned down Perna, Zlat, Krstinja, Kladuša, Vrnograč, Bojna and the surrounding settlements. In 1562, the Ottomans marched on Pern with four hundred soldiers, but were defeated by Herbert Auersperg's army. However, three years later they destroyed the walls of the Cistercian Abbey in Topusko. In 1689, the Croatian Bansko army invaded Pounje and defeated the Ottomans on Zrinsko Polje, thus freeing the area between Kupa and Una. The suppression of the Ottomans from the Banovina and Kordun areas resulted in the settlement of the Christian population, most often of Orthodox denomination. Thus, the process of revival of Topuski begins in 1687 and Vrginmost in 1688. However, Perna again suffers in the wars with the Ottomans in 1717 and 1788, and due to frequent conflicts with the Ottomans, a fleeing population left Topusko (Škiljan 2007: 91–91).

Agriculture and forestry, and to a lesser extent mining, represented a major part of the economic activities of the broader area of Blatuša during the Modern Period. This was a period of intensive deforestation, which Ban Esterhazy tried to prevent in the first half of the 18th century (Holjevac, Moačanin 2007: 72). Planting of fruit trees was introduced, especially plum (Pavličević 1988: 66), cultivation of cereals, tuber and lentil was intensified, and in the 19th century this part of Croatia became leader in its utilization of soil. Many of the smaller towns of Kordun and Banovina experienced a demographic peak in the middle or early part of the 19th century, such as Perna with the largest population (1317 inhabitants) numbering in 1857, after which the process of leaving rural areas and depopulation begun, and continued during the whole 20th century (Perna 2019).

2. MATERIALS AND METHODS

2.1. CORE EXTRACTION

Percussion coring in the year of 2015 yielded a more than 2 m-long sediment sequence (mostly peat material) from the mire site. For this purpose, an Eijkelkamp core sampler was used, modified in the way to be sharp as a knife by grinding the iron revetment. However, only the first meter of peat sediment was palynological interpreted in this article, due to significant difference in dating confidence of the layers between the top (first meter) and bottom (second meter) of this core. Sediments were transferred to PVC half-tubes, wrapped in transparent plastic foil and stored in fridge at 4°C for further analysis. The sequence was subsampled at 5 cm intervals for further studies.

antropogenom pritisku na okoliš vjerojatno su pridonijeli cistercitski redovnici koji općenito veliku pažnju posvećuju krčenju šuma, isušivanju močvara i natapanju zemljišta, pripremajući tako prostor za ekonomsku eksploataciju (Bali 2014: 54).

Tijekom kasnoga srednjeg i novoga vijeka osmanlijska prijetnja nadvila se nad cijelim teritorijem današnjeg Korduna, Banovine i Pokupskog. Godine 1548. napali su Pernu i imanje Steničnjak, ali tom prilikom grad nije spaljen. Međutim, deset godina kasnije Osmanlije, predvođene Malkočbegom, spalili su Pernu, Zlat, Krstinju, Kladušu, Vrnograč, Bojnu i okolna naselja. Godine 1562. Osmanlije su marširale na Pernu s četiri stotine vojnika, ali ih je nadjačala vojska Herberta Auersperga. Svejedno, tri godine kasnije Osmanlije su uništili zidove cistercitske opatije u Topuskom. Hrvatska banska vojska je 1689. napala Pounje i porazila Osmanlije na Zrinskom Polju, čime je područje između Kupe i Une oslobođeno osmanlijskoga utjecaja. Potiskivanje Osmanlija s područja Banovine i Korduna rezultiralo je naseljavanjem kršćanskoga stanovništva, najčešće pravoslavne denominacije. Proces oporavka Topuskog započinje 1687., a Vrginmosta 1688. Međutim, Perna opet stradava u sukobima s Osmanlijama 1717. i 1788., a zbog neprestane vojne opasnosti bježi i stanovništvo susjednoga Topuskog (Škiljan 2007: 91–91).

Poljoprivreda i šumarstvo, a u manjoj mjeri rudarstvo, predstavljaju važan dio gospodarskih aktivnosti na širem području istraživanoga područja tijekom novoga vijeka. Pretjeranu sječu šuma pokušava spriječiti ban Esterhazy tijekom prve polovice 18. stoljeća (Holjevac, Moačanin 2007: 72). Uskoro se uvodi sadnja voćaka, naročito šljiva (Pavličević 1988: 66) te se intenzivirana uzgoj žitarica, gomoljastih kultura i leće, da bi u 19. stoljeću ovaj dio Hrvatske postao predvodnik u iskorištavanju zemlje. Mnogi manji gradovi Korduna i Banovine doživjeli su demografski vrhunac početkom ili sredinom 19. stoljeća, uostalom Perna bilježi najveću populaciju (1317 stanovnika) 1857. godine, nakon čega započinje proces napuštanja ruralnih područja i depopulacije koji se nastavlja tijekom čitavoga 20. stoljeća (Perna 2019).

2. MATERIJALI I METODE

2.1. BUŠENJE JEZGRE

Postupak bušenja sedimenta proveden je tijekom 2015. godine. Pomoću bušilice Eijkelkamp, modificirane na način da metalna oplata uzorkivača brušenjem postane oštra poput noža, izvađena je neporemećena jezgra sedimenta duljine preko 2 m (većinom tresetni materjal). Međutim, samo je vršni metar treseta palinološki analiziran i interpretiran u članku zbog velike razlike u kronološkoj pouzdanosti datiranja sedimenta gornjega (prvi metar) i donjega (drugi metar) dijela jezgre. Sediment je u laboratorij prenesen u PVC cijevima, omotan prozirnom plastičnom folijom te je pohranjen u zamrzivač na temperaturu od 4°C. Poduzorci sedimenta uzorkovani su u intervalima od 5 cm u svrhu provedbe daljnjih analiza.

2.2. LITHOLOGICAL DESCRIPTION

All descriptions and analysis were made at 5 cm intervals. Composition and physical characteristics of sediments were described largely by using Troels-Smith classification, probably the most logical and comprehensive sediment classification system that provides information on physical characteristics of the sediment, the humification level and composition of the sediment (Birks, Birks 1980). The primary disadvantages of the Troels-Smith classification lie in its use of Latin terms (Schnurrenberger et al. 2003). So here we used a scheme modified by Kershaw (1997). Physical features includes: degree of darkness (varies from 0 in the lightest to 4 in the darkest sediments), degree of stratification (varies from 0 where the deposit is completely homogeneous to 4 which consists of clear thin layers or bands), degree of elasticity (varies from 0 in plastic sediments with great ability to regain its shape after being squeezed to 4 in disintegrated peat) and degree of dryness (varies from 0 which is characterised by clear water to 4 which characterised the air dry material). For sediment colour Munsell colours chart (Munsell Color 1994) were used. The degree of humification has not been determined. Composition includes six fundamental components and more subcomponents, whose sum of proportion must be equal to four (Birks, Birks 1980). Peat or turfa, the only component represented in the analyzed core section, can originate from mosses, arboreal plants or herbs (Kershaw 1997).

2.3. POLLEN, NON-POLLEN PALYNOMORPHS AND CHARCOAL – EXTRACTION AND DETERMINATION

In order to extract pollen, spores and charcoal from sediments, 1 cm^3 of samples were sieved (250 μm and 7 μm) and treated with 10% KOH and 20% HCl. After adding safranin palynological samples were stored in silica oil. Acetolysis was avioded (Faegri et al. 2000) to enhance preservation of non-pollen palynomorphs (NPPs) during the palynological extraction procedure. To enable calculation of pollen, NPPs and charcoal concentrations, an exotic marker, i.e. *Lycopodium* tablet with a known concentration of spores (Stockmarr 1971), was added to samples before treatment. Identification of pollen and spores followed standard keys (Moore et al. 1991; Beug 2015) and reference slide collections from the Department of Biology, Faculty of Science, University of Zagreb. NPP identifications were based on published papers: van Geel, 1972; 1978; van Geel, van der Hammen 1978; van Geel et al. 1980; 1983; 1989; 2003; Pals et al. 1980; Haas 1996; Kuhry 1997; Carrión, Navarro 2002; Aptroot, van Geel 2006; Barthelmes et al. 2006; Medeanic 2006; Prager et al. 2006; 2012; Cugny et al. 2010; Montoya et al. 2010; 2012; Kaczmarek et al. 2011; Dietre et al. 2012; Kołaczek et al. 2013; López-Vila et al. 2014; Hawksworth et al. 2016; Jankovská et al. 2016. NPP types were assigned to an existing code according to Miola (2012). Minimum pollen counts of 300 arboreal (AP) and non-arboreal (NAP) land pollen grains per sample were made and NPPs were simul-

2.2. LITOLOŠKI OPIS

Svi opisi i analize sedimenta jezgre napravljeni su u 5 centimetarskim intervalima. Sastav i fizička obilježja sedimenata opisani su u velikoj mjeri korištenjem Troels-Smithhove klasifikacije, vjerojatno najlogičnije i najsveobuhvatnije klasifikacije koja pruža informacije o fizičkim karakteristikama, razini humifikacije i sastavu sedimenta (Birks, Birks 1980). Primarni nedostaci Troels-Smith klasifikacije odnose se na korištenje latinskih izraza (Schnurrenberger et al. 2003), pa smo koristili prema Kershawu (1997) modificirani pristup. Fizičke značajke uključuju: stupanj tamnoće (varira od 0 u najsvjetlijim do 4 u najtamnijim sedimentima), stupanj stratifikacije (varira od 0, kada je sediment potpuno homogen, do 4, kada se sediment sastoji od jasno uočljivih tankih slojeva ili traka), stupanj elastičnost (varira od 0 u sedimentima velike plastičnosti koji imaju sposobnost povrati svoj oblik nakon što je sediment stisnut, do 4 u dezintegriranom tresetu) i stupanj suhoće (varira od 0, npr. bistra voda, do 4, vrijednosti karakteristične za na zraku posve suhi materijal). Za boju sedimenta korišten je Munsellov grafikon boja (Munsell Color 1994). Stupanj humifikacije nije utvrđivan. Sastav sedimenta pak uključuje šest temeljnih komponenti i više podkomponenti čiji zbroj proporcija mora biti jednak zbroju u vrijednosti četiri (Birks, Birks 1980). Treset ili turfa, kao jedini tip sedimenta u analiziranome 95 centimetara dugačkome odsječku jezgre, porijeklom može biti od mahovina, drvenastih ili pak zeljastih biljaka (Kershaw 1997).

2.3. PELUD, NEPELUDNI PALINOMORFI I POUGLJENJENE ČESTICE – IZOLACIJA I ODREĐIVANJE

U svrhu izolacije peluda, spora i pougljenjenih čestica, sediment volumena 1 cm^3 prosijavan je kroz sita (pore promjera 250 μm i 7 μm) te potom tretiran kalijevim hidroksidom (10% KOH) i klorovodičnom kiselinom (20% HCl). Nakon dodavanja safranina u svrhu bojanja stijenke palinorfa, palinološki uzorci su pohranjeni u silikatno ulje. U palinološkom postupku izrade predmetnica s palinomorfima namjerno smo izbjegli acetolizu (Faegri et al. 2000), a u svrhu očuvanja što većega broja nepeludnih tipova (NPPs). Kako bismo izračunali koncentracije peluda i nepeludnih palinomorfa u poduzorcima sedimenta, korišteni su egzotični markeri – *Lycopodium* tablete poznate koncentracije spora (Stockmarr 1971). Identifikacija peluda i spora provedena je pomoću standardnih palinoloških ključeva (Moore et al. 1991; Beug 2015) i referentne palinološke zbirke Biološkoga odsjeka Prirodoslovno-matematičkog fakulteta Sveučilišta u Zagrebu. Određivanje nepeludnih palinomorfa (NPP) temeljili smo na sljedećim objavljenim publikacijama: van Geel, 1972; 1978; van Geel, van der Hammen 1978; van Geel et al. 1980; 1983; 1989; 2003; Pals et al. 1980; Haas 1996; Kuhry 1997; Carrión, Navarro 2002; Aptroot, van Geel 2006; Barthelmes et al. 2006; Medeanic 2006; Prager et al. 2006; 2012; Cugny et al. 2010; Montoya et al. 2010; 2012; Kaczmarek et al. 2011; Dietre et al. 2012; Kołaczek et al. 2013; López-Vila et al. 2014; Hawksworth et al. 2016; Jankovská et al. 2016. NPP tipovi označeni su postojećim kodovima usklađenima prema Miola (2012). Interpretacija peludnoga dijagrama temelji se na minimalnom peludnom zbroju (total sum = TS) od 300 taneously identified and counted. Local pollen and NPPs values are expressed as a percentage in relation with total pollen sum (TS = AP + NAP), excluding local mire and wetland plants, like sedge (Cyperaceae) or *Typha latifolia* and *Myriophyllum spicatum*, ferns (Polypodiales, *Pteridium*) and mosses (Antocerotidae and *Sphagnum*).

For fire history reconstruction we used sediment based archives via quantification of charcoal on pollen slides. Microcharcoal particles (10 – 100 μm) were used as regional/extralocal and macrocharcoal particles (> 100 μm) as local fire indicators (Whitlock, Larsen 2001). For expression of charcoal data, we used percentages (ratio charcoals vs. total pollen sum) and abundance (an area of charcoal per unit volume of sediment, in our case $mm^2\ cm^{-3}$). As first method is not frequently used in modern literature (Mooney, Tinner 2011) we also take into account charcoal concentration abundance (Tinner et al. 1998) for interpreting fire history.

2.4. STATISTICAL ANALYSIS

For plotting diagrams (pollen and NPPs percentages and charcoal ratio and concentrations), PolPal software (Walanus, Nalepka 1999; Nalepka, Walanus 2003), version 2016 was used. To identify and determine the appropriate boundaries of the pollen/non-pollen assemblage zones CONISS statistical method, which is integral part of PolPal software, was used. This method calculates sums of squares for each cluster and recalculatations are done with merging clusters (Legendre, Birks 2012: 167–200). The matrix is required for two adjacent stratigraphic clusters whose joining gives the least increase in total dispersion. Agglomeration is continued until the entire data set is combined into one cluster. The measure of inequality most commonly used in the CONISS program is the squared Euclidean distance (Legendre, Birks 2012: 167–200) calculated from the non-transformed or transformed standardized, square root or normalized data (Prentice 1980), but other distances are also allowed. Also, due to fact that pollen sum varies between subsamples, we used the rarefaction analysis. This statistical tool, also integrated in PolPal software, enables comparison of pollen richness independently of the pollen sum (Birks, Line 1992) by standardizing pollen counts to a single sum (Birks et al. 2016).

2.5. CHRONOLOGY

Two organic samples (charcoal and seeds) were isolated from different depth levels. Radiocarbon ages reported in this paper were measured through accelerator mass spectrometry (AMS) ^{14}C in the Radiocarbon Laboratory of the Silesian University of Technology in Gliwice, Poland. Bayesian modelling was performed using gamma distributions as prior information on accumulation rates (AR). The plotted age-depth model is based on the weighted mean ages modelled using Bacon software (Blaauw, Christen 2011). Bacon models the accumulation rates of many equally spaced depth sections based on an autoregressive

drvenastih (arboreal pollen – AP) i nedrvenastih (non-arboreal pollen – NAP) peludnih zrnaca po svakome poduzorku. Nepeludni palinomorfi su prebrojavani i određivani istovremeno s peludnim zrncima. Udjeli lokalnih palinoloških vrsta i nepeludnih palinomorfa izraženi su kao postotak u odnosu na ukupan zbroj peluda (TS = AP + NAP), pri čemu su iz toga zbroja (TS) isključene tipične cretne ili močvarne vrsta, poput šaševa (Cyperaceae), rogoza (*Typha latifolia* tip), krocnja (*Myriophyllum spicatum*), paprati (Polypodiales, *Pteridium*) i mahovina (Antocerotidae i *Sphagnum*).

Za rekonstrukciju povijesti požara, korištene su u sedimentu akumulirane pougljenjene čestice koje se na predmetnicama prebrojavaju usporedno s palinomorfima. Pougljenjene mikročestice (veličina 10 – 100 μm) korištene su kao indikatori regionalnih/ekstralokalnih požara, a pougljenjene makročestice (> 100 μm) kao indikatori lokalnih požara (Whitlock, Larsen 2001). Za iskazivanje podataka o pougljenjenim česticama koristili smo postotke (omjer pougljenjenih čestica prema ukupnom zbroju peluda) kao i brojnost/koncentraciju istih (površina ugljena po jedinici volumena sedimenta, u našem slučaju $mm^2\ cm^{-3}$). Kako se prva metoda danas rijetko koristi (Mooney, Tinner 2011), kod tumačenja povijesti požara u obzir smo uzeli i potonju metodu, tj. koncentraciju pougljenjenih čestica (Tinner et al. 1998).

2.4. STATISTIČKA ANALIZA

Za iscrtavanje palinološkoga dijagrama (pelud, NPP i pougljenjene čestice), korišten je specijalizirani palinološki program PolPal (Walanus, Nalepka 1999; Nalepka, Walanus 2003), verzija 2016. U svrhu definiranja zona akumulacije peluda i nepeludnih palinomorfa, korištena je CONISS statistička metoda koja je sastavni dio PolPal programa. Kod ove metode disperzija ili suma kvadrata izračunava se za svaki klaster i ponovo preračunava kako se klasteri spajaju (Legendre, Birks 2012: 167–200). Matrica se traži za dva susjedna stratigrafska klastera čije spajanje daje najmanje povećanje ukupne disperzije. Aglomeracija se nastavlja sve dok se cijeli skup podataka ne kombinira u jedan klaster. Mjera nejednakosti koja se najčešće koristi u programu CONISS je kvadratna euklidska udaljenost (Legendre and Birks 2012), izračunata iz netransformiranog ili transformisanog (standardiziranog, kvadratnog korijena ili normaliziranog) podatka (Prentice 1980), ali i druge udaljenosti su dozvoljene. Također, zbog činjenice da se zbroj peluda razlikuje u svakome pojedinačnom poduzoraku, za izražavanje peludnoga bogatstva koristili smo rarefakciju. Ovaj statistički alat, također integriran u PolPal softver, omogućava usporedbu peludnoga bogatstva neovisno o količini prebrojnih peludnih zrnaca (Birks, Line 1992), standardizirajući „razrjeđivanjem“ broj peluda na istovjetni zbroj (Birks et al. 2016).

2.5. DATACIJA

U svrhu datiranja starosti jezgre, dva organska uzorka (ugljen i sjemenke) izolirana su iz različitih dubinskih odsječaka jezgre. Radiokarbonska starost prikazana u ovome radu mjerena je pomoću akceleratorske masene spektrometrije (AMS) ugljikovih izotopa ^{14}C u Radiokarbonskom laboratoprocess with gamma innovations. Inverse AR (sedimentation times expressed as year/cm) were estimated from 42 to 48 mln Markov Chain Monte Carlo (MCMC) iterations, and these rates form the age-depth model. AR was first constraint by prior information: acc. shape = 1.5 and acc. mean = 50 for the beta distribution, a memory mean = 0.7 and memory strength = 4 for beta distribution describing the autocorrelation of inverse AR. All input data were provided as ^{14}C yr BP and the model used the northern hemisphere IntCal13 calibration curve (Reimer et al., 2014) and post-bomb atmospheric NH1 curve (Hua et al. 2013) to convert conventional radiocarbon ages to calendar ages expressed as cal. AD. Age modelling was run to achieve a 1-cm final resolution. Calibrated ages are reported as age ranges at the 2-sigma confidence level (95.4%).

3. RESULTS

3.1. SEDIMENT DESCRIPTION AND CHRONOLOGY

The complete core sediment analysed in this article consists of woody peat which originated from the roots of trees and shrubs. However, different share of peat components is noticed (Tab. 1). The bottom part of the core (95 – 40 cm) is mainly characterised by the equal proportion of peat formed by mosses or herbs, with relative domination of woody fragments. Contrary, woody peat absolutely dominated through most of upper part of the core (40 – 10 cm) and herbal peat is mainly absent. The uppermost 10 cm of the core is composed of live *Sphagnum* taxa. Munsell colours show three different zones: black associated with catotelm characterised depth sequence from 95 to 40 cm, very dark brown is associated with acrotelm and dusky red is result of live peat mosses (*Sphagnum*) in the most upper part of the analyzed core (Tab. 1). For radiocarbon AMS dating charcoal from depth level of 58cm, and seed materials from depth level of 98 cm, were used (Tab. 2). The plotted age-depth model indicates that the 95 cm of sediment core sequence covers almost the last two millennia of palaeoecological changes (Fig. 2).

3.2. POLLEN-BASED VEGETATION, NPPs AND FIRE HISTORY

Two millennia of vegetation history of Blatuša mire is divided into two pollen assemblage zones or, more precisely, three subzones: Zone 1a, Zone 1b, Zone 2 (Fig. 3a). Changes in local mire/wetland vegetation are presented in Fig. 3b. A brief description of pollen-based vegetation records is presented in Fig. 4.

Zone 1a (depth 95–75 cm, 1818–1297 calBP or from the 2nd to the 7th century AD) can be described as "alder-beech/oak" zone (Fig. 3a; 4). Among trees, alder (*Alnus*) was relatively dominant with an average value of 26% (up to 46%); however its strong decline is observed during the 5th century. Beech (*Fagus*) was dominant in the colline/mountain forest belt with a proportion of 23% (up to 33%). Some trees were represented by more than 5%, eg. oaks (*Quercus*) with

riju Šlezijskog tehnološkog sveučilišta u Gliwicama, Poljska. Bayesovo modeliranje provedeno je pomoću gamma raspodjele priora temeljem akumulacijske rate (AR). Predstavljeni model „dubina-starost" baziran je na „izvaganim" srednjim starostima modeliranim pomoću programa Bacon (Blaauw, Christen 2011). Bacon modelira akumulacijske rate mnogih podjednako raspoređenih dubinskih odsječaka na osnovi autoregresivnoga postupka s gamma inovacijama. Inverzna akumulacijska rata (vrijeme sedimentacije izraženo kao godine po centimetru) procijenjena je temeljem 42 do 48 milijuna iteracija Markovljevog lanca metodom Monte Carlo (MCMC) i te rate definiraju model „dubina-starost". Akumulacijska rata konstruirana je prema sljedećim priorima: akumulacijski oblik = 1,5 i akumulacijska srednja vrijednost = 50 za beta distribuciju, srednja vrijednost memorije = 0,7, memorijska snaga = 4 za beta distribuciju, koji opisuju autokorelaciju inverzne AR. Svi ulazni podaci dati su kao ^{14}C yr BP (BP = *before present*, za što se okvirno uzima 1950. godina) te model upotrebljava sjevernohemisfernu IntCal13 kalibracijsku krivulju (Reimer et al. 2014) te „post-bomb" atmosfersku NH1 krivulju (Hua et al. 2013) za pretvaranje konvencionalne radiokarbonske starosti u kalendarsko vrijeme izraženo kao AD (*anno domini*). Modeliranje starosti jezgre provedeno je kako bi se postigla konačna razlučivost na jednocentimetarskoj skali. Kalibrirana starost prikazana je razinom pouzdanosti 2-sigma (95,4%).

3. REZULTATI

3.1. OPIS SEDIMENTA I DATACIJA

Sediment analiziranoga dijela jezgre sastavljen je pretežno od drvenastoga treseta porijeklom od korijenja drveća i grmlja. Međutim, treset porijeklom od različitih skupina biljaka ili njihovih dijelova može se razlikovati u analiziranome odsječku (tab. 1). Donji dio jezgre (95 – 40 cm dubine) uglavnom se odlikuje jednakim udjelom treseta formiranim od mahovina ili zeljastih biljaka, uz relativnu dominaciju drvenastih fragmenata. Suprotno tome, drvenasti treset apsolutno dominira glavninom gornjega dijela jezgre (40 – 10 cm dubine), uz istovremenu odsutnost zeljaste i mahovinske komponente. Vršnih 10 cm jezgre sedimenta sadrži živi mah tresetar – *Sphagnum* spp. Munsellove boje ukazuju na tri različite zone: crna boja povezana je s katotelmom te opisuje odsječak jezgre dubine 95 – 40 cm, izraženo tamno smeđa boja sedimenta povezana je s akrotelmom, a tamnocrvena boja, u krajnjem vršnom dijelu jezgre, odraz je pigmenata u živom mahu tresetaru (tab. 1). Za radiokarbonsko AMS datiranje starosti jezgre korišteni su pougljenjeni organski ostaci s dubine od 58 cm i sjemenke biljaka s dubine od 98 cm (tab. 2). Model „dubina-starost" pokazuje da 95 cm duga sekvence jezgre sedimenta obuhvaća gotovo dva tisućljeća peleokolišne povijesti (sl. 2).

