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ORIGINAL ARTICLE

Palaeoecological evidence from buried topsoils and colluvial layers at the Bronze Age fortification Corneşti-Iarcuri, SW Romania: results from palynological, sedimentological, chronostratigraphical and plant macrofossil analyses

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Abstract

Located in the Romanian Banat region, the Late Bronze Age (LBA) fortification Corneşti-Iarcuri is the largest known prehistoric settlement in Europe. Archaeobotanical and geoarchaeological investigations have targeted the reconstruction of vegetation, land use practices and subsistence strategies at the site, together with related human impact and environmental changes in the wider study area. Since colluvia constitute valuable archives in terms of landscape history and anthropogenic disturbance, one major focus was put on floodplain profiles. In the valleys, two generations of colluvium prevailed which were separated by fossil topsoils. Based on several radiocarbon datings, a chronology of events, including distinct phases of geomorphological activity and stability, has been established. Some of the buried palaeosurfaces contained pollen in sufficient concentrations to confirm off-site data from the Vinga area, where the regional vegetation during the Middle Copper Age consisted of *Tilia*-dominated woodlands with steppe elements. Following a major Late Copper Age deforestation phase that also led to considerable soil erosion, the gradual formation of a cultural landscape is documented by a progressive decline in tree cover in which *Quercus* gained relative importance, and a continuous presence of land use indicators. Plant macro-remains from archaeological excavations underpin both the openness of the semi-natural woodlands during the pre-fortification era and the increase of animal husbandry and farming in the LBA. Despite evident settlement pressure, it proved to be a geomorphologically stable phase. Towards the Early Iron Age, the values of anthropogenic markers in on-site pollen spectra rose to values comparable to those in surface samples.

Keywords Bronze Age fortification · Palynology · On-site archives · Land use changes · SW Romania

Introduction

Europe's largest known fortified settlement, Corneşti-Iarcuri (Corneşti is the name of the neighbouring village, while Iarcuri refers to the archaeological site itself. In this text, 'Corneşti' and 'Corneşti-Iarcuri' are used synonymously), is located approximately 20 km north of the town of Timişoara (Timiş county) in Romania's Banat region. The Banat forms the south-eastern part of the Pannonian Plain, bordered by the rivers Tisza (W), Danube (S), Mureş (N) and the western Romanian Carpathians (E) (Fig. 1a). Similar to other parts of the Carpathian Basin that have been under continental, partly semi-arid climatic influences, the opportunities to explore palynological archives in the vicinity of archaeological lowland sites are extremely limited. Even though vast

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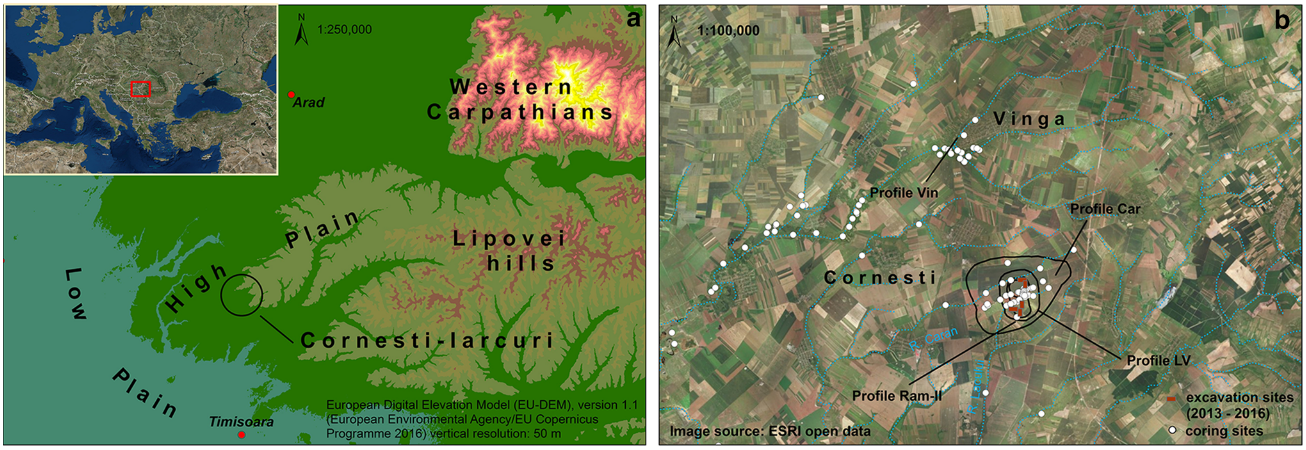


Fig. 1 **a** Overview of study area; **b** location of sampling sites (pollen cores and archaeological trenches) in and around Corneşti-Iarcuri

wetlands were once developed in the wide alluvial plains, which is impressively documented on historical maps (Heeb et al. 2017), far-reaching drainage measures have been put into effect from the 18th century onwards. Those areas still contain some isolated organic-rich deposits, but the given pollen concentrations are strikingly low; a fact that is mainly attributed to reoccurring wetting–drying cycles and post-sedimentary mineralisation within the predominant alkaline clay soils. Former studies have hence concentrated on peat