3.2. PROMJENE U BILJNOM POKROVU I POVIJEST POŽARA

Dva tisućljeća vegetacijskih promjena na području Blatuša ogleda se kroz dvije zone akumulacije peluda ili, preciznije, tri podzone: Zona 1a, Zona 1b, Zona 2 (sl. 3a). Promjene u sastavu lokalne cretne ili močvarne vegetacije

Depth/ Dubina (cm)	0-4				Munsell	Peat formed by/ Treset porijeklom od…		
	Darkness/ Tamnoća	Stratification/ Stratificiranost	Elasticity/ Elastičnost	Dryness/ Suhoća		Mosses/ Mahovine	Woody plants/ Drvenaste biljke	Herbs/ Zeljaste biljke
						Components (sum = 4)/ Komponente (zbroj = 4)		
0-5	1	0	4	3	HUE 10R 3/4 dusky red	4		
5-10	1	0	4	3	HUE 10R 3/4 dusky red	4		
10-15	3	0	2	2	10YR 2/2 very dark brown	1	2	1
15-20	3	0	2	2	10YR 2/2 very dark brown	1	3	
20-25	3	0	2	2	10YR 2/2 very dark brown	1	3	
25-30	3	0	2	2	10YR 2/2 very dark brown	1	3	
30-35	3	0	2	2	10YR 2/2 very dark brown	1	3	
35-40	3	0	2	2	10YR 2/2 very dark brown	1	3	
40-45	3	0	3	2	10YR 2/1 black	1	2	1
45-50	3	0	3	2	10YR 2/1 black	1	2	1
50-55	3	0	3	2	10YR 2/1 black	1	2	1
55-60	3	0	3	2	10YR 2/1 black	1	2	1
60-65	3	0	3	2	10YR 2/1 black	1	2	1
65-70	3	0	3	2	10YR 2/1 black	1	2	1
70-75	3	0	3	2	10YR 2/1 black	1	2	1
75-80	3	0	3	2	10YR 2/1 black	1	2	1
80-85	3	0	3	2	10YR 2/1 black	1	2	1
85-90	3	0	3	2	10YR 2/1 black	1	3	
90-95	3	0	3	2	10YR 2/1 black	1	2	1

Tab. 1 Stratigraphy and description of peat deposits in the Blatuša mire profile (made by: D. Hruševar)
Tab. 1 Stratigrafija i opis treseta u profilu sedimenta uzorkovanoga na cretu u Blatuši (izradio: D. Hruševar)

an average value of 17% (up to 20%), hornbeam (*Carpinus*) with an average of 8% and hazel (*Corylus*) with an average of 6%. Some of arboreal taxa were observed in very low proportions, less than 2%, eg. pine (*Pinus*), fir (*Abies*) and spruce (*Picea*). Birch (*Betul*a) exceeds 1% in this (sub)zone

predstavljene su u slici 3b. Sažeti opis vegetacijskih promjena dan je u sl. 4.

Zona 1a (dubina 95–75 cm, starost od 1818–1297 calBP ili od 2. do 7. st. pos. Kr.) može se opisati kao zona „joha-bukva/hrastovi" (sl. 3a; 4). Među drvećem joha (*Alnus*) je relativno

Laboratory code/ Laboratorijski kod	Depth/ Dubina (cm)	Material/ Materijal	^{14}C Age (BP)/ ^{14}C starost (BP)	Calibrated age range/ Kalibrirani starosni raspon 68.2% confidence level/ 68.2% razina pouzdanosti	Callibrated age range/ Kalibrirani starosni raspon 95.4% confidence level/ 95.4% razina pouzdanosti
GdA-5125	58	charcoal/ ugljen	925 ± 20	1045–1060 cal AD (13.0%)	1037–1158 cal AD (95.4%)
				1061–1095 cal AD (29.0%)	
				1120–1141 cal AD (19.4%)	
				1147–1154 cal AD (6.8%)	
GdA-5127	98	seeds/ sjemenke	1856 ± 65	83–232 cal AD (68.2%)	19–266 cal AD (87.0%)
					269–332 cal AD (8.4%)

Tab. 2 Results of radiocarbon AMS dating of charcoal and seeds from the Blatuša mire (made by N. Piotrowska; modified by: D. Hruševar)
Tab. 2 Rezultati radiokarbonskoga AMS datiranja ugljena i sjemenki iz creta u Blatuši (izradila: N. Piotrowska; izmijenio: D. Hruševar)

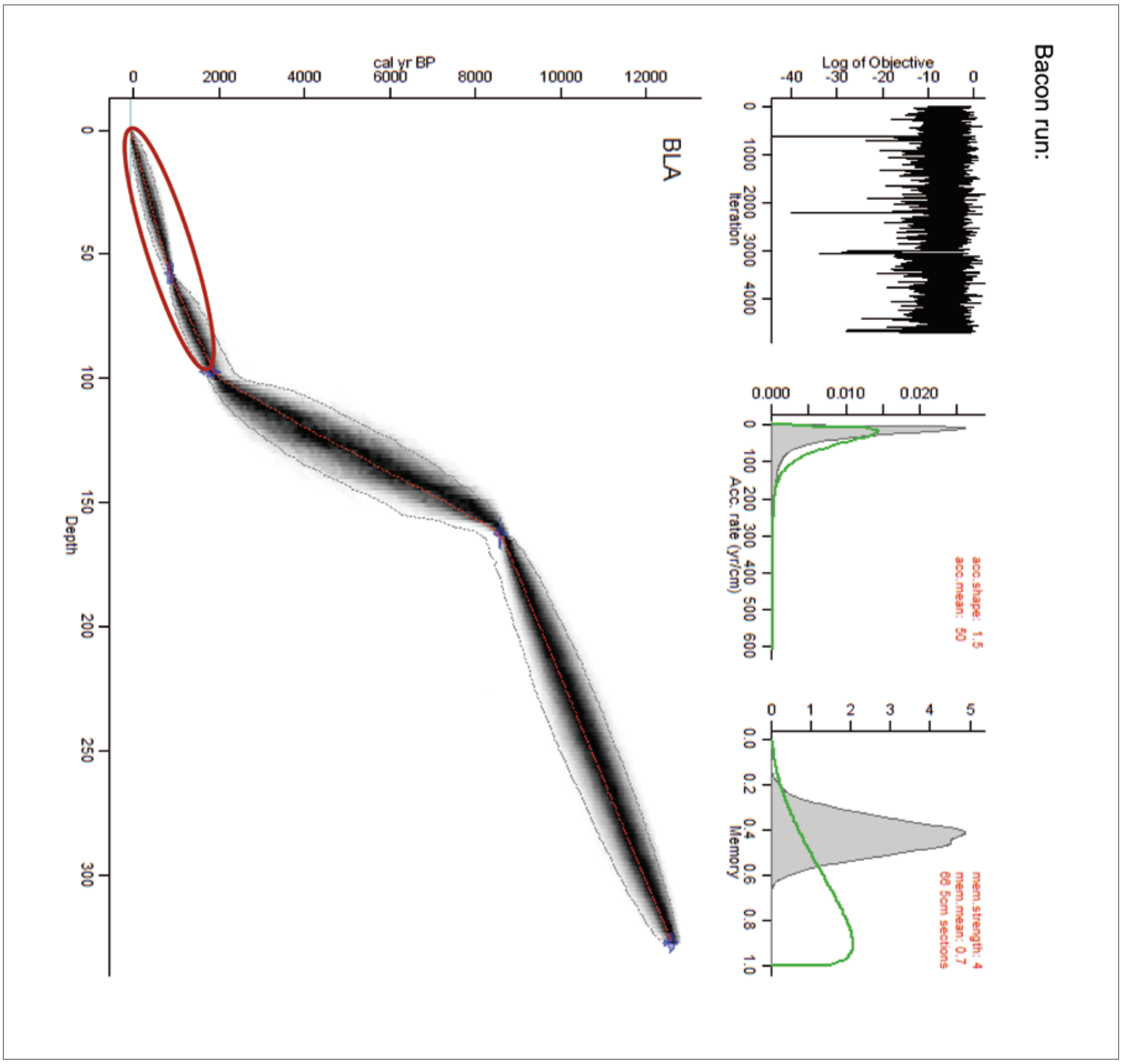

Fig. 2 Age-depth model. The red ellipsoid marks the last two millennia, period analysed in this article (made by: N. Piotrowska)
Sl. 2 Model „dubina-starost“. Crveni elipsoid označava posljednja dva tisućljeća, razdoblje analizirano u članku (izradila: N. Piotrowska)

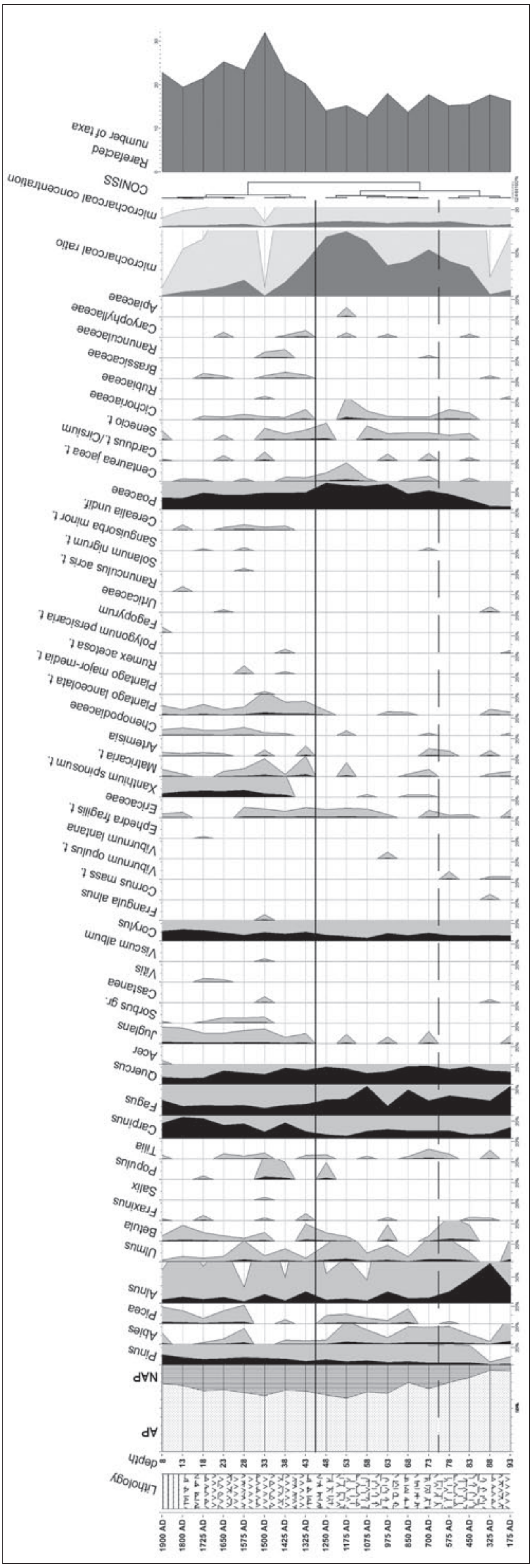

Fig. 3a Percentage pollen diagram of trees, shrubs and herbs, followed by microcharcoal curve (ratio and concentrations) as regional fire indicators. CONISS statistical dendrogram of similarities is used for distinguish different pollen assemblages (sub)zones. Lithology column is extensively discussed in the Tab. 1 (made by: D. Hruševar)

Sl. 3a Postotni peludni dijagram drveća, grmlja i zeljastih biljaka, praćen krivuljom pougljenjenih mikročestica (omjer i koncentracija) kao indikatora regionalnih požara. CONISS statistički dendrogram sličnosti koristi se za razlikovanje različitih (pod)zona akumulacije peluda. Litološki stupac opširno je opisan u tab. 1 (izradio: D. Hruševar)

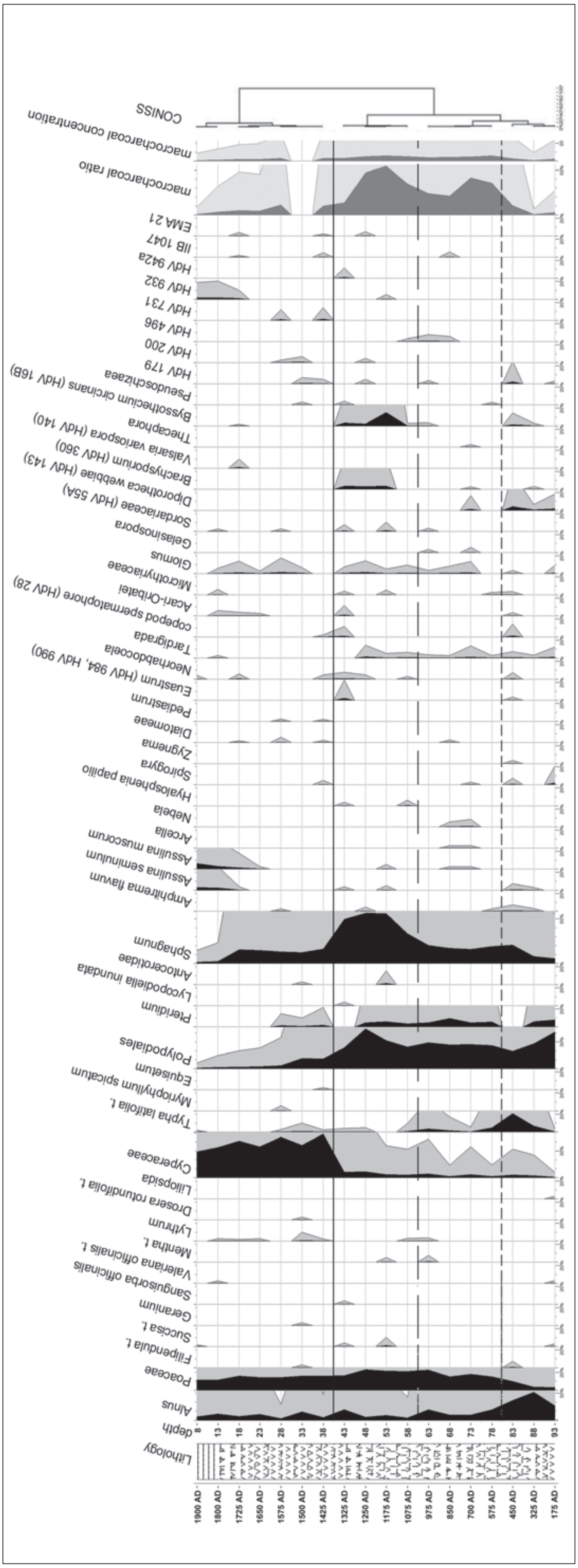

Fig. 3b Percentage diagram of local taxa (mire and wetland), followed by non-pollen palynomorphs curve, as indicators of trophic and moisture level, and macrocharcoal curve (ratio and concentrations), as local fire indicators. Due to ambiguous position of alder and grasses, this two taxa were also included in this diagram (made by: D. Hruševar)

Sl. 3b Postotni dijagram lokalnih svojti (cretnih i močvarnih), praćen krivuljom nepeludnih palinomorfa, indikatorima trofije i vlažnosti sedimenta te krivuljom pougljenjenih makročestica (omjer i koncentracija) kao indikatora lokalnih požara. Zbog dvojakoga položaja johe i trava, ove su dvije svojte također uključene u dijagram (izradio: D. Hruševar)

<table>
<tr><th>Age estimates (AD)
Procijenjena starost (AD)</th><th>Depth (cm)
Dubina (cm)</th><th>VEGETATION ON BROADER AREA
VEGETACIJA NA ŠIREM PODRUČJU</th><th>POSSIBLE MIRE TRANSITION
PROMJENE NA CRETU</th><th>TROPHIC STATE/HIDROLOGY
TROFIJA /HIDROLOGIJA</th><th>FIRE HISTORY
POVIJEST POŽARA</th><th>LOCAL LANDSCAPE MARKS
LOKALNA OBILJEŽJA KRAJOLIKA</th><th>TIMELINE
VREMENSKA LINIJA</th><th>CLIMATIC EVENTS
KLIMATSKE ANOMALIJE</th></tr>
<tr><td>1900</td><td>8</td>
<td rowspan="8">POACEAE-CARPINUS/ QUERCUS
GRASSES-HORNBEAM/OAKS
TRAVE-GRAB/ HRASTOVI</td>
<td rowspan="7">POOR FEN
MINEROTROFNI, NUTRIJENTIMA SIROMAŠAN PRIJELAZNI CRET</td>
<td rowspan="7">Oligotrophic to mesotrophic, probably wetter mire surface till the middle of 17th century, later probably drier but with fluctuation in moisture level
Oligotrofni do mezotrofni uvjeti na staništu, vjerojatno vlažnija cretna površina do sredine 17. stoljeća, kasnije vjerojatno suša, ali uz kolebanjem razine vlažnosti</td>
<td rowspan="7">Charcoal particles moderately numerous.
Regional fire indicators up to ~19%, and local fire indicators up to ~11%
Pougljenjene čestice umjereno brojne.
Indikatori regionalnog požara do ~19%, a lokalnog požara do ~11%</td>
<td rowspan="7">Mosaic of wetland and mire vegetation, on adjustment hills and mountains prevalence of hornbeam-oaks forest mixed with open habitats, like pastures and cultivated fields
Mozaik cretne i močvarne vegetacije, na okolnim uzvišenjima rasprostranjene šume hrasta i graba koje se izmjenjuju sa otvorenim staništima, poput pašnjaka i obrađenih polja.</td>
<td rowspan="2">MODERN AGE
SUVREMENO DOBA</td>
<td></td></tr>
<tr><td>1800</td><td>13</td><td rowspan="6">LITTLE ICE AGE
MALO LEDENO DOBA</td></tr>
<tr><td>1725</td><td>18</td><td rowspan="4">EARLY MODERN PERIOD
NOVI VIJEK</td></tr>
<tr><td>1650</td><td>23</td></tr>
<tr><td>1575</td><td>28</td></tr>
<tr><td>1500</td><td>33</td></tr>
<tr><td>1425</td><td>38</td><td rowspan="2">LATE MIDDLE AGES
KASNI SREDNJI VIJEK</td></tr>
<tr><td>1325</td><td>43</td>
<td rowspan="4">(RAISED?) BOG
OMBROTROFNI (UZDIGNUTI?) CRET</td>
<td rowspan="4">Oligotrophic / higher amount of precipitation and/or more frequent rainfall, drier mire surface
Oligotrofni uvjeti / veća količina oborina i / ili češće oborine, suha površina creta</td>
<td rowspan="9">Charcoal particles extremely numerous.
Regional fire indicators up to ~74%, and local fire indicators up to ~54%
Pougljenjene čestice iznimno brojne.
Indikatori regionalnog požara do ~74%, a lokalnog požara do ~54%</td>
<td rowspan="4">Domination of Sphagnum mosses, on adjustment hills and mountains codomination of beech, oaks and hornbeam forest with more open canopy
Na cretu prevlast maha tresetara (Sphagnum), na okolnim uzvišenjima bukva, hrastovi i grab u kodominaciji formiraju šume otvorenijeg sklopa.</td>
<td></td></tr>
<tr><td>1250</td><td>48</td>
<td rowspan="6">POACEAE-FAGUS/ QUERCUS
GRASSES-BEECH/ OAKS
TRAVE-BUKVA/ HRASTOVI</td>
<td rowspan="3">HIGH MIDDLE AGES
RAZVIJENI SREDNJI VIJEK</td>
<td rowspan="4">MEDIEVAL CLIMATE ANOMALY
SREDNJO-VJEKOVNA KLIMATSKA ANOMALIJA</td></tr>
<tr><td>1175</td><td>53</td></tr>
<tr><td>1075</td><td>58</td></tr>
<tr><td>975</td><td>63</td>
<td rowspan="4">POOR FEN
MINEROTROFNI, NUTRIJENTIMA SIROMAŠAN PRIJELAZNI CRET</td>
<td rowspan="4">Oligotrophic to mesotrophic
Oligotrofni do mezotrofni uvjeti na staništu</td>
<td rowspan="4">Mosaic of wetland and mire vegetation, on adjustment hills and mountains beech-oaks forest occurred, probably with more open canopy
Mozaik cretne i močvarne vegetacije, na okolnim uzvišenjima prevladavaju bukovo-hrastove šume otvorenijeg sklopa.</td>
<td rowspan="2">EARLY MIDDLE AGES
RANI SREDNJI VIJEK</td></tr>
<tr><td>850</td><td>68</td><td rowspan="6"></td></tr>
<tr><td>700</td><td>73</td><td rowspan="2">MIGRATION PERIOD
MIGRACIJSKI PERIOD</td></tr>
<tr><td>575</td><td>78</td>
<td rowspan="4">ALNUS-FAGUS/ QUERCUS
ALDER-BEECH/OAKS
JOHA-BUKVA/ HRASTOVI</td></tr>
<tr><td>450</td><td>83</td>
<td rowspan="3">ALDER CARR
JOHOM OBRASLO TRESETIŠTE</td>
<td rowspan="3">Oligotrophic to eutrophic / wetter mire surface but with fluctuation in moisture level
Oligotrofni do eutrofni uvjeti / vlažnija površina creta, ali uz kolebanje razine vlažnosti</td>
<td rowspan="3">Mosaic of alder stands and wetland vegetation, mire vegetation sparsely developed, on adjustment hills and mountains codomination of beech and oaks
Mozaik sastojina johe i močvarne vegetacije, cretna vegetacija slabo razvijena. Na okolnim uzvišenjima kodominacija bukve i hrastova.</td>
<td rowspan="3">ANTIQUITY
ANTIKA</td></tr>
<tr><td>325</td><td>88</td>
<td rowspan="2">Charcoal particles not numerous.
Regional fire indicators up to ~7% and local fire indicators up to ~3%
Pougljenjene čestice nisu brojne.
Indikatori regionalnog požara do ~7%, a lokalnog do ~3%</td></tr>
<tr><td>175</td><td>93</td></tr>
</table>

Fig. 4 Palaeoenvironmental reconstruction (in short), based on different proxies (made by: D. Hruševar)
Sl. 4 Paleookolišna rekonstrukcija (ukratko), temeljena na različim pokazateljima (izradio: D. Hruševar)

alone. Among NAP types, grasses (Poaceae) prevailed with an average of 9% (up to 18%). The average AP-NAP ratio was 88%, although with a sharp rise of non-arboreal pollen from the 2nd century (~7%) to the beginning of the 7th century (~20%). The anthropogenic indicator value was < 1%. Pollen richness is low, and ranges between 15 and 18 taxa. The ratio (percentages) and abundance (concentration) of micro- and macro- charcoal particles is low at the bottom part of this (sub)zone. However, their proportion greatly rised during the 5th century and stayed high till the end of this zone. Maximum percentages of microcharcoals rise up to 40%, and macrocharcoals to 36%. Total charcoal abundance trend is similar, ranging from 3,1 mm^2 cm^{-3} in lower part to 12,4 mm^2 cm^{-3} in uppermost subsample of this zone (Fig. 3a–b; 4).

From the typically mire or wetland plants in this (sub) zone (Fig 3b; 4), ferns (Polypodiales) are the most abundant with an average proportion of 29% (up to 41%), succeeded by peat mosses (*Sphagnum*) with 13% (up to 21%). Reed mace (*Typha latifolia* type) was observed in great proportions (8%, up to 21%), with a maximum value during the 5th century, simultaneously with the lack of bracken (*Pteridium*), even though this fern taxon is relatively abundant having an average of 5% (up to 8%). From non-pollen palynomorphs (NPPs), fungal spores of *Diporotheca webbiae* were most abundant (up to 7%), followed by *Byssothecium circinans* and *Glomus*. From algae *Spirogyra* was the most abundant (up to 3%). The most numerous thecamoebae were *Amphitrema flavum* and *Assulina seminulum*, each with less than 2% (Fig. 3b; 4).

Zone 1b (75–45 cm, 1297–647 cal BP or from the late 7th century to the end of the 13th century AD) can be described as "grasses-beech/oaks" zone (Fig. 3a; 4). For the first time some NAP pollen types overlaid AP pollen types – grasses (Poaceae) were relatively dominant (25%, up to 30%). Among AP a codomination of beech (21%, up to 33%) and oak (18%, up to 21%) is observed. In comparison with the previous (sub)zone, here very low values of alder (6%) and a stable low proportion of hazel (7%) is noticed. There is an increase in pine pollen (4%, up to 7%). in the same period. The AP-NAP ratio was 69%, with weak fluctuations compared to the previous (sub) zone. Even the proportion of arboreal pollen decrease to 62% which is the lowest value through the whole analyzed core. The anthropogenic indicator value stays below 1%. Pollen richness is low, and ranges between 12 and 18 taxa. Charcoal particles were extremely numerous, even reaching a ratio of 74% (microcharcoals) or 54% (macrocharcoals), respectively. Total charcoal abundance varies slightly, from 8,4 mm^2 cm^{-3} to 12,6 mm^2 cm^{-3}, but with highest average concentration through the whole core (Fig. 3a; 3b; 4).

From the typical mire plants (Fig. 3b; 4), peat mosses were the most abundant, with an average proportion of 33% (however, up to 57%), succeeded by ferns (31%, up to 45%).

dominantna vrsta s prosječnom vrijednošću od 26% (do 46%), međutim uz snažan pad udjela iste tijekom 5. stoljeća. Bukva (*Fagus*) dominira u brdskom/gorskom šumskom pojasu s udjelom od 23% (do 33%). Vrste zastupljene s više od 5% udjela su, primjerice, hrastovi (*Quercus*) s prosječnom vrijednošću od 17% (do 20%), grab (*Carpinus*) s prosjekom od 8% i lijeska (*Corylus*) s prosjekom od 6%. Neke od drvenastih vrsta zastupljene su s vrlo niskim udjelom, tj. s manje od 2%, npr. borovi (*Pinus*), jela (*Abies*) i smreka (*Picea*). Samo u ovoj (pod)zoni pelud breza (*Betula*) prelazi 1%. Među NAP tipovima peluda trave (Poaceae) prevladavaju s prosjekom od 9% (do 18%). Prosječni AP-NAP omjer iznosi 88%, premda ga karakterizira nagli porast peluda nedrvenastih vrsta od 2. stoljeća kada NAP udio iznosi oko ~7%, do početka 7. stoljeća kada vrijednost NAP udjela raste na oko 20%. Istovremeno, udio antropogenih indikator je < 1%. Peludnog bogatstvo je nisko i varira između 15 do 18 palinoloških vrsta. Mikro- i makro- pougljenjene čestice zastupljene su malim omjerom (postocima) i niskom brojnošću (koncentracijom) u najdubljem segmentu jezgre. Međutim njihov udio značajno se povećava tijekom 5. stoljeća i ostaje visok do kraja ove zone. Udio mikropougljenjenih čestica doseže do 40%, a makropougljenjenih čestica do 36%. Koncentracijski trend je sličan i kreće se od 3,1 mm^2 cm^{-3} u donjem do 12,4 mm^2 cm^{-3} u vršnom dijelu zone (sl. 3a–b; 4).

Od tipičnih cretnih ili močvarnih svojti (sl. 3b; 4), paprati (Polypodiales) su najobilnije zastupljene s prosječnim udjelom od 29% (do 41%), a slijede ih različite vrste maha tresetara (rod *Sphagnum*) s udjelom od 13% (do 21%). Rogoz (*Typha latifolia* tip) je također značajno zastupljen (8%, do 21%), s najvećom vrijednošću udjela tijekom 5. stoljeća kada iz peludnoga dijagrama nakratko iščezava bujad (*Pteridium*), iako su općenito spore ove paprati brojne tijekom ove (pod)zone, s učestalošću od 5% (do 8%). Od nepeludnih palinomorfa (NPPs), spore gljive *Diporotheca webbiae* su najučestalije (do 7%), a udjelom ih slijede vrste *Byssothecium circinans* i *Glomus*. Od algi najučestalija je S*pirogyra* (do 3%). Najbrojnije okućene amebe su *Amphitrema flavum* i *Assulina seminulum*, premda svaka od spomenutih vrsta s manje od 2% udjela (sl. 3b; 4).

Zona 1b (75–45 cm dubine, 1297–647 cal BP ili od kraja 7. do kraja 13. stoljeća) može se opisati kao zona „trave-bukva/hrastovi" (sl. 3a; 4). Po prvi puta relativno dominira skupina koja ne pripada drvenastim vrstama – trave (Poaceae) su zastupljene s prosječno 25% (do 30%). U šumskom pokrovu zapaža se kodominacija bukve (21%, do 33%) i hrasta (18%, do 21%). Istovremeno se zapaža vrlo niski udio johe (6%) u usporedbi s prethodnom (pod)zonom te kontinuirano niski udio lijeske (7%), dok se udio peluda borova povećava na prosječno 4% (do 7%). Prosječno AP-NAP omjer iznosi 69%, sa slabijom fluktuacijom vrijednosti u usporedbi s prethodnom (pod)zonom. Iako udio peluda drvenastih vrsta u nekim poduzorcima iznosi svega 62%, što je najniža vrijednost kroz cijelu analiziranu jezgru, vrijednost antropogenoga indikatora ostaje ispod 1%. Peludno bogatstvo je nisko i varira između 12 i 18 palinoloških vrsta. Pougljenjene čestice su izuzetno brojne te dosižu udio od 74% (mikročestice) ili 54% (makročestice). Ukupna koncentracija pougljenjenih čestica također ne varira značajno i kreće se između 8,4

A strong rise in *Sphagnum* started during the late 10th century and peat mosses soon became a dominant element. Bracken ferns (6%) slightly exceeded values of sedges (4%). From NPPs, fungal spores *Byssothecium circinans* (up to 15%) and *Brachysporium* (up to 4%) were the most abundant, followed by *Glomus* and *Diporotheca webbiae*. Algae never exceeded 1%, similarly to thecamoebae (Fig. 3b; 4).

Zone 2 (45–5 cm, 647–13 cal BP or from beginning of the 14th to middle of the 20th century) can be described as "grasses-hornbeam/oaks" zone (Fig. 3a; 4). However, grasses (17%, up to 19%) were codominant with hornbeam (16%, up to 24%), who's value was higher from the late 17th to the middle of the 20th century. At the same time oaks (12%, up to 19%) and beech (12%, up to 18%) were also very important in the woodland vegetation. Hazel slightly increases (10%), while alder proportions stay almost the same (6%) and for the first time walnut (*Juglans*) exceeds 1% (up to 2%). Also, for the first time primary anthropogenic indicators occurred – cereals pollens in the late 14th century, and some other secondary anthropogenic indicators were well represented: cocklebur – *Xanthium spinosa* type (5%, up to 8%), plantain – *Plantago lanceolata* type (1%, up to 3%), mayweed – *Matricaria* type (1%, up to 2%). Pollen from the fathen family (Chenopodiacae) also show a continuous trend. The AP-NAP ratio was 71% and the antropogenic indicator value varies between 5% and 10%. Pollen richness is higher than in previous (sub)zones, and ranges between 16 and 32 taxa. Charcoal particles were moderately numerous, displaying a continuous decline from the middle of the 17th century onwards (Fig. 3a–b; 4). Microcharcoals fall from 40% at the bottom of this (sub)zone, to less then 10% in the period from very late 17th to the beginning of the 20th century. The same trend is shown by macrocharcoals, accompanied by a complete lack of charcoal particles in the second half of the 15th century. This situation lasted for the next one hundred years. Total charcoal abundance trend is similar to microacharcoal/microcharcoal ratio, ranging from 7,8 mm^2 cm^{-3} in lower part to only 2 mm^2 cm^{-3} in uppermost subsample of this zone.

From the typical mire or wetland plants (Fig. 3b; 4), sedges (Cyperaceae) were the most abundant, with a sharp increase at the beginning of this (sub)zone and high values at its end (the average proportion of 35%, up to 49%), succeeded by peat-mosses (16%, up to 49%) and ferns (7%, up to 24%). However, peat mosses and ferns strongly decreased through the core sequence, and their value in the two uppermost subsamples don't exceed 3%. From NPPs (Fig. 3b; 4), amoebae from genus *Assulina* (*A. muscorum* > *A. seminulum*) were most abundant, exceeding 6% or 3%, respectively. *Glomus* was the most abundant fungi (up to 2%). However, its continuous rise is interrupted at the end of the 14th and beginning of the 15th century. From NPPs HdV 932 and HdV 731 were the most numerous (up to 2%).

mm^2 cm^{-3} do 12,6 mm^2 cm^{-3}, što predstavlja prosječno najviše vrijednosti duž cijele analizirane jezgre (sl. 3a-b; 4). Od za cret karakterističnih svojti (sl. 3b; 4), spore maha tresetara su najbrojnije s prosječnim udjelom od 33% (do 57%), a slijede ih spore paprati (31%, do 45%). Značajan porast udjela spora maha tresetara započinje tijekom kasnoga 10. stoljeća te uskoro mahovine roda *Sphagnum* postaju prevladavajući element na istraživanome području. Od lokalne flore valja istaknuti bujad čije spore udjelom (6%) neznatno premašuje vrijednosti peluda šaševa (4%). Od NPP-ova, spore gljiva *Byssothecium circinans* (do 15%) i *Brachysporium* (do 4%) su najbrojnije, a slijede ih *Glomus* i *Diporotheca webbiae*. Alge ne premašuju 1%, baš kao ni okućene amebe (sl. 3b; 4).

Zona 2 (45–5 cm, 647–13 cal BP ili od početka 14. do sredine 20. stoljeća) može se opisati kao zona „trave-grab/hrastovi" (sl. 3a; 4). Kodominantan travama (17%, do 19%) je grab (16%, do 24%) čija je vrijednost izrazito visoka od kasnog 17. do sredine 20. stoljeća. Pokrovnošću u šumskom pokrovu ističu se hrastovi (12%, do 19%) i bukva (12%, do 18%). Udio lijeske blago se povećava duž ove zone (10%), udio johe ostaje gotovo isti (6%), a orah (*Juglans*) po prvi puta prelazi 1% udjela (do 2%). Također, za ovu zonu karakteristična je pojava primarnih antropogenih indikatora – pelud žitarica pojavljuje se krajem 14. stoljeća, a značajnim udjelima ističu se brojni sekundarni antropogeni indikatori: dikica – *Xanthium spinosa* tip (5%, do 8%), trputac – *Plantago lanceolata* tip (1%, do 3%), kamilica – *Matricaria* tip (1%, do 2%). Pelud lobodnjača (Chenopodiacae) također je po prvi puta zastupljena kontinuiranom krivuljom. Prosječna vrijednost AP-NAP omjera iznosi 71%, a udio antropogenih indikatora varira između 5% i 10%. Peludno bogatstvo je značajno veće nego u prethodnim podzonama i varira od 16 do 32 palinološke vrste. Pougljenjene čestice su umjereno brojne, s kontinuiranim padom od sredine 17. stoljeća nadalje (sl. 3a–b; 4). Udio pougljenjenih mikročestica, koji na početku ove zone iznosi 40%, u razdoblju od vrlo kasnoga 17. do početka 20. stoljeća pada na manje od 10%. Isti oblik krivulje karakterističan je za pougljenjene makročestice koje u potpunosti nedostaju u poduzorcima iz druge polovice 15. stoljeća. Takva situacija traje sljedećih stotinu godina. Ukupna koncentracija pougljenjenih čestica prati trend udjela mikročestica/makročestica te se kreće od 7,8 mm^2 cm^{-3} u donjem dijelu, do svega 2 mm^2 cm^{-3} u vršnome dijelu zone.

Od tipičih cretnih i/ili močvarnih svojti (sl. 3b; 4) šaševi (Cyperaceae) su najbrojniji, s naglim povećanjem udjela početkom ove zone koji ostaje izrazito visok sve do kraja analizirane sekvence jezgre (prosječno 35%, do 49%). Visokim prosječnim udjelima ističu se i mah tresetar (16%, do 49%) te paprati (7%, do 24%), međutim udjeli obiju palinoloških vrsta snažno se smanjuju, da bi u posljednja dva poduzorka njihovi omjeri pali ispod 3%. Od NPPa (sl. 3b; 4) okućene amebe roda *Assulina* (*A. muscorum* > *A. seminulum*) su najbrojnije te udjelom premašuju 6%, odnosno 3%. *Glomus* je najzastupljenija gljiva (do 2%), međutim kontinuirana krivulja prisutnosti ovoga roda u sedimentu jezgre prekinuta je krajem 14. i početkom 15. stoljeća. Od struktura nepoznatoga porijekla, odnosno nejasne taksonomske pripadnosti, HdV 932 i HdV 731 su najbrojniji (do 2%).

4. DISCUSSION

The core sequence between the depths of 95 and 5 cm covers the period from the 2nd to the 20th centuries AD. As most of this period is characterised by almost complete lack of literature data about environment, there is no possibilities to compare written sources with pollen spectrum. Nevertheless, there are studies which show good correlation between vegetation data expressed as pollen equivalents and pollen in modern surface samples (Hjelle 1997; 1999) which also support comparison of vegetation data with accumulated pollen assemblage (Wei et al. 2011; Natlandsmyr, Hjelle 2016). Below, changes in vegetation, fire history and hydrological regime will be presented for each of three palynological (sub)zones and compared with data from broader Europe area.

4.1. VEGETION, FIRE AND HYDROLOGY CHANGES DURING LATE ANTIQUITY AND BEGINNING OF EARLY MIDDLE AGES – 2ND TO 7TH CENTURY

The core sequence between the depths of 95 to 75 cm covers five hundred years long period in which Roman, Avar and Slavic influences alternated, among others. Rise of non-arboreal pollen percentages and charcoal ratio and concentrations are observed during Migration Period (from 4th century till the end of this subzone).

4.1.1. Regional Vegetation Changes

The highest values of beech and fir pollen, comparing their curves throughout analysed core, suggested well developed natural beech-fir forests on the neighboring mountains (eg. Petrova gora, or Zrinska gora respectively). After beech, the second most abundant tree was oak, followed by hornbeam. Oaks and hornbeam formed stands probably closer to the study site. Changes in forest cover are manifested through a slight decline of beech and hornbeam pollen in the 3rd century, after which both taxa fluctuated insignificantly. Contrary, a slight continuous increase of oak pollen is complemented by a sharp increase of grasses pollen. Their low value during the 2nd century (~3%) was replaced by high values during the 5th and 6th centuries (~18%), simultaneously with a sharp increase in local and regional charcoal particles. Fire can positively have affected oaks (Jamrichová et al. 2017), which prosper under grazing activity (Olff et al. 1999) or are favoured by humans due to acorn production, important for pig husbandry (Rackham 2003). Moreover, only in the upper part of this (sub)zone birch, a pioneer tree (Jamrichová et al. 2012) reaches 3%. Still, the value for hazel stays constant. So fire occurrence can be linked to minor fluctuations in the tree cover only restrictedly. It is more likely that fire affected alder stands causing their decrease, even *Alnus* is a medium flammable tree (Xanthopoulos et al. 2012: 86) and combustion on study site maintenance increases of non-arboreal pollen with a domination of grasses pollen. On the other hand, changes in economic activity during this (sub)zone affected the

4. RASPRAVA

Odsječak sedimenta jezgre dubine od 95 do 5 cm obuhvaća povijesno razdoblje od 2. do 20. stoljeća. Glavninu ovoga razdoblja karakterizira odsustvo literaturnih zapisa o okolišu tako da najčešće ne postoje mogućnosti usporedbe pisanih izvora s peludnim spektrom akumuliranim u tresetnom sedimentu. Ipak, postoje studije koje pokazuju dobru korelaciju podataka o vegetaciji izraženih kao ekvivalenti akumuliranoga peluda i recentnoga peludanog spektra uzorkovanoga s površine sedimenta (Hjelle 1997; 1999), što dodatno ohrabruje utemeljenost opisa vegetacijskih promjena na osnovi akumuliranoga peludnog spektra (Wei et al. 2011; Natlandsmyr, Hjelle 2016). U nastavku slijedi prikaz vegetacijskih promjena, povijesti požara i hidrološkoga režima za svaku od tri palinološke (pod)zone kao i njihova usporedba sa situacijom na širem području Europe.

4.1. VEGETACIJA, POŽARI I HIDROLOGIJA TIJEKOM KASNE ANTIKE I POČETKOM RANOGA SREDNJEG VIJEKA – OD 2. DO 7. STOLJEĆA

Sekvenca jezgre dubina od 95 do 75 cm obuhvaća petsto godina dugo razdoblje u kojem su se, između ostalih, izmjenjivali rimski, avarski i slavenski utjecaji. Porast udjela peluda nedrvenastih vrsta kao i omjera i koncentracije pougljenjenih čestica primjećuju se od početka razdoblja Seobe naroda (~ 4. stoljeće pa do kraja ove podzone).

4.1.1. Regionalne vegetacijske promjene

Najviša vrijednost peluda bukve i jele, uspoređujući njihove krivulje duž cijele analizirane jezgre, ukazuje na dobro razvijene prirodne sastojine šuma ovih dviju svojti na gorskim masivima nedaleko creta (npr. Petrova gora, odnosno udaljenija Zrinska gora). Nakon bukve, najzastupljeniji su hrastovi, a potom grab, vrste čije su sastojine s većom pokrovnošću vjerojatno prisutne uz samo cretno lice. Promjene u šumskome pokrovu očituju se blagim padom udjela peluda bukve i graba u 3. stoljeću, nakon čega njihove vrijednosti ne fluktuiraju značajno. Suprotno tome, blago kontinuirano povećanje udjela peluda hrasta nadopunjeno je naglim porastom udjela peluda trava. Niske vrijednost peluda trava tijekom 2. stoljeća (~3%) u 5. i 6. stoljeću postižu visoke vrijednosti (~18%), istovremeno sa značajnim povećanjem broja pougljenjenih mikro- i makročestica, tj. regionalnih i lokalnih indikatora požarnih aktivnosti. Vatra može pozitivno utjecati na sastojine hrastova (Jamrichová et al. 2017) koji prosperiraju pod režimom ispaše (Olff et al. 1999) ili su pak favorizirani od strane ljudi uslijed prikupljanja žira, namirnice važne u svinjogojstvu (Rackham 2003). Štoviše, samo u vršnim poduzorcima ove (pod)zone breze, kao pionirska stabla (Jamrichová et al. 2012), dostižu 3%. Za razliku od breze, vrijednosti udjela lijeske ostaju iste tako da se samo na ograničen način pojava požara može dovesti u vezu s promjenama u pokrovnosti drvenastih vrsta. Vjerojatnije je vatra lokalno zahvatila jošike uzrokujući smanjenje udjela johe, premda je *Alnus* umjereno zapaljivo stablo (Xanthopoulos et al. 2012: 86). Izgaranje drveća odrazilo se pozitivno na povećanje udjela peluda nedrvenastih vrsta, s occurrence of secondary anthropogenic indicators and will be discussed later in this text.

4.1.2. The Role of Alder and Local Fire History

To understand the hydrological regime of an area, the knowledge of the plant ecology is crucial (eg. Brown et al. 2009: 564; Tiner 2009: 778–789). On the study area, according to fossil pollen spectrum, the dominant arboreal vegetation during the Late Antiquity was alder (*Alnus*). This tree grows in marshy areas, on wet or waterlogged, mostly acidic soils (Lakušić 1989: 90) periodically flooded during the spring. Sometimes the water table remains close to the surface even in the summer (Sburlino et al. 2011). In this way, alder indicates a moisture conditions. Position of alder in the pollen spectrum is ambiguous when we talk about its prevalence (local vs. regional) and relatively (wetness level) when used as an indicator of soil humidity. Due to its pollination strategy, it would be expected that alder is a regional vegetation element. Contrary, as a wetland taxon, its range is limited to wet or flooded riparian (sub)zone. The geomorphology of the study area – steep hills that surround the mire surface in three directions – indicates its local character, however the small river Čemernica in the eastern part of the mire site offers an expansion corridor for this taxon. So *Alnus* can cover a wider area within the Topusko district. Having that in mind, this tree is more extralocal than being only a species with local occurance and importance. Despite of this, alder can't be competitive on the dry soil slopes which are surrounding the Blatuša mire. Moreover, its presence on the peatland is also indicated by occurrence of some specific non-pollen palynomorphs, like fungal spores of *Diporotheca webbiae* (HdV 143) and *Brachysporium* (HdV 360), mostly connected with peatbogs dominated by alder (van Geel et al. 1989; Barthelmes et al. 2006; Prager et al. 2006; Cugny et al. 2010). The presence of the mentioned fungi indicates that the mire surface was overgrown by an arboreal vegetation. Due to the relative or absolute dominance of arboreal remains in peat formation, together with the occurences of fungal spores, this part of the core can be atributed as alder carr. Although in this (sub)zone alder pollen reached the highest values, a sharp decline of *Alnus* (from 46% to 13%) was observed during the 5th and the 6th centuries. A similar decrease in the proportion of alder was observed in some parts of Poland during the same period (Wacnik et al. 2012), and later, from the 9th to the 10th century on a much broader scale in Europe (Latałowa et al. 2019). Alder decline is usually caused by anthropogenic activity, eg. clearance for livestock grazing, hay mowing or using trees for firewood (Natlandsmyr, Hjelle 2016). Moreover, in our case decline of alder coincides with a strong increase of charcoal particles in the survey area. Damblon (1992) already stated that burning accelerated the recession of *Alnus* while the opening of the alder woodland favoured the flowering and expansion of other plants, grasses among others. Even fire frequency rises during dry phases of mire development

dominacijom peluda trava. S druge strane, promjene gospodarskih aktivnosti tijekom ove (pod)zone utjecale su na pojavu određenih sekundarnih antropogenih indikatora, što će biti dodatno raspravljeno u nastavku.

4.1.2. Uloga johe i lokalna povijest požara

Za razumijevanje hidrološkoga režima na nekom području bitno je poznavati ekologiju biljaka (npr. Brown et al. 2009: 564; Tiner 2009: 778–789). Na području istraživanja, tijekom kasne antike joha (*Alnus* cf. *glutinosa*) je prevladavajuća vrsta u vegetaciji, sudeći prema akumuliranom peludnom spektru. Ova vrsta raste u močvarnim područjima, na vlažnim i plavljenim, uglavnom kiselim tlima (Lakušić 1989: 90). Nerijetko se na staništima voda zadržava tijekom čitavoga proljeća, a vodno lice ostaje blizu površine tla čak i ljeti (Sburlino et al. 2011). Iz toga razloga prisustvo johe ukazuje na pojačanu vlažnost tla. Položaj johe u peludnom spektru je dvojak kada govorimo o njenoj rasprostranjenosti (lokalna ili regionalna svojta) te relativan (stupanj vlažnosti) kada se koristi kao pokazatelj mokrine tla. Naime, kao anemofilna (oprašivanje vjetrom) svojta, očekivalo bi se da je joha regionalni vegetacijski element. Nasuprot tome jošici, kao azonalna vegetacija, konkurentni su i ograničeni na područja vlažnih i plavljenih tla. Geomorfologija istraživanoga područja – strmi brežuljuljci okružuju površinu creta s tri strane – ukazuje na lokalni karakter johe. Međutim, mala rijeka Čemernica, koja protječe istočnom dijelom creta, otvara koridor za širenje ove drvenaste vrste na znatno veće područje. Zapravo, glavnina nizinskoga područja Topuskog pruža prikladne hidrološke uvjete za rast johe. Imajući to na umu, na istraživanome području ovo stablo je više od ekstralokalnoga značaja nego što ga možemo smatrati samo lokalnom pojavom ili vrstom od lokalnoga značaja. Kako joha ne može nastavati suhe strme padinama koje okružuju cret u Blatuši, a udjeli peluda johe su izrazito visoki, za pretpostaviti je pojavljivanje stabala johe na samom cretu. Uostalom, pojava johe na tresetištu je naznačena prisustvom nekih specifičnih nepeludnih palinomorfa, kao spora gljive *Diporotheca webbiae* (HdV 143) i *Brachysporium* (HdV 360), koje se uglavnom pronalaze u drvenastom tresetu porijeklom od johe (van Geel et al. 1989; Barthelmes et al. 2006; Prager et al. 2006; Cugny et al. 2010). Prisutnost spomenutih gljivica svakako ukazuje da je površina creta bila prorasla drvenastom vegetacijom. Uslijed relativne dominacije drvenastih ostataka u trsetu, nadopunjene pojavom spora saprofitskih gljiva, ovaj se dio jezgre može atributirati kao cretni jošik. Iako je u ovoj (pod)zoni pelud johe dosegao najviše vrijednosti, nagli pad udjela iste (s 46% na 13%) primijećen je tijekom 5. i 6. stoljeća. Sličan drastični pad johe u istom razdoblju primjećen je u nekim dijelovima Poljske (Wacnik et al. 2012) ili pak kasnije, od 9. do 10. stoljeća, diljem europskoga kontinenta (Latałowa et al. 2019). Smanjenje udjela johe obično je uzrokovano antropogenom aktivnošću, npr. sječom kako bi se oslobodile dodatne površine tla za ispašu stoke, formiranje livada košanica ili jednostavno uslijed prikupljanja drvne mase za ogrjev (Natlandsmyr, Hjelle 2016). Štoviše, smanjenje jošika podudara se s istovremenim značajnim

(Sillasoo et al. 2007; 2011; Tuittila et al. 2007; Väliranta et al. 2007; Morris et al. 2015), non-pollen palynomorphs on our study site indicated wetter conditions during most of this (sub)zone. In our case it is more likely that higher moisture level, than dryness, together with fire events, caused the alder decline. At the end of the 4th and the beginning of the 5th century, colder winters, which swept Europe, reached even Byzantine territory (Sedov 2012: 417) and frozen water could sustain tree damage, by mechanical and/or biological patogen. Summer flooding and/or persistent stagnant water can have negative effects on *Alnus* stands, due to anoxia or fungal diseases (Bjelke et al. 2016) which support transition from alder carr to mosaic of wetland and mire habitat. Besides, Pyne et al. (1996) found that low intensity fires (low heat release per unit time) produce a significant amount of particles due to their low combustion efficiency which can explain its high value in our subsamples during this historical period. Moreover, in some other studies charcoal particles reached higher value during wet phase (Sillasoo et al. 2007, Marcsiz et al. 2017).

4.1.3. Environmental Changes on the Mire Surface

Decrease in the share of alder through the upper part of this (sub)zone corresponds to an increase of *Typha* (short lasting peak), accompanied by continuously step-by-step increase of grasses pollen and *Sphagnum* spores. These changes are probably caused by fire events and fluctuation in moisture level. Väliranta et al. (2007) explain how fires can lead to soil deterioration by altering moisture conditions: by changing local evapotranspiration and run-off regimes which results in a general rise in water level and/or deep combustion of the dry bog surface layer can lead to a local hollow formation. It is possible that depression formed by fire was suddenly occupied by reed mace and some local grasses, probably *Molinia* or *Phragmites*, as increased nutrient availability caused by fire led to dominance of highly productive graminoids in different mire types (Curtis 1959; van Diggelen et al. 2015). The presence of reed mace suggests higher wetness on the mire surface (Stivrins et al. 2014), with a water depth of a half meter or deeper (Klosowski, Jablonska 2009; Šumberová, 2011: 401–405). However, this species can tolerate summer drought (Šumberová, 2011a: 401–405).

Colder and wetter conditions during the Late Antiquity and/or Migration Period are recorded by several authors in Europe (Magny 2004; Büntgen et al. 2011; Galka et al. 2017a). However, the observed changes in vegetation in our case do not allow making inferentions about temperature changes. Despite of this, the presence of *Amphitrema flavum* (*Archerella flavum*) and *Assulina seminulum* in the study site indicates a low nutrient level characteristic for drier poor fans (van Geel et al. 1989) dominated by *Sphagnum* (Mazei, Tsyganov 2007). Nevertheless, these two thecamoebae could indicate a rise in the water table on the mire (Kołaczek et al. 2010). Moreover, *Amphitrema flavum* indicates wet condi-

povećanjem udjela pougljenjenih čestica na području istraživanja. Damblon (1992) je utvrdio da opožarivanje izaziva gubitak johe na staništu, što pogoduje širenju i cvatnji drugih biljaka, trava među ostalih. Iako je učestalost pojave požara izraženija tijekom suhe faze razvoja creta (Sillasoo et al. 2007; 2011; Tuittilaet al. 2007; Väliranta et al. 2007; Morris et al. 2015), akumulirani nepeludni palinomorfi naznačuju vlažnije uvjete tijekom glavnine ove (sub)zone. Čini se vjerojatnijim da je na području istraživanja pojačana vlažnost, a ne suša, zajedno s opožarivanjem, uzrokovala značajno lokalo smanjenje sastojina johe. Krajem 4. i početkom 5. stoljeća hladnije zime koje su okovale Europu dosegnule su čak i bizantski teritorij (Sedov 2012: 417) te je smrznuta voda mogla pridonijeti mehaničkom oštećenju stabala koja tako postaju podložnija biološkim patogenima. Ljetne poplave i/ili dugotrajna stagnacija vode pak mogu negativno utjecati i na ovu, močvarnim staništima dobro prilagođenu vrstu uslijed anoksije ili gljivičnih oboljenja (Bjelke et al. 2016), što je zasigurno pospješilo prijelaz iz johom obrasloga tresetišta u mozaik cretne i močvarne vegetacije. Osim toga, Pyne et al. (1996) pokazali su kako požari niskoga intenziteta (nisko oslobađanje topline po jedinici vremena) proizvode značajnu količinu pougljenjenih čestica zbog niske učinkovitosti sagorijevanja organskoga materijala, što vjerojatno objašnjava visoku brojnost indikatora požara tijekom ovoga povijesnog razdoblja.

4.1.3. Lokalne promjene okoliša na području samoga creta

Pad udjela johe u gornjem dijelu ove (pod)zone podudara se s povećanjem udjela rogoza (kratkotrajni maksimum), zajedno s kontinuiranim graduiranim povećanjem udjela peluda trava i spora maha tresetara. Te su promjene vjerojatno uzrokovane požarima i promjenama u zasićenosti supstrata vodom. Väliranta et al. (2007) objašnjavaju kako požari mogu dovesti do degradacije kvalitete tla promjenom uvjeta vlažnosti: izmjenom lokalnoga režima evapotranspiracije i režima otjecanja, što rezultira općim porastom razine vode, i/ili dubokim izgaranjem površinskoga sloja treseta, što dovodi do formiranja površinskih udubljenja. Dakle, uslijed jakih požara izgledno je da će se nastale depresije ispuniti vodom koje nastavaju sastojine rogoza ili pak trava poput beskoljenke (*Molinia*) ili trske (*Phragmites*), uostalom i zato što povećana dostupnost hranjivih tvari, oslobođenih izgaranjem, potiče dominaciju visoko produktivnih trava, šaševa ili sitova u različitim tipovima cretova (Curtis 1959; van Diggelen et al. 2015). Prisutnost rogoza na istraživanome području upućuje na povećanu zasićenost supstrata vodom (Stivrins et al. 2014) ili na pojavu stagnirajuće vode, nerijetko sa stupcem dubine od pola metra ili više (Klosowski, Jablonska 2009; Šumberová, 2011: 401–405). Istovremeno, ova vrsta podnosi i ljetno isušivanje tla (Šumberová, 2011a: 401–405).

Hladniji i vlažniji uvjeti tijekom kasne antike i/ili Seobe naroda zabilježeni su od strane nekoliko autora u Europi (Magny 2004; Büntgenet al. 2011; Galka et al. 2017). Međutim, promjene vegetacije u našem slučaju ne dozvoljavaju tions (Schnitchen et al. 2003; Lamentowicz et al. 2007; Fiłoc, Kupryjanowicz 2015) and is abundant in high humidity and oligotrophic environments (Beyens, Meisterfeld 2001; Mitchell et al. 2001; Lamenowitz, Obremska 2010). A slight increase of *Sphagnum* is followed by the occurrence of *A. flavum*, a characteristic amoeba of young *Sphagnum* peat (Fiłoc, Kupryjanowicz 2015). The presence of *Zygnema* and *Spirogyra* additionaly confirmed the prevalence of moist conditions (Feeser, O'Connell 2009; Feeser, O'Connell 2010; Riera et al. 2006) and stagnant waters (van Geel et al. 1989), as was the case with HdV 179 (van Geel et al. 1989; Wolowski 1998) and Copepoda spermatophore (van Geel 1978; Eisner, Peterson 1998: 245–248; López-Merino et al. 2011). However, while HdV 16 usually occurs in wet environments (Pędziszewska, Latałowa 2016) it still avoida areas with a relatively high water-table (van Geel 1978; López-Merino et al. 2011). Contrary, a sharp decline or occasional occurrence of the mentioned NPPs, together with the occurrence of *Pseudoschizaea* in late the 6th or the begining of the 7th century, indicates seasonal droughts (Scott 1992). All this indicates a fluctuation in lavel through this (sub)zone. Even some NPPs and *Sphagnum* are good indicators of oligotrophy, meso-eutrophic indicators prevailed, eg. *Spirogyra* (van Geel, van der Hammen 1978; Pals et al. 1980; van Geel et al. 1980; 1989; Bakker, van Smeerdijk 1982; Kuhry 1997), *Zygnema* (van Geel, van der Hammen 1978; van Geel et al. 1980; Kuhry 1997; Lôpez-Sâez et al. 1998) and HdV 179 (van Geel et al. 1989; Kuhry 1997), Copepoda spermatophores or HdV 28 (van Geel 1978, Eisner, Peterson 1998: 245–248), *Diporotheca webbiae* or HdV 143 (van der Woude 1983; van Geel et al. 1986) followed by vascular plants like alder, reed mace, grasses and ferns (Šumberová 2011a: 401–405; 2011b: 405–409; Slezák et al. 2014), highlighting in the same time a mosaic of different trophic conditions from micro-site olygotrophic to, probably, more meso-eutrophic conditions on the broader mire area.

Fluctuations in moisture levels is mostly linked to higher amounts of precipitation (rain and snow), but some other factors like animal behaviour, eg. action of beavers (*Castor* spp.), may have influenced local hydrology as well (Pollock et al. 1995: 117–126). So, animal and/or human impact, together with climate changes, could also lead to wetter conditions during the most of this (sub)zone but also support changes of moisture level on studied site. All this speaks in favor of how complex is, based just on the results from the pollen diagram, to interpret the hydrological regime.

4.1.4. Human Impact and Regional Fire History

The share of NAP value increased from the 7% in the 2nd century to the 20% during the first half of the 7th century. This can be either result of autogenous processes on mire/wetland surface or anthropogenic pressure on surrounding forest cover or alder stands. The average AP-NAP value during this (sub)zone is a little bit lower than expected for forest dominaned areas. However, the lack of primary ant-

donošenje zaključka o temperaturnim kretanjima. Prisutnost ameba *Amphitrema flavum* (*Archerella flavum*) i *Assulina seminulum* u sedimentu creta ukazuje na nisku razinu hranjivih tvari karakterističnih za suše, minerotrofne cretove siromašne nutrijentima (van Geel et al. 1989) s prevlašću maha tresetara (Mazei, Tsyganov 2007). Ipak, spomenute okućene mogu indicirati porast vodnoga lica na tresetištu (Kołaczek et al. 2010). Štoviše, *Amphitrema flavum* upućuje na naglašenu mokrinu sedimenta (Schnitchen et al. 2003; Lamentowicz et al. 2007; Fiłoc, Kupryjanowicz 2015) te je ta vrsta brojna u uvjetima pojačane vlažnosti i oligotrofije (Beyens, Meisterfeld 2001; Mitchellet al. 2001; Lamenowitz, Obremska 2010). Blagi porast udjela spora roda *Sphagnum* nadopunjuje pojava *A. flavum*, amebe karakteristične za mladi treset porijeklom od maha tresetara (Fiłoc, Kupryjanowicz 2015). Pojava algi, npr. *Zygnema* i *Spirogyra* dodatno potvrđuju zasićenost sedimenta vodom (Feeser, O'Connell 2009; Feeser, O'Connell 2010; Riera et al. 2006) ili stajaću vodu na staništu (van Geel et al. 1989), čemu u prilog govori pojava HdV 179 (van Geel et al. 1989; Wolowski 1998) i spermatofora kopepodnih rakova (van Geel 1978; Eisner, Peterson 1998: 245–248; López-Merino et al. 2011). I HdV 16 se obično javlja u uvjetima pojačane vlažnosti (Pędziszewska, Latałowa 2016), premda izbjegava relativno visok vodni stupac (van Geel 1978; López-Merino et al. 2011). Nasuprot tome, značajna fluktuacija u brojnosti spomenutih nepeludnih palinomorfa, tj. nagli pad njihove učestalosti u pojedinim poduzorcima, zajedno s pojavom *Pseudoschizaea* krajem 6. ili početkom 7. stoljeća, ukazuju na sezonalnu sušu (Scott 1992). Čini se da ovu (pod)zonu karakterizira značajno kolebanje hidrološkoga režima. Iako su određeni NPP-ovi i *Sphagnum* dobri pokazatelji oligotrofije, mezo-eutrofni indikatori prevladavaju, npr. *Spirogyra* (van Geel, van der Hammen 1978; Pals et al. 1980; van Geel et al. 1980; 1989; Bakker, van Smeerdijk 1982; Kuhry 1997), *Zygnema* (van Geel, van der Hammen 1978; van Geel et al. 1980; Kuhry 1997; Lôpez-Sâez et al. 1998) i HdV 179 (van Geel et al. 1989; Kuhry 1997), spermatofori kopepodnih rakova ili HdV 28 (van Geel 1978, Eisner, Peterson 1998: 245–248), *Diporotheca webbiae* ili HdV 143 (van der Woude 1983; van Geel et al. 1986), odreda praćeni pojavom vaskularnih biljaka poput johe, rogoza, trava ili paprati (Šumberová 2011a: 401–405; 2011b: 405–409; Slezák et al. 2014). Sve navedeno naglašava lokalnu mozaičnost trofičkih stanja u rasponu od oligotrofije, vjerojatno na samome području uzorkovanja jezgre, do mezo-eutrofije na širem području ili rubnom dijelu creta.

Fluktuacija razine vlažnosti uglavnom je povezana s većom količinom padalina (kiša i snijeg), ali neki drugi čimbenici, poput ponašanja nekih životinjskih vrsta, npr. djelovanje dabrova na vodotokove (*Castor* spp.), mogu značajno utjecati na lokalne hidrološke prilike (Pollock et al. 1995: 117–126). Dakle, životinjski i/ili ljudski utjecaj, uz klimatske promjene, mogao je dovesti do izraženije vlažnosti supstrata tijekom većega dijela ove (pod)zone, ali ujedno i pospješiti izmjenu vlažnijih i suših faza na uzorkovanome području. Sve to govori u prilog tvrdnji koliko je otežano, samo na temelju rezultata peludnog dijagrama, tumačiti hidrološki režim.

hropogenic indicators and a very low proportion of secondary anthropogenic indicators do not allow us to confirm agriculture or livestock farming activities on the study site. Although pollen and NPPs do not reflect strong or even moderate anthropogenic pressure, a rise of NAP types simultaneously with a sharp increasing value of charcoal particles are less probable result of natural circumstances. Lightening during storm causes natural fires (eg. Franzen, Malmgren 2012; Marcisz et al. 2017). However, it is not likely that less flammable deciduous trees (Dietze et al. 2018), as fire prone conifer taxa were not abundant on study site, were combusted frequently or significantly contributed to charcoal curve without human impact; even charcoal particles originating from grasses or herbs can't be excluded. On the other hand, iron metallurgy was well developed in the Topusko area, within a radius of five to seven kilometers from the study site, confirmed by the finds of pottery kilns at this site (Škiljan 2007: 96–97). Mining and metallurgical activities were maintained during the Illyrian-Celtic and Roman periods, thanks to the metal ore deposits on mountains Petrova (Škiljan 2006: 97; Lazić et al. 2010: 62) and Zrinska gora (Lazić et al. 2010: 62). This may probably partly explain the significant occurrence of peat-accumulated charcoal particles. Colapians, mixture of indigenous and Celtic people who inhabited Kordun from the Early Iron Age (Škiljan 2007: 5), were engaged in metallurgy, and animal husbandry was the main economic branch. Goats and sheep were most common livestock, although the remains of pigs and cattle were found accompanied with deer remains, animal often hunted by Colopians (Škiljan 2007: 96–97). The Roman government supported the existing economic activity, however their influence failed earlier or during the late 6th century when Avars and Slavic tribes occupied Siscia (Škiljan 2007: 7), the capital city of Pannonia Savia (Škiljan 2008: 6).

Vegetation underground layers presented by ferns (Polypodiales) are mainly suppressed by disturbance (Ryan, Blackford 2010) and their high proportion indicates low grazing pressure (Natlandsmyr, Hjelle 2016) directly on the study site. Moreover, a complete lack of coprophilous fungal spores (Sordariaceae), which are good indicators of grazing animals (Cook et al. 2011; Krug et al. 2004), speak in favour of more natural than seminatural circumstances on mire surface. The transition of power between the Romanized people and the arriving Avars and Slavs is not entirely clear. However, archaeological finds speak of the continuity of life in Sisak during the 6th and the 7th century (Škiljan 2008: 7). This period which corresponds to the end of (sub)Zone 1a is marked by the first peak of charcoal particles, however without dramatic change in vegetation cover but with lack of some secondary anthropogenic indicators. Fire occurrence maybe sustained the weak birch expansion on the site and transition to the next (sub)Zone 1b is marked by peak of grasses pollen.

4.1.4. Utjecaj čovjeka i regionalna povijest požara

Udio vrijednosti peluda nedrvenastih vrsta (NAP) povećao se sa 7% u 2. stoljeću na 20% tijekom prve polovice 7. stoljeća. To je posljedica autogenih procesa na površini samog creta ili antropogenog pritiska na okolni šumski pokrov ili sastojine johe. Prosječna vrijednost AP-NAP omjera tijekom ove (sub)zone malo je niža od očekivane za područje nastavano dominantno drvenastom vegetacijom. Međutim, nedostatak primarnih antropogenih indikatora i vrlo nizak udio sekundarnih antropogenih indikatora ne dopuštaju nam zaključiti da se na istraživanom području odvijala zamjetna ratarska ili stočarske djelatnost. Iako niti peludni spektar niti nepeludni palinomorfi ne ukazuju na značajniji antropogeni pritisak, rast udjela peluda nedrvenastih vrsta, uz istovremeno naglo povećanjem udjela pougljenjenih čestica, vjerojatno nisu rezultat samo prirodnih čimbenika. Iako olujne munje uzrokuju prirodne požare (npr. Franzen, Malmgren 2012; Marcisz et al. 2017), nije vjerojatno da su teže zapaljiva listopadna stabla (Dietze et al. 2018), s obzirom da četinjače nisu s većom brojnošću zastupljene u biljnom pokrovu, učestalo gorjela ili da su mogla značajno doprinijeti povećanom udjelu pougljenjenih čestica bez uplitanja čovjeka. Iako se mogući doprinos zeljastih biljaka, napose trava, ukupnom broju pogljenjenih čestica ne može isključiti. S druge strane, metalurgija željeza dobro je razvijena na širem području Topuskog, a u polumjeru od pet do sedam kilometara, gledano od mjesta uzorkovanja jezgre, nađeni su dijelovi keramičkih peći (Škiljan 2007: 96–97). Rudarstvo i metalurgija bitne su gopodarske grane kako u ilirsko-keltskom tako i u rimskom razdoblju zahvaljujući obilju metalne rude na obližnjoj Petrovoj gori (Škiljan 2006: 97; Lazić et al. 2010: 62) ili nešto udaljenijoj Zrinskoj gori (Lazić et al. 2010: 62). To vjerojatno djelomično objašnjava značajnu pojavu pougljenjenih čestica akumuliranih u sedimentu jezgre. Kolapijani, mješavina starosjedilačkoga stanovništva i Kelta, naseljavali su područje Korduna od ranoga željeznog doba (Škiljan 2007: 5) baveći se metalurgijom, premda je stočarstvo bila njihova glavna gospodarska grana. Ovce i koze činili su osnovu stočnoga fonda, međutim pronađeni su ostaci svinja i goveda te skeleta jelena koje su rado lovili (Škiljan 2007: 96–97). Dolaskom Rimljana održava se zateknuta postojeća gospodarska aktivnost, međutim njihov utjecaj slabi tijekom kasnoga 6. stoljeća ili nešto ranije kada Avari i Slaveni zauzimaju Sisciju (Škiljan 2007: 7), glavni grad provincije Panonije Savije (Škiljan 2008: 6).

Na istraživanome području prizemni sloj rašća predstavljen je papratima (Polypodiales) za koje je utvrđeno da im se pokrovnost smanjuje uslijed disturbancije (Ryan, Blackford 2010) te njihov visok udio na cretu indicira nisku razinu ispaše (Natlandsmyr, Hjelle 2016). Štoviše, potpuni nedostatak spora koprofilnih gljiva (Sordariaceae) koje su inače dobri pokazatelji ispaše životinja na nekom području (Cook et al. 2011; Krug et al. 2004), govori više u prilog prirodnoga nego poluprirodnoga stanja okoliša. Iako prijenos vlasti između romaniziranoga stanovništa i novopridošlih Avara i Slavena nije posve jasan, arheološki nalazi govore o kontinuitetu života u Sisku tijekom 6. i 7. stoljeća (Škiljan 2008: 7). Ovo razdoblje, koje odgovara kraju (pod)Zone 1a, obilježeno je prvim maksimumom udjela pougljenjenih čestica, istovremeno bez dra-

To conclude, a lack of primary anthropogenic indicator during these five hundred years probably is linked to weakly developed agronomy during pre-Roman, short-lived Roman presence and the just-beginning of Avar-Slavic period. Secondary anthropogenic indicators, even presented by low percentages, probably point to extensive livestock on the broader study site till the 5th century. However, the lack of Urticaceae and Chenopodiaceae pollen, accompanied by *Polygonum persicaria* type and *Matricaria* type, from the very late 4th or beginning of 5th century, probably reflect the change in the economic and political stability linked to the collapse of the Western Roman Empire and beginning of the Migration period.

4.2. VEGETATION, FIRE AND HIDROLOGY CHANGES DURING EARLY AND HIGH MIDDLE AGES – 7TH TO 13TH CENTURY

The core sequence between the depths of 75 to 45 cm covers period from the mid of 7th do the end of the 13th century. During these seven hundred years Central Croatia was under different influences: Ostrogoths, Langobards, Avars, Franks, Croats, Hungarians, with short lasting Mongol invasion (Goldstein 2008; Gračanin 2011). However, their impact on vegetation is still questionable. Even the political history of that period is to some extent known, there is a complete lack of information about the natural environmental conditions and only a few pieces of information about economy are available. This part of the core segment is characterised by great changes in the ratio between arboreal and non-arboreal pollen which could indicate human impact on plant cover. For the first time some groups of non-arboreal pollen types become relatively dominant – increased proportion of grasses during previous period turned to their relative dominance during the end of Migration Period and later.

4.2.1. The Regional Vegetation Changes and Regional Fire History

In the forest cover, beech and oak stay dominant, like in the previous (sub)Zone 1a. However, a strong fluctuation of beech is observed, with slight changes of other proportions in tree abundance. This is accompanied by the greatest ratio and concentrations of charcoal particles through the whole core. The lowest value of beech in the 10th and beginning of the 11th century is followed by a slight decrease of fir, spruce and oak, although the latter one is light demanding (Aas 2002a; 2002b; Eaton et al. 2016) and its increase would be expected. Beech saplings reached an optimum growth at 10% of above-canopy light (Ligot et al. 2013) and can even survive on only 2% of the sunlight for a period of five years (Peters 1997). However, Ligot et al. (2013) marked that after canopy opening, pre-existing beech trees benefited more from the increase of light availability than oak, and a succession of mixed beech-oak stands are directed to pure beech stands. At the same time, the occurrence of some discontinuously presented taxa, like walnuts (*Juglans*), birch

matične promjene u strukturi i sastavu vegetacije i uz izostanak određenih sekundarnih antropogenih indikatora. Pojava požara vjerojatno je potaknula slabu ekspanziju breza te je općenito kronološki prijelaz ka nadolazećoj (pod)Zoni 1b naznačen povećanjem udjela peluda trava.

Da zaključimo, nedostatak primarnih antropogenih indikatora tijekom razdoblja od petsto godina vjerojatno je povezan sa slabo razvijenom poljoprivrednom aktivnošću tijekom predrimskoga, zatim kratkotrajnoga rimskog i početka avarsko-slavenskoga razdoblja dominacije na području Korduna i Banovine. Iako zastupljeni nižim postotkom, određeni sekundarni antropogeni indikatori vjerojatno su rezultat ekstenzivnoga stočarenja u razdoblju što prethodi 5. stoljeću. Izostanak peluda iz porodica Urticaceae i Chenopodiaceae, uz istovremeno gubitak *Polygonum persicaria* tipa i *Matricaria* tipa od kasnoga 4. ili početka 5. stoljeća u peludnome dijagramu, vjerojatno odražava promjenu gospodarske i političke stabilnosti povezane s kolapsom Zapadnoga Rimskog Carstva i početkom razdoblja Seobe naroda.

4.2. VEGETACIJA, POŽARI I HIDROLOGIJA TIJEKOM RANOG I RAZVIJENOG SREDNJEG VIJEKA – OD 7. DO 13. STOLJEĆA

Odsječak sedimenta jezgre od 75 cm do 45 cm dubine obuhvaća povijesno razdoblje od sredine 7. do kraja 13. stoljeća. Tijekom ovih sedam stotina godina središnja Hrvatska bila je pod različitim utjecajima: Ostrogoti, Langobardi, Avari, Franci, Hrvati, Mađari, s kratkotrajnom mongolskom invazijom (Goldstein 2008; Gračanin 2011). Međutim, njihov utjecaj na vegetaciju je nepoznat. Bez obzira što je politička povijest toga razdoblja djelomično poznata, informacije o okolišu nedostaju, uz tek sporadične i djelomične informacije o gospodarskim aktivnostima. Za ovaj dio jezgre indikativna je značajna promjena u omjeru između arborealnog i nearborealnog peluda što bi moglo odražavati ljudski utjecaj na biljni pokrov. Po prvi puta neka grupa peluda nedrvenastih vrsta postaje relativno dominantna – tj. povećan udio trava u prethodnoj (pod)zoni postiže relativnu dominaciju tijekom Seobe naroda i kasnije.

4.2.1. Regionalne promjene vegetacije i regionalna povijest požara

U šumskom pokrovu bukva i hrastovi ostaju dominantni, kao u prethodnoj (pod)Zoni 1a. Međutim, opaža se izraženije fluktuiranje udjela bukve, uz neznatne promjene učestalosti drugih drvenastih vrsta. Istovremeno, omjeri i koncentracije pougljenjenih čestica najveći su upravo tijekom ovoga razdoblja. Najniže vrijednost bukve u 10. i početkom 11. stoljeća praćene su blagim smanjenjem udjela jele, smreke i hrastova, iako su potonji svjetloljubivi (Aas 2002a; 2002b; Eaton et al. 2016) te bi porast udjela peluda hrasta bila očekivana u navedenim okolnostima. Mladice bukve dosežu optimalni rast pri 10% svjetlosnoj zasićenosti (Ligot et al. 2013), a preživljavaju čak i ako u petogodišnjem razdoblju primaju svega 2% sunčeve svjetlosti (Peters 1997). Međutim, Ligot et al. (2013) utvrdili su kako otvaranje šumskoga sklopa više pogoduje konkurentnosti bukve nego svjetloand ash (*Fraxinus*) were noticed. In fact, the last two mentioned taxa are light demanding (Prpić 1974: 68) and probably prospered by opening the forest canopy due to reduction of conifers, oak and beech. Moreover, birch is also a pioneer (Jamrichova et al. 2012) and fireprone tree (Xanthopoulos et al. 2012), reaching the flowering stage in only several years (Jonsson 1949). The lowest value of hazel at the end of the 11th and beginning of the 12th century is synchronous with the highest peak of beech pollen.

Deep shade of *Fagus* dominated forests restricted the growth of hazel and some other taxa, as was suggested by Gardner (2002), with great impact on mostly light demanding hazel or oak (Aaby 1983; Rösch et al. 2014; Eaton et al. 2016). Surprisingly, the two peaks of charcoal particles don't correspond to maxima of *Corylus* and *Quercus*, although hazel is favored by fire (Tinner et al. 2000), and oak is a positively correlated (Jamrichova et al. 2017) or fire-indifferent taxon (Tinner et al. 2000). Feurdean et al. (2017) stressed that the proportion of more disturbance-adapted tree species, including *Pinus*, *Betula*, *Carpinus betulus* and *Corylus avellana* are expected to increase by fire events. It is interesting that from the 11th century to the end of (sub)Zone1b, beech continuously decreased, and oak pollen slightly increased in proportion, accompanied by an increased charcoal trend. The highest alder value during (sub)Zone 1b corresponds to the lowest value of beech. So it is also possible that oscillations in regional taxa abundance are influenced by very local occurrences or, close to the study site, developed stands of ash (*Fraxinus*) and alder trees, which are adapted to periodically swamped ground-water soils (Wacnik et al. 2016). Unfortunately, variations in the deposition of local and extralocal pollen of one taxon will result in reciprocal changes in the representation of all taxa in the pollen sum (Waller et al. 2017) which means that some caution is needed when pollen diagrams are interpreted.

Although beech seldomly survives mild fires (Berli 1996), its value stays high during the whole (sub)Zone 1b, despite the fact that charcoal particles reached the highest value also in this part of the analysed core, quite probably due to human impact. The ceased mining activity and metallurgy was renewed in this area with the arrival of the Saxons during the late 10th century (Lazić et al. 2010: 63) which certainly contributed to the rise of microcharcoal. However, there is no statistically significant correlation between charcoal particles and arboreal pollen proportions so it is not easy to stress if fire caused changes in abundance of particular tree species. This could be also due to difficulties to correlate charcoal values and AP on low resolution (5cm samplings). Still, probably in some periods fire burned beech forests, as the pollen of that taxon fluctuated greatly in this (sub)zone. The same can be considered for fir and hornbeam. Or, perhaps, people preferred to cut the mentioned taxa and used it as building material for houses and defense systems

ljubivim hrastovima, što olakšava sukcesiju mješovitih bukovo-hrastovih šuma prema čistim sastojinama bukve. U isto vrijeme primjećena je povremena pojava svojti poput oraha (*Juglans*), breza i jasena (*Fraxinus*), od kojih su dvije potonje svjetloljubive (Prpić 1974: 68) te im otvaranje šumskoga sklopa, uslijed redukcije četinjača, hrastova i bukve, pogoduje. Štoviše, obična breza je pionirska (Jamrichova et al. 2012) i na požare otporna vrsta (Xanthopoulos et al. 2012) koja fenofazu cvatnje doseže u samo nekoliko godina (Jonsson 1949). Najniže vrijednosti udjela lijeske krajem 11. i početka 12. stoljeća podudaraju se s najvišim vrijednostima udjela peluda bukve.

Sjenovite bukove sastojine ograničavaju rast lijeske i nekih drugih svojti kao što sugerira Gardner (2002), a zasjena najviše utječe baš na sastojine lijeske i hrastova (Aaby 1983; Rösch et al. 2014; Eaton et al. 2016). Iznenađujuće, najviše vrijednosti udjela pougljenjenih čestica ne podudaraju se s najvišim vrijednostima peluda lijeske i hrastova, iako je prethodna svojta favorizirana djelovanjem vatre (Tinner et al. 2000), dok je hrast ili pozitivno koreliran (Jamrichova et al. 2017) ili na vatru indiferentna svojta (Tinner et al. 2000). Feurdean et al. (2017) naglašavaju kako se u područjima izloženima djelovanju vatre očekuje veći udio onih vrsta drveća koje su prilagođene disturbanciji, poput bora (*Pinus*), breze (*Betula*), običnog graba (*Carpinus betulus*) i lijeske (*Corylus avellana*). Zanimljivo, u razdoblju od 11. stoljeća do kraja (pod)Zone 1b udio bukve kontinuirano se smanjuje, a pelud hrastova blago povećava, kao i krivulja pougljenjenih čestica. Najveći udio peluda johe u (pod)Zoni 1b podudara se s najnižoj vrijednošću bukve tako da je vjerojatno pretpostaviti kako su promjene u regionalnome peludnom spektru zasjenjene lokalnom pojavom sastojina johe ili jasena (*Fraxinus*), vrstama prilagođenima periodičnim poplavama tla (Wacnik et al. 2016) koje su vjerojatno nastavale rub creta. Kako udjeli akumuliranog lokalnoga i ekstralokalnoga peluda određenih palinoloških vrsta rezultiraju recipročnim promjenama u zastupljenosti ostalih svojti u peludnome zbroju (Waller et al. 2017), potreban je stanoviti oprez pri interpretaciji peludnih dijagrama.

Iako bukva rijetko kad preživljava blage požare (Berli 1996), udio ove vrste ostaje visok tijekom cijele (pod)zone, unatoč činjenici da istovremeno čestice ugljena dostižu najveću vrijednost (postotnu i koncentracijsku) također u ovome razdoblju, a što može biti rezultat antropogenoga pritiska. Posustala rudarska djelatnost i metalurgija obnovljena je na ovome području dolaskom Sasa krajem 10. stoljeća (Lazić et al. 2010: 63), što je svakako trebalo doprinijelo porastu udjela pougljenjenih čestica akumuliranih u supstratu. Međutim, ne postoji nikakva statistički značajna korelacija između pougljenjenih čestica i udjela peluda drvenastih vrsta tako da nije lako zaključiti je li vatra uzrokovala promjene u pokrovnosti drveća. Uspoređivanje vrijednosti udjela i koncentracije pougljenjenih čestica i peluda drvenastih vrsta pri niskoj razlučivosti (uzorkovanje u intervalima od 5 cm) također stvara teškoće. Ipak, vjerojatno su u nekim razdobljima sastojine bukve bile zahvaćene požarima s obzirom na značajna kolebanja peluda ove vrste. Isto se može smatrati za jelu i grab. Doduše, ne može se isključiti mogućnost rather than oak which was maybe spared to allow food for pigs and humans.

4.2.2. Grasses – Just Local Overgrown or Indicator of Human Impact?

The key question during this period is whether the increase in the share of grass pollen is the result of anthropogenic pressure or a natural succession process. Grasses have ambiguous position – they can highlight regional pollen input, as well as a possible local origin from hydrophytic communities (Muller et al. 2012). Large increases in grasses indicate extensive opening of the landscape (Kulkarni 2016) and usually are considered as secondary anthropogenic indicators (Kozáková et al. 2015). However, in some parts of Europe, increase in grass pollen during the medieval period is correlated with the warm dry optimum of the Medieval Climate Anomaly (Mensing et al. 2016). On our study area, a relative dominance of grass pollen corresponds to discontinuous curves of secondary anthropogenic indicators or their value stay low. This can suggest that an increase in grass proportion may be related only weakly to anthropogenic pressure. Nevertheless, the highest abundance of grass pollen corresponds to the largest ratio and concentrations of charcoal particles. It is not expected that all or most of burning events were caused naturaly, especially in the top part of this (sub)zone when human impact was recorded in the literature sources. There are many examples where burning was used for improving grazing and/or slash and burn crop cultivation (Damblon 1992; Esteban 2003; Niklasson et al. 2002). Moreover, in our case grazing on the study site is supported by the occurrence of coprofilous fungal *Sordaria* spores from the 10th century onwards. Although this statement must be taken with caution as fungal spores may occur also on wild, not only domestic animal feces.

Unfortunately, palynological analysis does not allow us to distinguish different grass taxa, with the exception of "cultivated" and "wild" (Moore et al. 1991), although it still remains a delicate attempt (Dörfler 2013). That means that pollen evidence does not offer possibility for differentiation of meadow/pasture grasses, eg. *Festuca*, *Dactylis*, *Trisetum*, *Lolium*, *Arrhenatherum*, from typical mire/wetlands taxa, eg. *Molinia*, *Deschampsia*, *Phragmites*. To be more accurate in interpreting the high grass proportions and AP-NAP ratio as a valid anthropogenic pressure indicator, NPPs were used too. This multiproxy approach has yielded fruitful results. Some fungal spores are found in the peat formed by *Molinia* – eg. HdV 16b or *Byssothecium circinans* and HdV 496 (van Geel 1978). However, *Byssothecium circinans* was later also recognised in peat formed by *Sphagnum* and *Narthecium* root (van Geel, Middeldorp 1988). In a small proportion, but present continuously during almost three hundred years on the study site, fungus HdV 496 indicated the origin of the peat to *Molinia* (van Smeerdijk 1989) – grasses nowadays very abundant on mire surfaces. Moreover, Damblon (1992) found that fire-induced disturbation lead to a decline in al-

da su stanovnici radije sjekli maloprije spomenute vrste stabala i koristili njihova debla kao građevinski materijal ili u svrhu podupiranja/unapređenja obrambenih sustava radije nego li hrastove koji su možebitno pošteđeni sječe kako bi žirevi prehranili svinje i ljude.

4.2.2. Trave – lokalna zaraslost creta istima ili pokazatelj ljudskoga utjecaja?

Ključno pitanje ove podzone je sljedeće – da li je povećanje udjela peluda trava rezultat antropogenoga pritiska ili prirodne sukcesije? Trave imaju dvojak položaj – njihova akumulacija u sedimentu može naznačavati regionalni peludni utjecaj ili pak ukazivati na razvoje lokalne sastojine cretnih i/ili močvarnih svojti (Muller et al. 2012). Veliko povećanje udjela trava ukazuje na naglašeno otvaranje krajolika (Kulkarni 2016) te se trave obično smatraju sekundarnim antropogenim indikatorima (Kozáková et al. 2015). Međutim, u nekim dijelovima Europe povećanje njihovoga udjela tijekom srednjega vijeka podudara se sa suhim toplim optimumom srednjovjekovne klimatske anomalije (Mensing et al. 2016). Na našem području istraživanja relativna prevlast vegetacije trava istovremena je s povremenim pojavljivanjem sekundarnih antropogenih indikatora ili pak njihovi udjeli ostaju niski. To naznačuje da povećanje udjela peluda trava tek djelomično, ako uopće, možemo povezati s antropogenim pritiskom. Međutim, najveći udjeli peluda trava podudaraju se s pojavom najvećega omjera i koncentracije pougljenjenih čestica. Teško je očekivati da su požari, osobito krajem ove (pod)zone, kada je ljudski utjecaj zabilježen i u pisanim izvorima, glavninom bili uzrokovani prirodnim čimbenicima. Tim više što postoje brojni primjeri gdje je spaljivanje vegetacije korišteno za poboljšanje kvalitete ispaše i/ili uzgoj usjeva metodom „posijeci i spali" (Damblon 1992; Esteban 2003; Niklasson et al. 2002). Koprofilne spore gljive *Sordaria,* koje se periodički pojavljuju od 10. stoljeća nadalje, podupiru mogućnost ekstenzivnoga stočarenja i s njim povezane ispaše, iako se od ove tvrdnje valja i djelomično ograditi jer se spore pojavljuju i na izmetu divljih, a ne nužno domaćih životinja.

Palinološka analiza ne omogućava razlikovanje trava na razini vrste, međutim moguće je odjeliti „kultivirane" od „divljih" svojti (Moore et al. 1991), premda uz stanovit oprez zbog ograničenja preciznosti determinacije (Dörfler 2013). To zapravo znači da temeljem peluda nije moguće razdvojiti za livade ili pašnjake karakteristične vrste, primjerice svojte iz rodova *Festuca*, *Dactylis*, *Trisetum*, *Lolium*, *Arrhenatherum*, od onih karakterističnih za cretna ili močvana staništa, poput svojti iz rodova *Molinia*, *Deschampsia*, *Phragmites*. Iz toga razloga, kako bi s većom sigurnošću interpretirali vrijednosti AP-NAP omjera kao potencijalno valjanoga indikatora antropogenoga pritiska, dodatno su u istraživanju korišteni nepeludni palinomorfi. Takav pristup daje plodonosne rezultate. Neke se spore gljiva gotovo redovito pronalaze u tresetu porijeklom od beskoljenke (*Molinia*) – primjerice, HdV 16b ili *Byssothecium circinans* i HdV 496 (van Geel 1978). Međutim, *Byssothecium circinans* je kasnije pronađen i u tresetu porijeklom od maha tresetra (*Sphagnum*) ili korijena svojti roda *Narthecium* (van Geel, Middeldorp 1988). S der population, which opens space for grass expansion. Repeated fires can favour *Molinia* intrusion and lead to its dominance (Hamilton 2000; Brys et al. 2005). *Molinia* is adapted to fire events, forming tussocks whose shoots remain intact during the fire (Damblon 1992). This means that high grass pollen level does not necessary highlight pronounced deforestation and/or a significant increase in the proportion of meadows and pastures on broader area, but may be the result of overgrowth of the habitat with local mire taxa. Nevertheless, with increasing human impact, fires are recorded more frequently (Pitkänen 2000; Olsson et al. 2010) and it can be stressed with great certainty that this fire-vegetation interaction was caused by human impact, at least in the broader area, if not directly on mire surface.

4.2.3. Ombrotrophication – Indicator for Humid Environment?

The most intriguing phenomenon in local vegetation refers to strong ombrotification in the study site, with the highest peak of *Sphagnum* spores in the period from the 12th to the 15th century. This process mainly corresponds to the Medieval Climate Anomaly (MCA) which lasted from about 900 to about 1350 AD (Graham et al. 2011). Transformation from the alder carr to a transition mire with some typical elements of (raised) bog vegetation can be understood as a result of mire growing surface separation from subsurface water supplies (Hughes, Barber 2003), especially because areas dominated by *Alnus* indicate a base-rich groundwater (Ellenberg: 278). The isolation of the surface from alkaline water can be maintained by vertical peat accumulation or lowering of the water table (Hughes, Barber 2003) which leads to transition towards *Sphagnum* dominated mire communities (Barsoum et al. 2005: 127). Thus, vascular plants can promote *Sphagnum* growth by providing both scaffolding and protection (Rydin, Jeglum 2006: 213). The distribution of *Sphagnum* taxa is associated with north – south (cold-warm) and oceanic-continental (humid-dry) gradient (Daniels, Eddy 1990; Gignac, Vitt 1990; Gignac et al. 1991; Hill, Preston 1998; Hájková, Hájek 2007; Séneca, Söderström 2008; Flatberg 2013; Popov 2016; Popov, Fedosov 2017). Even the ombrotrophication is not always associated with increased moisture (Lamentowicz et al. 2007) and dry conditions can also be marked by colonization of *Sphagnum* species (Gałka et al. 2018; Genet et al. 2013; Tuittila et al. 2013), greater peat growth rates and shifts to ombrotrophy have been found to occur during wet and warm periods (eg. Hughes 2000). Moreover, Conway (1954) suggested that sudden excessive sporulation by *Sphagnum* might be induced by an increase in wetness on a bog surface, as increase in rainfall accelerate *Sphagnum* growth (Gorham 1957). Mawby (1995) also concludes that many *Sphagnum* species grow well in flooded conditions but do poorly or do not grow at all on higher, drier sites. Gałka et al. (2017b) in the Eastern Carpathian Mountains found that the increased prevalence of *Sphagnum magellanicum* and *S. angustifolium*

malim udjelom, ali kontinuirano prisutan tijekom gotovo tri stotine godina u sedimentu jezgre, gljiva HdV 496 upućuje na treset porijeklom od beskoljenke (van Smeerdijk 1989) – trave koja je i u današnje vrijeme vrlo obilno zastupljena na površini creta. Štoviše, Damblon (1992) je otkrio da požarom izazvana disturbancija dovodi do pada udjela johe na staništu što otvara prostor za širenje trava. Učestalo opožarivanje pogoduje obraštanju nekoga područja beskoljenkom i nerijetko *Molinia* postaje dominantna vrsta (Hamilton 2000; Brys et al. 2005). Formirajući busene čiji izdanci ostaju netaknuti tijekom požara, beskoljenka je dobro prilagođena požarnim epizodama (Damblon 1992). To znači da visoki udjeli peluda trava nisu nužno rezultat krčenja šuma („gola sječa“) niti uvijek ukazuju na značajno širenje livada, pašnjaka ili obradivih površina na nekome području, već može biti posljedica obraštanja tresetišta tipičnim cretnim ili močvarnim travama. Ipak, kako pojačani ljudski utjecaj na okoliš dovodi do sve češćih požara (Pitkänen 2000; Olsson et al. 2010), može se sa stanovitom sigurnošću smatrati da je utjecaj požara na vegetaciju tijekom ove (sub)zone izazvan ljudskom djelatnošću, barem u širem području, ako ne izravno na samoj površini creta.

4.2.3. Ombrotrofikacija – pokazatelj pojačane vlažnosti?

Najintrigantniji fenomen u lokalnoj vegetaciji odnosi se na snažnu ombrotrofikaciju staništa, s najvišim udjelom spora maha tresetara (*Sphagnum*) u razdoblju od 12. do 15. stoljeća. Ovaj proces glavninom se poklapa s trajanjem srednjovjekovne klimatske anomalije (MCA) koja se smješta u razdoblje od 900. do oko 1350. godine (Graham et al. 2011). Transformacija iz johom obrasloga tresetišta u prijelazni cret s nekim tipičnim elementima (uzdignute) cretne vegetacije može se shvatiti kao rezultat procesa odvajanja slobodnorastuće površine samoga creta od podzemne ili podpovršinske vode bogate mineralnim tvarima (Hughes, Barber 2003). Do toga je odvajanja tim više trebalo doći jer područja u kojima prevladava joha ukazuju na podzemne vode bogate bazama (Ellenberg: 278). Izolacija površine creta od alkalne vode može se objasniti na dva načina – vertikalnom akumulacijom treseta ili spuštanjem vodenoga lica (Hughes, Barber 2003), što dovodi do razvoja *Sphagnum* dominirajuće cretne vegetacije (Barsoum et al. 2005: 127). Vaskularne biljke mogle su promicati takve promjene na cretu pružanjem zasjene i zaštite vrstama roda *Sphagnum* (Rydin, Jeglum 2006: 213). Rasprostranjenost maha tresetara u vezi je sa sjever – jug (hladno-toplo) i oceansko-kontinentalnim (vlažno-suho) gradijentom (Daniels, Eddy 1990; Gignac, Vitt 1990; Gignac et al. 1991; Hill, Preston 1998; Hájková, Hájek 2007; Séneca, Söderström 2008; Flatberg 2013; Popov 2016; Popov, Fedosov 2017). Unatoč tome što ombrotrofikacija nije uvijek povezana s povećanom vlažnošću sedimenta (Lamentowicz et al. 2007) te ponekad suhi uvjeti također mogu biti naznačeni kolonizacijom vrstama maha tresetara (Gałka et al. 2018; Genet et al. 2013; Tuittila et al. 2013), veća stopa rasta i pojačana ombrotrofija utvrđeni su u uvjetima vlažnih i toplih perioda (npr. Hughes 2000). Štoviše, Conway (1954) sugerira da bi iznenadna naglašena sporulacija maha treseis linked to moist periods, and a decline of *Sphagnum* has been observed in some areas of England, possibly because of increased drainage (Latto, Fitter 1989). Moreover, severe droughst have a negative impact on *Sphagnum*-fens due to changes in mineral availability (Mettrop et al. 2014). There are some different opinions about which level of moisture is indicated by the same *Sphagnum* taxa, for instance Barber et al. (2003) consider that presence of *Sphagnum* section *Acutifolia* in England and Ireland reflect dry bog surfaces conditions, while Castro et al. (2015) have an opposite opinion for its occurance in the Iberian Peninsula. It is obvious that the same taxa in different biogeographical regions may indicate different environmental conditions, depending on the prevailing climate type. Campbell (2019), based on Gignac et al. (2000) and Oke, Hager (2017), summarise that peatlands do not occur where precipitation minus potential evapotranspiration was < -500 mm $^{-1}$ and Schultheis et al. (2010), based on Gunnarsson (2005), stressed that *Sphagnum* productivity increased with mean annual temperature and precipitation up to a threshold – temperature ~6°C, precipitation ~1150 mm, beyond which peat mosses decreased as the physical variables continued to increase. Even *Sphagnum* growth can be affected by temperature or precipitation (Robroek et al. 2007; 2017; Campbell, Rydin 2019). Gerdol et al. (2007) showed that high summer temperature can have negative impact on *Sphagnum* growth in the area south of the Alps. The modern mean annual temperature at the study site is almost 4°C higher than calculated as suitable for *Sphagnum* growth (Schultheis et al. 2010), although nowadays precipitation is within the threshold value. Nevertheless, potential evapotranspiration (ET_0) on Banovina-Kordun area ranges from 701 to 800 mm (Nistor et al. 2017a) while mid-season crop evapotranspiration (ETc mid) is between 400 and 600 mm y^{-1} (Nistor et al. 2017b). Due to the fact that the *Sphagnum* peak at the study site mostly corresponds to the Medieval Climate Anomaly (MCA), when the temperature was about 0.6°C higher than in the reference period of 1880 – 1960 AD (Christiansen, Ljungqvist 2012), it is very likely that *Sphagnum* could became dominant in the mire vegetation only if the precipitation was higher. Moisture stress and dehydration (Weltzin et al. 2001; Gerdol et al. 2007; Hájek, Beckett 2008) during high temperature leads to the situation when evapotranspiration exceeds capillary transport (Skre, Oechel 1981) and photosynthetically active parts of the peatmosses can't maintain sufficient water content for growth (McCarter, Price 2014). It means that not only the higher amount of precipitation occured during MCA, but also rainfall frequencies probably increased during High and Late Medieval Ages to support abundant *Sphagnum* growth. Of course, it is possible that higher mean annual temperature during MCA is rather maintained by mild winters than higher summer temperature. Krebs et al. (2016) already suggested that the precipitation frequency is more important than precipitation amount for *Sphagnum* growth. The wetter period during MCA is just partly in

tara mogla biti izazvana povećanjem vlažnosti cretne površine, uostalom kao što povećanje padalina akcelerira rast maha tresetara (Gorham 1957). Mawby (1995) također zaključuje da mnoge vrste roda *Sphagnum* rastu dobro u uvjetima plavljenja, ali slabo na izdignutijim, sušnim mjestima. Gałka et al. (2017b) uočili su kako se povećana zastupljenost nekih vrsta maha tresetara, poput *Sphagnum magellanicum* i *S. angustifolium,* može povezati s razdobljima pojačane vlažnosti na području istočnih Karpata. Nasuprot tome, pad udjela maha tresetara u nekim područjima Engleske vjerojatno je uzrokovana pojačanom drenažom (Latto, Fitter 1989). Štoviše, izrazite suše imaju negativan utjecaj na sfagnumske cretove zbog promjena u dostupnosti minerala (Mettrop et al. 2014). Međutim, postoje različita mišljenja o tome koju razina vlažnosti indicira pojava određenih (istih) vrsta maha tresetara na nekome staništu. Primjerice, Barber et al. (2003) smatraju da prisutnost vrsta roda *Sphagnum* sekcije *Acutifolia* u Engleskoj i Irskoj naznačava suhu površinu creta, dok Castro et al. (2015) imaju suprotno mišljenje za pojavu istih na Iberskom poluotoku. Očito je da iste svojte u različitim biogeografskim regijama mogu ukazivati na različite uvjete okoliša, ovisno o prevladavajućem tipu klime. Campbell (2019), temeljem istraživanja Gignac et al. (2000) te Oke, Hager (2017), sažimlje da tresetišta ne nastaju ondje gdje je razlika između količine oborina i potencijalne evapotranspiracije < -500 mm $^{-1}$, a Schultheis et al. (2010), na osnovi Gunnarssona (2005), naglašava da se produktivnost maha tresetara povećava s rastom srednje godišnje temperature i padalina, do praga u kojem srednja godišnja temperatura iznosi ~6°C, a prosječna godišnja količina padalina ~1150 mm. Izvan toga praga porast navedenih varijabli (temperatura, padaline) dovodi do pada pokrovnosti maha tresetara. Uostalom, i sama brzina rasta mahovina roda *Sphagnum* utjecana je temperaturom ili oborinama (Robroek et al. 2007; 2017; Campbell, Rydin 2019). Gerdol et al. (2007) dokazuju da visoka ljetna temperatura može negativno utjecati na rast maha tresetara u području južno od Alpa. Na cretu u Blatuši sadašnja srednja godišnja temperatura zraka je gotovo 4°C viša od izračunate kao pogodne za rast mahovina roda *Sphagnum* (Schultheis et al. 2010), iako su oborine unutar praga pogodnih vrijednosti. Ipak, potencijalna evapotranspiracija (ET_0) na području Banovina-Kordun kreće se od 701 do 800 mm (Nistor et al. 2017a), dok je srednjosezonska evapotranspiracija usjeva (ETc sredina) između 400 i 600 mm y^{-1} (Nistor et al. 2017b). Uzevši u obzir činjenicu da su najveće vrijednosti udjela spora maha tresetara zabilježene u razdoblju koje se glavninom preklapa s trajanjem srednjovjekovne klimatske anomalije (MCA), kada je temperatura bila oko 0,6°C viša nego u referentnom razdoblju 1880. – 1960. godine (Christiansen, Ljungqvist 2012), za očekivati je da je *Sphagnum* mogao postati prevladavajući u cretnoj vegetaciji samo ako je količina oborina također bila povećana. Vodni stres i dehidracija (Weltzin et al. 2001; Gerdol et al. 2007; Hájek, Beckett 2008) tijekom visoke temperature dovode do situacije kada evapotranspiracija premašuje kapilarni transport (Skre, Oechel 1981) te fotosintetski aktivni dijelovi maha tresetara ne sadrže dovoljnu količinu vode potrebnu za rast (McCarter, Price 2014). To vjeagreement with the results from Romania (Feurdean et al. 2015) and started later and lasted longer than in the eastern part of the Balkan Peninsula. Moreover, during the humid period in Central Croatia, marked by strong ombrotrofication, drier period in Romania already begun.

4.2.4. Environmental Changes on Mire Surface

Great proportion of peat mosses indicated transition from previous poor fen to (raised?) bog in the 11th century. *Sphagnum* and ferns (Polypodiales) spores were the most abundant on the mire surface during this period, reaching its highest value in the 13th century. A high share of *Assulina muscorum*, *Nebela* and *Arcella* amoebae, accompanied by fungi *Valsaria variospora*, *Gelasinospora* and Sordariaceae characterised the lower part of the (sub)zone, the period preceding the 11th century. Although *Nebela* and *Arcella* amoebae are not determined on the species level, occurrence of *Assulina muscorum*, *Nebela militaris* and *Arcella catinus* is linked to drier conditions on the fen (Opravilová, Hájek 2006). Later, in the upper part of this (sub)zone, some indicators of higher moisture level occurred: *Hyalosphenia papilio* and *Amphitrema flavum*, although just periodically. *Arcella*, *Assulina, Amphitrema* and *Hyalosphenia* are dominant amoebae in peatland communities (Fiłoc, Kupryjanowicz 2015). The most abundant *Assulina muscorum* is regarded as typical of the early stages of raised bog formation (Mazei, Bubnova 2007; Glime 2017) and it is recognized as a xerophylous taxa (Kołaczek et al. 2010) found in dry hummocks in different geographical locations (Mazei, Tsyganov, 2006; Amesbury et al. 2016). Contrary, *Hyalosphenia papilio* is often numerous during high humidity (Lamentowicz et al. 2007; Glime 2017) and its decrease can indicate warming in peatlands (Basińska et al. 2020). Did higher temperature cause its dissaperance during the 12th and the 13th century, although it was abundant during the 11th and the 14th centuries? Having in mind that differences in the number of amoebae and the abundance of particular taxa can be caused by changes in temperature, moisture, nutient status and degree of peatland development (Opravilová, Hájek 2006) it is obvious how complex the answer to this question is.

The appearance of the largest number of micro- and macro- charcoal particles in the period when *Sphagnum* was the most abundant is the most intriguing. Although the surface of the raised bog is drier in comparison with a fen, as decreasing surface wetness supports succesion from a fen to bog (Magnan et al. 2012), a single fire event can lead to reduced *Sphagnum* over 60 years later (Noble et al. 2018); it is not expected that combustion on the mire surface would support pronounced growth of peat mosses. Moreover, higher fire severity increases the abundance of ericoids, graminoids and acrocarpous mosses, and decreases the abundance of pleurocarpous mosses (Grau-Andrés et al. 2019). On cumbusted areas *Sphagnum* decreases, probably due to post-fire stresses such as desiccation (Tsuyuzaki et al. 2009), and recoveres slower than vascular plants (Tsuyuzaki et al. 2013). Nevertheless, *Sphagnum capillifoli-*

rojatno znači da se, osim ukupne godišne količine oborina, u razdoblju razvijenoga i kasnoga srednjeg vijeka povećala i učestalost samih padalina pospješujući rast mahovina roda *Sphagnum*. Naravno, moguće je da viša srednja godišnja temperatura tijekom MCA prije održava blage zime nego izrazito vruća ljeta. Krebs et al. (2016) međutim zaključuju da je učestalost padalina važnija od ukupne količine oborina za uspješan rast maha tresetara. Vlažno razdoblje tijekom srednjovjekovne klimatske anomalije na području istraživanja samo se djelomično podudara s rezultatima iz Rumunjske (Feurdean et al. 2015) te počinje kasnije i traje duže nego u istočnome dijelu Balkanskog poluotoka. Štoviše, tijekom vlažnoga razdoblja u središnjoj Hrvatskoj, indiciranoga snažnom ombrotrofikacijom, sušnije razdoblje u Rumunjskoj već je bilo započelo.

4.2.4. Okolišne promjene na području creta

Visoki udjeli spora maha tresetara ukazuju na tranziciju iz siromašnoga minerotrofnog prijelaznog prema (uzdignutom?) cretu u 11. stoljeću. *Sphagnum* i paprati (Polypodiales) pretežu, s najvišim udjelima spora tijekom 13. stoljeća. Visoki udio ameba – *Assulina muscorum, Nebela* i *Arcella*, praćenih sporama gljiva – *Valsaria variospora*, *Gelasinospora* i Sordariaceae karakterizira donji dio (pod)zone, razdoblje koje prethodi 11. stoljeću. Iako amebe *Nebela* i *Arcella* nisu determinirane do razine vrste, pojava svojti poput *Assulina muscorum, Nebela militaris* i *Arcella catinus* povezuje se sa sušim uvjetima na cretu (Hájek 2006). Kasnije, u gornjem dijelu ove (pod)zone, pojavljuju se vrste koje indiciraju višu razine vlage: *Hyalosphenia papilio* i *Amphitrema flavum*, premda samo povremeno. *Arcella*, *Assulina, Amphitrema* i *Hyalosphenia* dominantne su vrste ameba na cretnim staništima (Fiłoc, Kupryjanowicz 2015). Na staništu najzastupljenija vrsta *Assulina muscorum* smatra se tipičnom za rane faze razvoja uzdignutoga creta (Mazei, Bubnova 2007; Glime 2017) i prepoznata je kao kserofilna vrsta (Kołaczek et al. 2010) sfagnumskih humaka u različitim geografskim područjima (Mazei, Tsyganov, 2006; Amesbury et al. 2016). Suprotno tome, vrsta *Hyalosphenia papilio* česta je tijekom pojačane vlažnosti (Lamentowicz et al. 2007; Glime 2017) i smanjenje brojnosti iste može ukazivati na uvjete zatopljenja na tresetištima (Basińska et al. 2020). Je li i povišena temperatura uzrokovala nestanak ove vrste tijekom 12. i 13. stoljeća, iako je bila brojna tijekom 11. i 14. stoljeća? Imajući u vidu da razlike u broju vrsta i brojnosti određene vrste mogu biti uzrokovane promjenama temperature, vlage, raspoloživih nutrijenata i stupnja razvoja samoga tresetišta (Prodová, Hájek 2006), očito je da odgovor teško može biti jednoznačan.

Neočekivana je pojava najvećega broja mikro- i makropougljenjenih čestica (kako njihovoga udjela, tako i koncentracije) istovremeno s najobilnijom zastupljenošću mahovina roda *Sphagnum* na staništu. Iako je površina uzdignutoga creta suša u usporedbi s prijelaznim cretom, uostalom manja mokrina površine i potiče sukcesiju od prijelaznoga ka uzdignutom cretu (Magnan et al. 2012), pojedinačno opožarivanje može dovesti do redukcije maha tresetara u periodu od 60 godina ili duže (Noble et al. 2018). Dakle, *um*, nowadays present at the study site, shows a degree of resilience to fire (Grau-Andrés et al. 2017) and often occurs on burned sites (Burch 2008; Lee et al. 2013). Still, substances released in organic matter by fire may be toxic for many mosses and restricts the number of species that can survive after the fire, and these tend to be nitrophilous species (Brown 1982: 383–444). All this calls into question whether the charcoal particles > 100 micrometers are really good indicators of a local fire as recently was stressed by Adolf et al. (2018). However, fire probably occured at the mire edges, as numerous *Pteridium* spores indicated. The expansion of *Pteridium aquilinum* may suggest the occurrence of local fires because soil acidification after combustion favours the germination of its spores, so that young plants appear in a great number on soils fertilized by ash (Page 1986; Oberdorfer 1990: 1050). Bracken is a common fern in habitats of acidophilic oaks and beech (Petřík et al. 2009: 400–402) disturbed by fire and due to its rapid regeneration, it can spread en masse even on burnt surfaces (Marrs, Watt 2006). However, Behre (1981) attributes increasing *Pteridium* values to the cattle grazing in the forests, as this economic activity recorded among the Slavic tribes (Beug 2011) was not always supported by numerous charcoal particles. In our study site, high values of *Pteridium* spores were followed after the 10th century by an increase in pollen frequencies of Ericaceae, both taxa often linked to fire activity (Tinner et al. 2000; Feurdean et al. 2015; Pędziszewska, Latałowa 2016). Moreover, the high abundance of *Calluna vulgaris* and *Pteridium aquilinum* were found to be significantly correlated with human activity (Kuneš 2008). As was already stated by Pędziszewska, Latałowa (2016), the regular occurrence of light-demanding *Pteridium* and *Calluna* (Ericaceae) and the presence of charcoal are probably indicators of the use of fire in forest management and we assume that it was also a case on Banovina-Kordun area.

4.3. VEGETATION, FIRE AND HIDROLOGY CHANGES FROM THE LATE MIDDLE AGES TO MODERN PERIOD – 14TH TO 20TH CENTURY

This period is characterised by more available literature data about environment and economy which can be brought into connection with the pollen digrams. The area of Topusko was an economically important center, together with the nearby town of Perna at the beginning of this zone. Nevertheless, this area has been a zone of conflict with Ottoman invaders since the late 15th century, characterised by mass exodus of the people and declining economic activity. For more than 200 years this area could be marked as "no man's land" (eg. Blanc 2003: 97–115). In this sense it would be interesting to see if pollen diagrams follow and confirm historical sources about depopulation and loss of the economy activity. Contrary, in the 19th century this was one of the most dynamic areas of the Military Frontier, highly populated and with strong human pressure on environment. From a climatic point of view, most of this period was marked by a climatic anomaly known as the Little Ice

izgaranje treseta zasigurno ne pogoduje obilnijem razvoju maha tresetara. Štoviše, požari većega inteziteta povećavaju pokrovnost vrijesovki, travolikih vrsta i akrokarpnih mahovina, a smanjuju pokrovnost pleurokarpnih mahovina (Grau-Andrés et al. 2019). Na opožarenim površinama dolazi do pada udjela maha tresetara, vjerojatno uslijed postpožarnoga stresa, primjerice isušivanja (Tsuyuzaki et al. 2009), a i oporavak sfagnuma je sporiji u odnosu na vaskularne biljke (Tsuyuzaki et al. 2013). Ipak, *Sphagnum capillifolium*, danas prisutan na cretu, pokazuje određen stupanj otpornosti na vatru (Grau-Andrés et al. 2017) te se često pojavljuje na opožerenim površinama (Burch 2008; Lee et al. 2013). Međutim, spojevi koji se gorenjem organske tvari oslobađaju u okoliš mogu biti otrovni za brojne mahovine te samo neke vrste, pretežno nitrofilne svojte, mogu preživjeti požarne epizode (Brown 1982: 383–444). Utjecaj vatre na pokrovnost maha tresetara dovodi u pitanje jesu li čestice ugljena > 100 mikrometara zaista dobri pokazatelji lokalnoga požara na što su nedavno ukazali Adolf et al. (2018). Međutim, požari su vjerojatno zahvaćali rubna područja creta, što naznačuje pojava velikoga broja spora bujadi (*Pteridium*). Širenje bujadi može ukazivati na pojavu lokalnih požara jer zakiseljenje tla, uslijed izgaranja, potiče klijanje spora iste, tako da se mlade biljke pojavljuju u velikom broju na tlima oplemenjenim pepelom (Page 1986; Oberdorfer 1990: 1050). Bujad je česta paprat na acidofilnim staništima hrastova i breze (Petřík et al. 2009: 400–402) koja su izložena požarima te se zbog brze regeneracije može masovno širiti na spaljenim površinama (Marrs, Watt 2006). Međutim, Behre (1981) pripisuje povećanje udjela *Pteridium* spora u sedimentu ispaše stoke u šumama, jer takav tip gospodarenja, zabilježen među slavenskim plemenima (Beug 2011), istovremeno nije uvijek podržan visokim udjelom pougljenjenih čestica. U našem istraživanju visoki udjeli spora bujadi praćeni su nakon 10. stoljeća visokim udjelom peluda vrijesovki, dakle vrstama karakterističnima za opožarene površine (Tinner et al. 2000; Feurdean et al. 2015; Pędziszewska, Latałowa 2016). Štoviše, utvrđeno je da su visoke vrijednosti peluda crnjuše (*Calluna vulgaris*) i spora bujadi (*Pteridium aquilinum*) značajno korelirani s ljudskom aktivnošću (Kuneš 2008). Kao što su već naveli Pędziszewska, Latałowa (2016), redovita pojava svjetloljubivih bujadi i vrijesovki, uz prisutnost pougljenjenih čestica, ukazuje na korištenje vatre u gospodarenju šumama i pretpostavljamo da je to bio slučaj i na području Banovine i Korduna.

4.3. VEGETACIJA, POŽARI I HIDROLOGIJA OD KASNOGA SREDNJEG VIJEKA DO SUVREMENOGA DOBA – 14. DO 20. STOLJEĆE

Ovo razdoblje karakteriziraju dostupniji literaturni podaci o okolišu i gospodarstvu područja koji se mogu dovesti u vezu s palinološkim dijagramima. Topusko je ekonomski važno središte, zajedno s obližnjim gradom Pernom, početkom ovoga razdoblja. Svejedno, još od kraja 15. stoljeća područje Banovine i Korduna postaje zona sukoba s osmanlijskim zavojevačima, što rezultira masovnim egzodusom ljudi i usporavanjem gospodarske aktivnosti. Kroz više od 200 godina ovo se područje može označiti kao „ničija zemlja"

Age (LIA), which in addition to cooling is characterized by changes in precipitation levels.

4.3.1. Regional Vegetation Changes

Like in the previous (sub)Zone 1b, grasses were still dominant, however for the first time hornbeam become the most abundant tree in the woodlands, accompanied by oak and beech. There are two possible reasons for the increase in the proportion of hornbeam in the woodlands – climate change and human activity. The Little Ice Age, lasting from 1300 to 1800 AD (Fagan 2002) or 1400 to 1850 AD (Mann 2002), was characterised by lower temperatures and more snowfall. Due to the fact that hornbeam's flexible crowns suffer the least damage during winter storms, in comparison with beech and especially oaks (Körner 2004: 23), its greater proportion could be a result of the LIA anomaly. Colder climate probably caused the reappearance of spruce (*Picea*) with its continuous curve from the later 16th century onwards and birch, noticed one century earlier. The same happens with pine, capable of thriving in drier-cooler conditions (Panagiotopoulos et al. 2013). Moreover, *Betula pubescens*, nowadays very rare on the study site, *B. pendula* and/or *Pinus sylvestris* suggest cold winters and early springs (Paal et al. 2016), which is in accordance with the general climate during LIA. The higher value of later taxon was also observed from the 18th century onwards in the central Balkan (Kulkarni et al. 2018).

Although climate change in this zone may largely explain the fluctuation in the proportion of some arboreal taxa, low values of oak and high values of hornbeam probably reflect human impact or pressure of expanding *Carpinus* prevents development of a more open shrub-wood vegetation, as was shown for some regions in Poland (Karpińska-Kołaczek et al. 2014). Feeding pigs with acorns accompanied by grazing of other livestock in the forest were common practices during Late Middle Ages and later in Central Croatia (Gračanin, Pisk 2017: 52). Oaks were the most valuable timber used for reparation and fortification of old fortresses in the Late Middle Ages/Early Modern Period (Andrić 2017: 75) and later, especially in the 19th century, for the construction of sawmills and railway sleepers (Živaković-Kerže 2017). Also, even hornbeam proportions can be stimulated by LIA, its spread is favored by deforestation caused by people (Ralska-Jasiewiczowa, van Geel 1998). It is the most resistant tree against animal browsing, being a strong competitor under conditions of herbivore pressure (Kuijper et al. 2010). Logging of beech and fir for timber or animal food (Palairet 1997) or burning episodes opened the area for coppice and promoted the share of light-demanding pioneer species like pine and hazel (Kolář et al. 2018; Kulkarni et al. 2016). The mentioned taxa and birch usually indicate a period of intense forest disturbances (Pędziszewska, Latałowa 2016) or the presence of a not very closed forest canopy (Wacnik et al. 2016). Even the establishment of pine can be linked to changes in bog surface wetness (Adamsson 2013). However,

(npr. Blanc 2003: 97–115). U tom je smislu zanimljivo usporediti peludne dijagrame s navodima iz povijesnih izvora o depopulaciji i gubitku gospodarske aktivnosti tijekom vojne ugroze. Nasuprot tome, u 19. stoljeću ovo područje Vojne krajine gusto je naseljeno i izloženo snažnom antropogenom pritisku na okoliš. Klimatološki gledano, većinu ovoga razdoblja obilježilo je klimatska anomalija poznata kao malo ledeno doba (LIA) koju karakterizira zahladnjenje i promjena u količini oborina.

4.3.1. Regionalna promjena vegetacije

Kao i u prethodnoj (sub)Zoni 1b, trave su i dalje najzastupljenija palinološka vrsta u Zoni 2, a po prvi puta grab postaje najzastupljenija stablašica u šumskome pokrovu. Nakon graba, od drvenastih vrsta najzastupljeniji su hrastovi i bukva. Postoje dva moguća razloga za povećanje udjela graba u šumskome pokrovu – klimatske promjene i/ili ljudska aktivnost. Malo ledeno doba, klimatska anomalija koja traje u razdoblju od 1300. do 1800. godine (Fagan 2002) ili 1400. do 1850. godine (Mann 2002), karakterizira niža temperatura i više snježnih padalina. Zbog činjenice da fleksibilna krošnja graba trpi manje štete tijekom zimskih olujnih nepogoda, u usporedbi s bukvom i, posebice, hrastovima (Körner 2004: 23), veći udio graba mogao biti rezultat LIA anomalije. Hladnija klima vjerojatno je uzrokovala povratak smreke (*Picea*) u područje nedaleko creta te se ta vrsta kontinuiranom krivuljom pojavljuje u peludnom dijagramu od kasnoga 16. stoljeća nadalje, uostalom kao i breze stoljeće ranije. Slično je i sa borom, vrstom konkurentnom u uvjetima suše i hladnoće (Panagiotopoulos et al. 2013). Štoviše, cretna breza (*Betula pubescens*), s trenutno malom populacijom stabala na cretu, obična breza (*B. pendula)* i/ili bijeli bor (*Pinus sylvestris)* sugeriraju niske zimske i ranoproljetne temperature (Paal et al. 2016), što je u skladu s klimatskim obrascem tijekom malog ledenog doba. Više vrijednosti omjera bora na području središnjega Balkana zabilježene su od 18. stoljeća nadalje (Kulkarni et al. 2018).

Iako klimatske promjene u ovoj zoni mogu uvelike objasniti fluktuaciju u proporciji nekih vrsta stablašica, niski udjeli peluda hrasta i visoke vrijednosti graba vjerojatno odražavaju ljudski utjecaj. Doduše, širenje sastojina graba također je moglo sprečavati razvoj otvorenije grmoliko-drvenaste vegetacije kao što je uočeno u nekim područjima Poljske (Karpińska-Kołaczek et al. 2014). Hranjenje svinja žirom te ispaša stoke u šumama dio su uobičajene prakse tijekom kasnoga srednjeg vijeka i kasnije na području središnje Hrvatske (Gračanin, Pisk 2017: 52). Hrastovi pak predstavljaju najdragocjeniju drvnu građu korištenu za popravak ili ojačavanje utvrda u kasnome srednjem ili ranome novom vijeku (Andrić 2017: 75), a kasnije, osobito u 19. stoljeću, za izgradnju pilana i željezničkih pragova (Živaković-Kerže 2017). Također, iako širenje graba može biti potaknuto klimatskim obrascem malog ledenog doba, a antropogena deforestacija također favorizira ovu drvenastu vrstu (Ralska-Jasiewiczowa, van Geel 1998). Ujedno, grab je na brstenje najotpornije stablo, u biti jak konkurent ostalim biljnim vrstama u uvjetima pritiska biljoždera (Kuijper et al. 2010). Sječa bukve i jele, u svrhu hranjenja životinja i dobivanja drvne its occurrence at the study site is dubious and probably more reflects its high pollen productivity (Baker et al. 2015) and distant transport (Dörfler 2013; Margielewski et al. 2011). Connor et al. (2004) stress that *Pinus* pollen comprises up to 35–50% when it is found nearby and over 50% when it is present and locally-dominant so we assume that its increasing, but still very low value, probably doesn't mark its local occurrence.

Surprisingly, a continuous and simultaneous increase of *Pinus, Betula* and *Corylus* proportion is not followed by a rise in the number of charcoal particles, as could be expected. The same is with hornbeam, a dominant tree in the forest belt of the study area, although this taxon is related positively to the fire (Lamentowicz et al. 2019) and its seedlings are light-demanding (Gardner 2002). Moreover, the numbers of charcoal particles were the lowest through the whole core, almost lacking during the late 15th and most of the 16th century. This could be linked to a depopulation of the area during the period of Ottoman incursion to Kordun and Banovina, probably followed by a collapse of mining and metallurgy.

4.3.2. Anthropogenic Indicators

During Zone 2 AP-NAP ratio slowly increased, however with a synchronized significant increase in anthropogenic indicators. For the first time many secondary anthropogenic indicators occurred together with cereal pollens – primary anthropogenic indicator which appeared in the late 14th century onwnard, however with occasional occurrence. Lack of cereals are noticed in the late 17th and the most of the 18th century, and in the late 19th and the beginning of the 20th century when *Fagopyrum*, not really true cereal as this genus does not belong to grass family, was noticed. However, the interruption in the continuous appearance of cereal pollen is not necessarily proof that agricultural activity has ceased in some periods, still it may be indicative. This discontinuity may be also due to non-entrapment of cereal pollen by the drilled core or because of differential pollen production of cereals (Kuneš et al. 2015), as barley (*Hordeum*) or wheat (*Triticum*) are autogamous (Mercuri et al. 2013a). However, millet (*Panicum*) was the most widespread and common cereal in Central Croatia, at least since the 17th century when some statistical records of cultivated grasses for that area existed (Blanc 2003: 223–224). Unfortunately, its pollination strategy is still not acknowledged (Damialis, Konstantinou 2011).

In this zone walnut (*Juglans*), as an example of arboriculture, occurred for the first time at the end of the 13th century with a continuous curve, as well as plantain (*Plantago lanceolata* type), succeeded by cocklebur (*Xanthium spinosum* type) and goosefoot (Chenopodiaceae) at the end of the 14th century and, somewhat later, wormwood (*Artemisia*). All these plants indicate grazing and arable farming, or generally human-influenced land (Behre 1981; Court-Picon et al. 2006; Li et al. 2008; Brun 2011). Literature data tells

građe (Palairet 1997), uz povremene požare, pridonosi otvaranju šumskoga sklopa omogućujući time razvoj šikara, ali i širenje svjetloljubivih pionirskih vrsta poput bora i lijeske (Kolář et al. 2018; Kulkarni 2016). Spomenute svojte, uz pojavu breza, obično ukazuju na intenzivne šumske poremećaje (Pędziszewska, Latałowa 2016) ili na razvoj šume otvorenoga sklopa (Wacnik et al. 2016). Iako pojava peluda bora također može indicirati pojavu ove vrste na površini creta, što se također može dovesti u vezu s promjenom vlažnosti na samom tresetištu (Adamsson 2013), njegova pojava je dvojaka i vjerojatno više odraz visoke produktivnosti peluda (Baker et al. 2015) i dalekoga transporta istoga (Dörfler 2013; Margielewski et al. 2011). Connor et al. (2004) naglašavaju da bor doprinosi s 35–50% akumuliranom peludnom spektru kada se njegove sastojine nalaze u blizini mjesta uzorkovanja i s preko 50% kada je lokalno prevladavajuća svojta. Iz toga proizlazi kako blago povećanje udjela bora, s obzirom na njegovu vrlo nisku vrijednost, ne treba shvatiti kao pokazatelj lokalne prisutnosti ove vrste na samom cretu.

Iznenađujuće, istovremeno kontinuirano povećanje udjela bora, breze i lijeske nije praćeno istovjetnim trendom pojave pougljenjenih čestica kao što bi se moglo očekivati. Slično je i s grabom, dominantnim stablom u šumskome mozaiku, iako je ova svojta pozitivno korelirana s vatrom (Lamentowicz et al. 2019) i njegove mladice su svjetloljubive (Gardner 2002). Štoviše, udjeli i koncentracije pougljenjenih čestica niži su nego u ostatku jezgre, a gotovo nedostaju tijekom kasnoga 15. i većine 16. stoljeća. To je možda povezano s depopulacijom toga područja tijekom razdoblja osmanlijskih upada na područja Korduna i Banovine koji su praćeni kolapsom rudarstva i metalurgije.

4.3.2. Antropogeni indikatori

Tijekom Zone 2 AP-NAP omjer polako se povećava, međutim uz istovremeno značajno povećanje udjela antropogenih indikatora. Po prvi puta se pojavljuju mnogobrojni sekundarni antropogeni indikatori, zajedno s peludom žitarica – primarnim antropogenim indikatorom koji se u sedimentu diskontinuirano pojavljuje od kasnoga 14. stoljeća nadalje. Nedostatak žitarica primjećuje se krajem 17. i većine 18. stoljeća te na prijelazu iz 19. u 20. stoljeće kada se ujedno zapaža pelud heljde (*Fagopyrum*), pseudožitarice koja ne pripada porodici trava. Međutim, prekid u kontinuiranoj pojavi peluda žitarica ne predstavlja nužno dokaz o izostanku ratarske proizvodnje u određenim periodima, ali je indikativan. Naime, moguće je da se prilikom bušenja jezgre sedimenta ne zahvati sekvenca u kojoj se pelud neke svojte akumulirao ili izostanak iste može biti posljedica niske stope porodukcije peluda (Kuneš et al. 2015), s obzirom da su ječam (*Hordeum*) ili pšenica (*Triticum*) autogamni (Mercuri et al. 2013a). Međutim, tijekom većega dijela Zone 2 čini se da je proso (*Panicum*) najraširenija i najčešća žitarica središnje Hrvatske, barem od 17. stoljeća nadalje kada postoje statistički zapisi o uzgojnim kulturama na području središnje Hrvatske (Blanc 2003: 223–224). Na žalost, strategija oprašivanja prosa nije utvrđena (Damialis, Konstantinou 2011).

Orah (*Juglans*), kao primjer arborikulture, prvi se puta pojavljuje kontinuiranom krivuljom krajem 13. stoljeća, kao us that in the beginning of this period, economic activity increased rapidly in Central Croatia due to the construction of a Cistercian monastery in Topusko and the construction of a Catholic church on Nikolina Hill during the 13th century, which provides the basis for the development of a settlement that soon grew into a market (Jakaša Borić, Dumbović Bilušić 2008). In 1303 a monastery was founded at Petrovac (Petrova Gora), and not far from Blatuša was a town of Perna, to which royal privileges were granted as early as 1225 (Škiljan 2007: 91). The Archdeaconate of Gorizia, whose marginal area cover the study site, numbered more than 40 churches in the first half of the 14th century (Razum 2003; Vedriš 2016). All this points to increased economic activity during the Late Middle Ages, which is also reflected in the bottom part of this zone. After all, the area between Kupa and Una during the Late Middle Ages and Early Modern Period was probably among the most densely populated areas of the Hungarian-Croatian Kingdom in general (Vedriš 2016). However, in the second half of the 15th century, due to the Ottoman incursions, the economy of Topusko began to decline and the trade in the Una river valley generally ceased (Adamček 1969), which culminated in the burning of city of Perna in the middle of the 16th century (Škiljan 2007: 8, 92) and the situation stayed mostly unstable untill the beginning the 18th century. Although the period of Ottoman conquest is related to the devastation of the border area, which should not be understood as a clearly defined line but rather as a belt of "no man's land" or "sunkend world" (Vlašić 2017), what can be seen from the pollen diagrams is somewhat different than what is usually stated for that period. It is certainly mostly true that war devastation caused depopulation which lead to decline in agricultural activity (Šarić 2003: 245, 247). However, in the pollen diagrams there is no lack of anthropogenic indicators, neither their curves become discontinuous during Ottoman presence in the adjacent area of the sampling site. One explanation is that the pollen resolution in our investigation does not allow accurate identification of economic opportunities for narrow time units. Another explanation is that in the wider area of Topusko and Perna agricultural activities have not ceased, despite the fact, that a lack of charcoal particles indicates a decline of economy. These two claims are not contradictory as the state of imminent danger inevitably leads to changes in the social organization. Positioned as a border area with ever-present army which had to be fed, it seems that the probable depopulation of the area was not accompanied by a simultaneous abandonment of agricultural or livestock production or levels of land-use activities don't correspond well with the depopulation process. Moreover, indirect information in preserved Ottoman documents indicates larger number of watermills which stands in disproportion to the data on cereals production (Buzov 2003: 241).

Obviously, army support necessarily required maintaining livestock farming, and partly a crop production in the area between the Kupa and Una rivers. At the end of the 17th

i trputac (*Plantago lanceolata* tip), a na njih se krajem 14. stoljeća nadovezuje pelud dikice (*Xanthium spinosum* type) i lobodnjača (Chenopodiaceae) te, nešto kasnije, pelina (*Artemisia*). Sve ove vrste ukazuju na ispašu ili ratarstvo, ili općenito čovjekom utjecano stanište (Behre 1981; Sud-Picon et al. 2006; Li et al. 2008; Brun 2011). Literaturni podaci govore u prilog snažnoga ekonomskg razvoja središnje Hrvatske početkom ove zone, što se ogleda u izgradnji cistercitskoga samostana u Topuskom i izgradnji katoličke crkve na Nikolinom brdu tijekom 13. stoljeća, što je uostalom pružilo okvir za formiranje naselja Topusko koje će se uskoro razviti u trgovišće (Jakaša Borić, Dumbović Bilušić 2008). Godine 1303. osnovan je samostan na Petrovcu (Petrova Gora), a nedaleko od Blatuše nalazio se grad Perna, danas zaselak, kojem su kraljevske povlastice dodijeljene davne 1225. godine (Škiljan 2007: 91). Gorički arhiđakonat, čija jurisdikcija rubnim dijelom obuhvaća istraživano područje, broji više od 40 crkvi u prvoj polovici 14. stoljeća (Razum 2003; Vedriš 2016). Sve to ukazuje na pojačanu gospodarsku aktivnost tijekom kasnoga srednjeg vijeka, što se odražava i u sastavu palinomorfa donjega dijela ove zone. Uostalom, područje između Kupe i Une tijekom kasnoga srednjeg vijeka i ranoga novog vijeka vjerojatno je bilo među najgušće naseljenim područjima Ugarsko-hrvatskoga kraljevstva (Vedriš 2016). Međutim, u drugoj polovici 15 stoljeća, zbog osmalijskih upada, ekonomija Topuskog počinje slabiti te se trgovina dolinom rijeke Une uglavnom prekida (Adamček 1969), što kulminira sredinom 16. stoljeća kada grada Perna biva spaljen (Škiljan 2007: 8, 92). Općenito situacija ostaje nestabilna do početka 18. stoljeća. Iako se razdoblje osmanlijskih osvajanja povezuje s devastacijom i razaranjem pograničnoga područja, koje se ne treba shvatiti kao jasno definiranu linija već više kao pojas „ničije zemlje" ili „potonulog svijeta" (Vlašić 2017), peludni dijagrami ukazuju na stanje stvari ponešto drugačije od onoga koje se obično podrazumjeva. Zasigurno je točno pretpostaviti kako ratna razaranja uzrokuju depopulaciju koja dovodi do pada gospodarske (poljoprivredne) aktivnosti (Šarić 2003: 245, 247), međutim u peludnom dijagramu ne zapaža se izostanak antropogenih indikatora, niti njihove krivulje postaju prekinute tijekom osmanlijskih prodora. Jedno od mogućih objašnjenja je da rezolucija našega istraživanja ne omogućuje preciznu identifikaciju gospodarskih prilika za kratke vremenske odsjećke. Drugo objašnjenje je da na širem području Topuskog i Perne poljoprivredne aktivnosti nisu zamrle, premda pad udjela i koncentracije pougljenjenih čestica ukazuju na to. Ove dvije tvrdnje nisu kontradiktorne jer opsadno stanje neizbježno dovodi do promjena u društvenoj organizaciji. Pozicionirano u graničnome području sa stalno prisutnom vojskom koju je valjalo hraniti, čini se da depopulacija širega područja Topuskog nije praćena istovremenim napuštanjem ratarske ili stočarske proizvodnje, odnosno da zemljoradnju i depopulaciju valja promatrati kao dva, ne posve usklađena, procesa. Štoviše, neke informacije sačuvane u osmalijskim dokumentima neizravno ukazuju na veći broj vodenica (mlinica) no što je očekivano s obzirom na podatke o uzgoju i proizvodnji žitarica (Buzov 2003: 241).

Očito, smještaj vojske u pograničnome području nužno zahtijeva održavanje stočnoga fonda i djelomičnu proizcentury the Ottomans withdrew to Bosnia and the Vlachs inhabitans mainly settled in the liberated area (Škiljan 2007: 9; Budak 2007: 110). During this period grape pollen (*Vitis*) is noticed. As the Vlach population was predominantly cattle-breeding (Blanc 2003: 131), maybe changes in ethnical composition led to the neglect of arable farming which can partly explain why cerealia pollen is lacking from the peat sequence from the 18th century. During the 19th century, the Military Frontier had higher developed animal husbandry and fruit production, especially plums, then 'civilic' Croatia (Pavličević 1988). Also, that part of Habsburg Monarchy / Austro-Hungarian Empire was among the last in terms of forest cover proportion area, and Glina was the most populated town in the entire Military Frontier. From that period the first occurrence of buckwheat (*Fagopyrum*) in the pollen diagrams can be noticed.

4.3.3. *Xanthium spinosum* Pollen Type and Its Dubious Position in Pollen Records

Accidental findings of *Xanthium spinosum* type in the 9th century in our study site, together with continuous occurrence and high abundance from the 14th/15th century onwards, can be compared with similar cases from Central Europe before Columbian discoveries (Kołaczek et al. 2010; Beug 2011), but usually is neglected and is still a question open for discussion. According to Beug (2015), *Xanthium spinosum* type include pollen of *Ambrosia artemisiifolia*, *A. maritima*, *A. trifida* and *Xanthium spinosum*, all alien taxa for Europe except *A. maritima*. A usually high value of this pollen type marks European 19th and/or 20th century because, according to recent knowledge, *Xanthium spinosum* was introduced from South America via Europe to United Kingdom by 1713 and was later naturalised (*Xanthium spinosum* 2020). The first occurrence of *Ambrosia* taxa can be placed in the 17th or the 18th century (*Ambrosia artemisiifolia* 2020). Even *Ambrosia artemisiifolia* and *Xanthium spinosum* were noticed on Croatian territory in the 19th or the 20th centuries, respectively (Mitić 2014a: 64–69; 2014b: 284–287), in the 16th century Mathioli already wrote a note on *Xanthium* growth in Europe (Jankovska 2011). Jankovska (2011) supports the evaluation of the taxon as an archaeophyte, i.e. a plant already introduced to Europe by pre-Columbian times. Moreover, Nosova et al. (2017) recorded *Ambrosia* pollen before a new era, suspecting that this species become present on the European continent during or after Early Modern Period. Therefore, although the early appearance of pollen of this species can be interpreted as an error in age dating of the soil layers (Kołaczek et al. 2010) or disturbances in the peat accumulation, the appearance of this species remains intriguing. Phytogeographical analysis of some plants has already been shown as dubious, eg. *Datura stramonium* is treated as Asian or American taxon (Mitić 2014c: 134–137) and originated either in Mexico or Caspian/ India region (Busia, Heckels 2006). On the other hand, some of the plants like *Chamomilla suaveolens* (Purxh) Rydb. have both American and Asian distribution (Boršić 2014: 106–109),

vodnju usjeva. Ipak, krajem 17. stoljeća dolazi do povlačenja Osmanlija u Bosnu te vlaški stanovnici uglavnom naseljavaju oslobođeno područje (Škiljan 2007: 9; Budak 2007: 110). U tom razdoblju primjećuje se pojava peluda grožđa (*Vitis*). Kako je vlaška populacija bila pretežno orjentirana na stočarstvo (Blanc 2003: 131), možda je napuštanje ratarske proizvodnje uzrokovano promjenom etičkoga sastava stanovništva dio objašnjenja zašto pelud žitarica nedostaje u segmentu jezgre datiranom u 18. stoljeće. Tijekom 19. stoljeća Vojna krajina ima razvijenije stočarstvo i voćarstvo, osobito uzgoj šljiva, od 'građanske' Hrvatske (Pavličević 1988). Također, taj dio Habsburške Monarhije/Austro-Ugarskoga Carstva bio je među posljednjima po površini nastavanoj šumskom vegetacijom, a nedaleka Glina bila je najnaseljeniji grad u cijeloj Vojnoj krajini. U tome razdoblju može se primijetiti i prva pojava heljde u peludnom dijagramu.

4.3.3. *Xanthium spinosum* peludni tip i dvojbe oko njegove pojave u peludnom dijagramu

Pojava dikice (*Xanthium spinosum* peludni tip) na istraživanome području tijekom 9. stoljeća, zajedno s kontinuiranom pojavom i visokom zastupljenošću iste od 14./15. stoljeća nadalje, može se usporediti sa sličnim zapažanjima na području srednje Europe prije Kolumbovoga otkrića Amerika (Kołaczek et al. 2010; Beug 2011). Međutim, takva rana pojava ovoga peludnog tipa obično se zanemaruje i predstavlja otvoreno pitanje za raspravu. Prema Beug (2015), *Xanthium spinosum* tip uključuje pelud svojti *Ambrosia artemisiifolia*, *A. maritima*, *A. trifida* i *Xanthium spinosum*, odreda strane svojte za područje Europe izuzev *A. maritima*. Obično visoki udio ovoga peludnog tipa označava prijelaz iz 19. na 20. stoljeće jer je, prema novijim saznanjima, svojta *Xanthium spinosum* uvezena iz Južne Amerike preko Europe do Velike Britanije oko 1713. godine, a potom je naturalizirana (*Xanthium spinosum* 2020). Pojava svojti roda *Ambrosia* na europskome tlu može se pak smjestiti u 17. ili 18. stoljeće (*Ambrosia artemisiifolia* 2020). Iako su i *Ambrosia artemisiifolia* i *Xanthium spinosum* zamijećeni na hrvatskom ozemlju u 19., odnosno 20. stoljeću (Mitić 2014a: 64–69; 2014b: 284–287), Matthioli još u 16. stoljeću piše opasku o prisutnosti roda *Xanthium* u Europi (Jankovska 2011). Jankovska (2011) podržava mišljenje da bi dikicu valjalo smatrati arheofitom, odnosno svojtom koja je u Europi od pretkolumbovskoga vremena. Štoviše, Nosova et al. (2017) uočili su akumuliranu pelud ambrozije u sedimentu datiranom prije nove ere dovodeći u sumnju prisutnost ove svojte tek od razdoblja novoga vijeka. Premda se rana pojava *Xanthium spinosum* peludnoga tipa može opravdati pogreškom u preciznosti radiodatiranja starosti odsječaka sedimenta (Kołaczek et al. 2010) ili poremećajima u kontinuitetu akumuliranja treseta, rana pojava ovoga peludnog tipa svejedno je neočekivana. Fitogeografska analiza već je pokazala dvojbenost u tumačenju porijekla nekih vrsta, npr. bijeli kužnjak (*Datura stramonium*) tretira se kao azijski ili američki takson (Mitić 2014c: 134–137) te prirodni areal ove svojte obuhvaća ili područje Kaspijskoga jezera/Indije ili pak Meksika (Busia, Heckels 2006). S druge strane, neke vrste poput žute kamilice (*Chamomilla suaveolens*) imaju i američku i azijsku rasprostranjenost (Boršić 2014: 106–109), Dakle, je li moguće da

So, is it the same with plants that belongs to *Xanthium* or *Ambrosia* genus? Is it possible that *Ambrosia artemisiifolia* has American and Euroasiatic distribution naturally? Or that some other taxon of the genera *Ambrosia* and *Xanthium* was more widespread in the past? Is it possible that pollen from some other plants, not yet included in the pollen atlases, belong to *Xanthium spinosum* pollen type? Obviously, more investigation about this question needs to be conducted in future.

4.3.4. Environmental Changes on the Mire Surface

Sharp decline of *Sphagnum* spores in the late 14th century, accompanied by simultaneously sharp increase of sedge pollen marked the transition from ombrotrophic bog to more minerotrophic poor fen. Succession pattern can be changed or induced by climate, fires, flooding, land uplifting, or changes in catchment water (Tuittila et al. 2007) which may result in an accelerated or reversed hydroseral succession (Hughes, Dumayne-Peaty 2002; Rydin, Jeglum 2006; McClymont et al. 2008). So, it seems that transition which occured during the last 600 years, from ombrotrophic to more minerotrophic conditions, can be explained in different ways and will be discussed shortly here. There are many examples when drier conditions trigger the decline in *Sphagnum* abundance (eg. Latto, Fitter 1989; Mawby 1995; Gałka et al. 2017b) with simultaneous increase in sedges pollen (Stallegger 2008; Gałka et al. 2017a; 2017b). In very well studied drier parts of Britain, where ombrogenous bog is unable to develop, complexes of reed swamp, sedge fen, carr and *Molinia-Myrica-Sphagnum* communities occurred. To this type of mire linked term "valley bogs" (Newbould, Gorham 1956) is accepted and adopted in Central Europe (Kulczynski 1949). This mosaic of wetland communities is very similar to nowadays situation on the study site in Croatia. In general, drier conditions on a bog surface (increasing the depth of the oxygenated acrotelm) will increase decomposition rates and increase nitrogen mineralisation (Anderson 2002). Secondly, dry peatland surface maintenance burning episodes and fire activity may release enough nutrients to favor succession to more minerotrophic peatlands (Kost et al. 2007). Although charcol particles were not numerous as in the previous (sub)zones, even lacking during the 16th century, their decrease could be linked to stronger combustion and not only to lower frequency of burning. Anthropogenic activities like mowing followed by burning counteracted acidification but increased nutrient availability and led to dominance by highly productive graminoids (Craft 2016: 178). Jassey et al. (2017) also showed that vascular plants benefit from decreasing water level with an increase of graminoids, especially *Eriophorum vaginatum*.

The opposite scenario is also possible. Although ombrotrophication process will be supported when high precipitation is combined with low evapotranspiration (Rydin, Jeglum 2006: 131) there is some sporadic evidence that the same process can be ceased by flooding episodes. Granath

svojte koje pripadaju rodovima *Xanthium* ili *Ambrosia* također imaju dvojbeno porijeklo? Je li moguće da *Ambrosia artemisiifolia* zapravo ima američku i euroazijsku distribuciju? Ili pak da je neka svojta iz rodova *Ambrosia* i *Xanthium* bila raširenija u prošlosti? Postoji li mogućnost da pelud nekih drugih, peludnim atlasima ne obuhvaćenih svojti, pripada *Xanthium spinosum* peludnome tipu? Očito, potrebno je prikupiti dodatne podatke kako bi se ovo pitanje razmrsilo u budućnosti.

4.3.4. Okolišne promjene na području samoga creta

Nagli pad udjela spora maha tresetara (*Sphagnum*) u kasnom 14. stoljeću, uz istovremeni izraziti porast spora paprati, označuje prijelaz iz ombrotrofnog u siromašni minerotrofni prijelazni cret. Obrazac sukcesije se općenito mijenja, odnosno potiče klimatskim promjenama, požarima, poplavama, uzdizanjem kopna ili promjenama u slivnovodnom području (Tuittilaet al. 2007), što može rezultirati ubrzanom ili obrnutom hidroserijskom sukcesijom (Hughes, Dumayne-Peaty 2002; Rydin, Jeglum 2006; McClymont et al. 2008). Stoga se čini da tranziciju tijekom posljednjih 600 godina, od ombrotrofnih do prevladavajućih minerotrofnih uvjeta, možemo sagledati i razjasniti na različite načine, što je i svrha ovoga odlomka. Mnogo je primjera kada suši uvjeti postaju okidaći nestajanja maha tresetara na određenom području (npr. Latto, Fitter 1989; Mawby 1995; Gałka et al. 2017b), uz istovremeno povećanje udjela šaševa (Stallegger 2008; Gałka et al. 2017a; 2017b). U vrlo dobro potkrijepljenim istraživanjima suših dijelova Britanije, gdje se ombrogeni cretovi ne mogu razviti, nalazimo kompleksna močvarna staništa s razvijenim tršćacima, šaševima, grmoliko-drvenastom vegetacijom (najčešće s prevlašću johe i vrba) te *Molinia-Myrica-Sphagnum* zajednice. Ovakav tip creta naziva se „dolinskim cretom" (Newbould, Gorham 1956) ili „cretom udoline", a pojam je prihvaćen i usvojen u srednjoj Europi (Kulczynski 1949). Takav mozaik staništa neodoljivo podsjeća na trenutno stanje creta u Blatuši. Općenito, suši uvjeti na površini creta (povećana dubina oksigeniranog akrotelma) povećati će stopu raspadanja organske tvari i mineralizaciju dušika (Anderson 2002). Ujedno, suša površina creta olakšava požarne epizode, a vatrom zahvaćeno područje oslobođa dovoljno nutrijenata što potiče sukcesiju prema minerotrofnim cretovima (Kost et al. 2007). Iako pougljenjene čestice nisu brojne kao u prethodnim (pod)zonama, a čak izostaju tijekom 16. stoljeća, pad njihovoga udjela i koncentracije nužno ne znaći izostanak ili nižu učestalost požara, već može biti posljedica jačega izgaranja organske tvari (požari visokoga intenziteta). Antropogene aktivnosti, primjerice košnja nakon koje slijedi spaljivanje otkosa, sprečavaju zakiseljavanje supstrata, a povećana dostupnosti hranjivih tvari dovodi do prevlasti visoko produktivnih travolikih svojti (Craft 2016: 178). Jassey et al. (2017) također su pokazali da vaskularne biljke imaju koristi od snižavanja razine vode prilikom čega se povećava udio, primjerice, cretne suhoperke (*Eriophorum vaginatum*).

Obrnuti scenarij također je moguć. Iako povećana količina oborina podupire ombrotrofikaciju u uvjetima niske evapotranspiracije (Rydin, Jeglum 2006: 131), postoje neki sporadični dokazi da isti proces može biti zaustavljen uslijed poplavnih epizoda. Granath et al. (2010) su pokazali da čak i kratko razdoblje potapljanja maha tresetara može uzrokoet al. (2010) has shown that even a short period of submergence can be lethal for some *Sphagnum* taxa in a way that the ombotrophication process is stopped. Also, Umeda et al. (1986), Svensson (1988), Glaser et al. (1990) noticed retrogression on the mire surface – transition from bog to fen due to flooding events. Haliuc et al. (2017) observed for Central-Eastern Europe drier conditions during the Little Ice Age which are in contrast with the situation in the Alps (Wirth et al. 2013) – these differences highlighted all the complexity of hydrological conditions during the last half millennia. As the studied site is on a one-third distance between Alps and Carpathians, the key question is whether wet or dry conditions prevailed in the northernwest part of the Balkan Peninsula. Today the mire surface is overgrown by *Molinia*, a grass which grows on sites with high water fluctuation which often falls below the shallow root and peat layer (Rybníček et al. 1984: 15–68). This taxon is best adapted to water-table fluctuations, fire action, aeration and mineralization of the peat substrate which is increased by peripheral drainage (Deuse 1949; Rutter 1955; Webster 1962). However, its high abundance may be a result of more recent digging of canals, or the use of peat than the drought indicator caused by lower precipitation. A slightly different moisture level is required with stands of *Typha latifolia* and *Phragmites australis* (reed), mostly found at a water depth of 10–50 cm. However, both taxa tolerate significant fluctuations in water column height (Šumberová 2011a; 2011b). Moreover, when reed plants are completely flooded (especially young shoots) during floods, the plants die (Zákravský, Hroudová 2007) and habitat of *Typha latifolia* quite often dry out during the summer. Nevertheless, *Typha* shows strong increase at permanently inundated sites (Timmermann et al. 2006). Its constant presence at the study site during this zone, accompanied by a short appearance of *Myriophyllum spicatum* pollen, suggest the occurrence of small temporary shallow water body. Both taxa indicate a higher moisture level during the first half of this zone similarly to the nowadays frequent *Carex lasiocarpa*, mostly found on sites where water table is slightly above the soil surface for most of the year (Hájková 2011: 534–537). As was explained above, the most of recent growing sedges taxa have ambiguous position when we are talking about their water requirements, but prevailed during a higher moisture level. A short appearance of amoebae *Hyalosphenia papilio* and *Amphitrema flavum* (Lamentowicz et al. 2007), accompanied by some discontinuous occurence of *Spirogyra* and Diatomeae confirms wetter episodes. Luckily, some information about weather conditions from Croatia or bordering area during the Little Ice Age (LIA) is known from written sources (Šušnjara 2003; Mrgić 2018). Excessively wet (years 1770, 1778, 1785, 1789) or very warm summers with lack of precipitation (years 1772, 1774, 1779, 1783, 1788, 1797) occurred in eastern Croatia (Mrgić 2018). Similar extreme circumstances with, for example, episodes of snowfall during the

vati ugibanje nekih svojti roda *Sphagnum* čime se ujedno i proces ombrotrofikacije zaustavlja. Također, Umeda et al. (1986), Svensson (1988), Glaser et al. (1990) primijetili su retrogresiju – prijelaz iz uzdignutoga prema prijelaznome cretu uslijed plavljenja površine creta. Haliuc et al. (2017) ističu suše uvjete na području srednjoistočne Europe tijekom malog ledenog doba, što je u suprotnosti s opažanjima na području Alpa (Wirth et al. 2013) – te razlike naznačuju svu složenost hidroloških uvjeta tijekom posljednjih pola tisućljeća. Kako je područje uzorkovanja naše jezgre sedimenta na trećini udaljenosti između Alpa i Karpata, ključno je pitanje je li u krajnjem sjeverozapadnom dijelu Balkanskoga poluotoka tijekom LIA anomalije prevladavao sušniji ili vlažniji klimatski obrazac. Danas je površina creta obrasla beskoljenkom (*Molinia*), svojtom koja nastava mjesta visoke fluktuacije vode koja najčešće pada ispod sloja rizosfere i tresetnog supstrata (Rybníček et al. 1984: 15–68). Ova svojta trave najbolje je prilagođena promjenama razine vodnoga lica, požarima, aeraciji i mineralizaciji tresetne podloge, procesima koje periferna drenaža potiče (Deuse 1949; Rutter 1955; Webster 1962). Međutim, proraštenost creta beskoljenkom možda je više rezultat melioracijskih zahvata ili vađenja tresetnoga materijala od strane čovjeka nego indikator zasušivanja uzrokovanoga manjom količinom oborina. Nešto drugačija razina zasićenosti tla vodom potrebna je za razvoj sastojina širokolisnoga rogoza (*Typha latifolia*) ili trske (*Phragmites australis*), vrsta koje uglavnom nalazimo na staništima s vodnim stupcem dubine od 10–50 cm. Međutim, obje svojte toleriraju značajna kolebanja visine vodnoga lica (Šumberová 2011a; 2011b). Štoviše, kada je trska potpuno poplavljena (posebice mladi izbojci), biljke ugibaju (Zákravský, Hroudová 2007), a i staništa širokolisnoga rogoza nerijetko se ljeti isuše. Ipak, rogoz pokazuje snažnu konkurentnost na trajno plavljenim mjestima (Timmermann et al. 2006). Kontinuirana prisutnost peluda rogoza u sedimentu ove zone, nadopunjena pojavom peluda klasastoga krocnja (*Myriophyllum spicatum*), ukazuje na kratkotrajno postojanje plitkoga vodenog tijela na površini creta. Obje spomenute vrste ukazuju na veću zasićenost tla vodom tijekom prve polovice Zone 2. Na slično navodi danas poveća populacija končastog šaša (*Carex lasiocarpa*), vrste koja se uglavnom bilježi na mjestima gdje je vodeno lice iznad površine tla veći dio godine (Hájková 2011: 534–537). Kao što je prethodno objašnjeno, i većina danas rastućih šaševa na cretu ima dvojak položaj kada govorimo o njihovim zahtjevima za zasišćenošću tla vodom, premda prevladavaju tijekom više razine vlažnosti. Kratkotrajna pojava ameba *Hyalosphenia papilio* i *Amphitrema flavum* (Lamentowicz et al. 2007), nadopunjena povremenom pojavom algi *Spirogyra* i Diatomeae, potvrđuju epizode izrazite vlažnosti. Srećom, neke informacije o vremenskim prilikama tijekom malog ledenog doba na području Hrvatske ili u pograničnom području poznate su iz pisanih izvora (Šušnjara 2003; Mrgić 2018). Pretjerano kišne godine (1770., 1778., 1785., 1789.) ili godine s vrlo toplim ljetima i nedostatkom padalina (1772., 1774., 1779., 1783., 1788., 1797.) pogodile su istočnu Hrvatsku tijekom novoga vijeka (Mrgić 2018). Slične ekstremne klimatske prilike, primjerice s epizodama snježnih padalina tijekom ljetnih sezona, zabilježene su u franjevačkim kronisummer season were recorded in the Franciscan chronicles in neighboring Bosnia and Herzegovina, in the area close to Croatian border (Šušnjara 2003). Dry and wet years in the last four centuries were confirmed for the Balkans by dendroclimatological analysis (Levanič et al. 2013; Hafner et al. 2014) accompanied by extreme high and very low values of sunshine hours, the latter connected to volcanic eruptions in the past (Poljanšek et al. 2013). Moreover, the cultivation of sensitive crop varieties and *Juglans* (Mercuri et al. 2013b; Gogou et al. 2016) along the Sava river (Kulkarni et al. 2018) or spread of rice (*Oryza sativa*) in the Balkans can be attributed to both the wetter climate regime during LIA and to its extensive use in the Ottoman cuisine (Sharma 2010). All these support the idea that if LIA was described like cooler and drier period for Central Europe, the western part of the Balkans did not suffer a drought. More likely the last 600 years can be described as a period with extreme episodes of flooding events followed by drought. For this reasons, strong mineralisation on broader mire area occurred, marked by very high percentage of sedge pollen, but still some ombrotrophic taxa are preserved nowadays on the study site, eg. *Sphagnum megallanicum*, *Sphagnum capillifolium* and S. *rubellum* (Alegro, Šegota 2009). Stallegger (2008) show that when preturbation ceases, ephemeral pioneeric vegetation is quickly displaced by better competitors, like taller Cyperaceae. Still, a sharp decline of *Sphagnum* in the late 14th and during the 15th century, and its very low value from the very late 18th to the 20th century is accompanied by a sharp increase of *Assulina muscorum* and *A. seminulum* in the 17th century, thecoamoebae characteristic for drier poor fens (van Geel et al. 1989) or general low nutrient content in *Sphagnum* dominated mire. Lamentowicz et al. (2015) showed that both species are correlated with low depth to the water table. A similar rapid increase of *Assulina muscorum* during the last 300 years, after the expansion of vascular plants, was observed in Poland by Marcisz et al. (2019). It seems that *Assulina* can quickly migrate to dry habitats (Lamentowicz, Mitchell 2005). This reflects the complexity of the study site (ombrotrophy vs. minerotrophy, dry vs. wet) on the broader mire area.

Still, higher moisture level prevailed, probably caused by prolonged snow retention, higher amount of precipitation or a decrease in evapotranspiration caused by lower temperatures. However, it is impossible to conclude if retrogression from ombrotrophy to mineritrophy during this zone is more a result of changing of precipitation, flood frequencies caused by river Čemernica or human impact reflected in peat burning or even peat mining. Although this one-site study maybe doesn’t reflect the regional hydrological regime and is more a result of specific topographical features accompanied by fire regime or other human impact on the study site, a more humid LIA period than stated for Romania (Feurdean et al. 2015) is also indicated for Serbia (Kulkarni et al. 2018) highlighting possibly decreasing moisture gradient from western to eastern part of the Balkans.

kama susjedne Bosne i Hercegovine za područja uz samu granicu s Hrvatskom (Šušnjara 2003). Izuzetno suhe i vlažne godine potvrđene su kroz posljednja četiri stoljeća na Balkanu dendroklimatološkom analizom (Levanič et al. 2013; Hafner et al. 2014) od kojih se neke odlikuju ekstremno visokim ili vrlo niskim trajanjima sunčanih sati – potonji ishod povezan je s vulkanskim erupcijama u prošlosti (Poljanšek et al. 2013). Štoviše, uzgoj osjetljivih usjeva i oraha (Mercuri et al. 2013b; Gogou et al. 2016) uz rijeku Savu (Kulkarni et al. 2018) ili širenje riže (*Oryza sativa*) na Balkanu može se pripisati vlažnijem klimatskom režimu tijekom LIA anomalije te obilnoj upotrebi spomenutih biljnih kultura u osmanlijskoj kuhinji (Sharma 2010). Sve to podržava ideju da, ako se malo ledeno doba opisuje kao hladnije i sušnije razdoblje za područja središnje Europe, zapadni dio Balkana nije pretrpio sušu. Prije bi se posljednjih 600 godina moglo opisati kao razdoblje s ekstremnim epizodama poplavnih događaja nakon čega slijede razdoblja suše. Nevedeni razlozi doveli su do snažne mineralizacije na širem području creta obilježene vrlo visokim postotkom peluda šaševa, ali ipak uz očuvanje nekih ombrotrofnih svojti koje su i danas prisutne, npr. *Sphagnum megallanicum*, *S. capillifolium* i *S. rubellum* (Alegro, Šegota 2009). Stallegger et al. (2008) ukazuju da kada poremećaji na staništu prestanu, privremena pionirska vegetacija biva brzo zamjenjena kompetititorskim vrstama kao što su zajednice visokih šaševa. Strmoglavi pad udjela maha tresetara krajem 14. i tijekom 15. stoljeća, uz vrlo niske vrijednosti istoga od kraja 18. do 20. stoljeća, prati nagli porast udjela okućenih ameba *Asulina muscorum* i *A. seminulum* u 17. stoljeću. Obje vrste ameba karakteristične su za suhe siromašne prijelazne cretove (van Geel et al. 1989) ili općenito nizak sadržaj hranjivih tvari u sfagnumskim cretovima. Lamentowicz et al. (2015) pokazali su kako su amebe roda *Assulina* u korelaciji s malom udaljenošću do vodnog lica. Značajno povećanje udjela vrste *Assulina muscorum* nakon ekspanzije vaskularnih biljaka u posljednjih 300 godina, slično našem primjeru, primjećeno je u Poljskoj (Marcisz et al. 2019). Čini se da *Assulina* može brzo migrirati na suha staništa (Lamentowicz, Mitchell 2005). To odražava svu mozaičnost mikrostaništa (ombrotrofija vs. minerotrofija, suho vs. mokro) koji se istovremeno mogu nalaziti na području creta.

Ipak, glavninom ove zone prevladava pojačana vlažnost supstrata, vjerojatno uzrokovana dugotrajnim zadržavanjem snijega, većom količinom padalina ili smanjenom evapotranspiracijom zbog nižih temperatura. Doduše, nemoguće je sa sigurnošću zaključiti je li retrogresija od ombrotrofije prema minerotrofiji tijekom ove zone više posljedica promjene količine padalina, učestalosti plavljenja riječice Čemernice ili ljudskoga utjecaja koji se ogleda u paljenju ili kopanju treseta. Premda ova studija možda ne odražava regionalni hidrološki režim i više je rezultat specifičnih topografskih značajki upotpunjenih požarnim epizodama ili drugim ljudskim utjecajem na samome cretu, vlažniji klimatski obrazac tijekom malog ledenog doba, od utvrđenog za Rumunjsku (Feurdean et al. 2015), indiciran je na području susjedne nam Srbije (Kulkarni et al. 2018), što dodatno naglašava mogući padajući gradijent vlažnosti od zapadnoga prema istočnom dijelu Balkana.

5. CONCLUSION

In short, three different pollen assemblage (sub)zones can be distinguished: a dominance of alder-beech/oaks from the 2nd to the middle of the 7th century – Zone 1a; grasses-beech/oaks from middle of 7th to the end of the 13th century – Zone 1b; grasses-hornbeam/oaks from the beginning of 14th to the beginning of the 20th century – Zone 2. On mire site, transition from alder carr to poor fen occured during 6th century (Zone 1a) followed by succession from poor fen to (raised?) bog in the 11th century (Zone 1b) and finally retrogression to more minerotrophic poor fen occured from the late 14th century to the beginning of 20th century (Zone 2). Microcharcoal and macrocharcoal curves showed the same shape across the whole analyses core, questioning whether customary charcoal size (microcharcoal 10 – 100 μm, macrocharcoal > 100μm) reflects regional and local fire events properly. Charcoal percentages (ratio) and abundance (concentrations) were highest during the Zone 1b, which mostly coincides with wetter Medieval Climate Anomaly on our research area. Retrogression on mire site from ombrotrophy to minerotrophy at the beginning of Little Ice Age is probably caused by fluctuation in moisture level, with frequent flooding events. Direct human impact on vegetation can be traced from the 14th century onwards when cerealia pollen for the first time occurred, accompanied by continuous curves and/or higher percentages of secondary anthropogenic indicators and higher pollen richness, as well.

Although this paper provides introduction to environmental changes on Central Croatia during the last two millennia and it is the first attempt to evaluate palaeoenvironment by using different proxies, a whole set of additional analysis is needed to describe hydrological regime, fire history or trophic state of mire surface more accurately and with greater certainty. Nevertheless, as was stressed above, pollen assemblage zones give us information about plant cover and changes in abundance of arboreal, non-arboreal and local taxa, caused by human impact or climate changes. The abundance and concentrations of charcoal particles and non-arboreal pollen can indicate the level of anthropogenic pressure that is not always accompanied by significant changes in vegetation structure and composition, just as high proportions of grass pollen may better reflect natural succession processes than necessarily indicate habitat opening or forest clearing in a wider area. The appearance of some palynomorphs indicates the presence of species that no longer grow on the mire surface or are rarely recorded, such as *Lycopodiella inundata* and Antocerotidae. Differentiation between human impact or climate change, however, still remains difficult.

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5. ZAKLJUČAK

Na istraživanome području mogu se razlikovati tri (pod) zone akumulacije peluda: joha-bukva/hrastovi dominiraju Zonom 1a, od 2. do sredine 7. stoljeća; trave-bukva/hrastovi dominiraju Zonom 1b, dakle od sredine 7. do kraja 13. stoljeća; trave-grab/hrastovi dominiraju Zonom 2, od početka 14. do početka 20. stoljeća. Lokalno na Blatuši tijekom 6. stoljeća odvija se prijelaz iz johom obrasloga tresetišta prema siromašnom minerotrofnom prijelaznom cretu (Zona 1a), a potom slijedi sukcesija prema ombrotrofnom (uzdignutom?) cretu u 11. stoljeću (Zona 1b) i konačno retrogresija prema siromašnom minerotrofnom prijelaznom cretu krajem 14. stoljeća (Zona 2), što odgovara uvjetima na staništu sve do početka 20. stoljeća. Krivulje omjera i koncentracija mikro (10 – 100 μm) i makro (> 100 μm) pougljenjenih čestica pokazuju podjednak oblik duž cijele analizirane jezgre, čime se dovodi u pitanje jesu li izabrane veličinske frakcije zbilja valjani pokazatelji lokalnih, odnosno regionalnih požara. Postoci (omjer) i abundancija (koncentracije) pougljenjenih čestica bili su najviši tijekom Zone 1b, što se uglavnom podudara s vlažnijom srednjovjekovnom klimatskom anomalijom na istraživanome području. Retrogresija od ombrotrofije do minerotrofije početkom malog ledenog doba vjerojatno je uzrokovana kolebanjem razine vlažnosti, uz brojne poplavne epizode. Izravni utjecaj čovjeka na vegetaciju može se pratiti od 14. stoljeća nadalje kada se po prvi puta pojavljuje pelud žitarica, ujedno praćen kontinuiranim krivuljama i/ili većim udjelom sekundarnih antropogenih indikatora kao i većim peludnim bogatstvom u odnosu na ranije (pod)zone.

Iako ovaj rad daje okvirni pregled promjena okoliša na području središnje Hrvatske tijekom posljednja dva tisućljeća, a ujedno predstavlja i prvi pokušaj vrednovanja paleookolišnih promjena korištenjem različitih pokazatelja, čitav niz dodatnih analiza potreban je kako bi se promjene hidrološkoga režima, učestalost i jačina požara ili trofičko stanje samoga creta mogle preciznije i s većom sigurnošću utvrditi. Uprkos tome, zone akumulacije peluda daju nam informacije o biljnom pokrovu i promjenama u učestalosti drvenastih (arborealnih), zeljastih (neaborealnih) i lokalnih palinoloških vrsta uzrokovanih ljudskim utjecajem ili klimatskim promjenama. Povišeni omjeri i koncentracije pougljenjenih čestica i peluda nedrvenastih vrsta mogu ukazivati na stopu antropogenoga pritiska koja nije uvijek popraćena jednako značajnim promjenama u strukturi i sastavu vegetacije, kao što visoki udjeli peluda trave mogu ponekad bolje odražavati procese prirodne sukcesije nego što nužno ukazuju na otvaranje staništa ili krčenje šuma na širem području. Pojava nekih peludnih tipova dokazuje prisutnost vrsta koje više ne rastu na samom cretu u Blatuši ili se rijetko bilježe, kao što su cretna crvotočina (*Lycopodiella inundata*) i antocerote (Antocerotidae). Razlikovanje antropogenih od klimom uzrokovanih procesa, međutim, i dalje ostaje zamršeno.

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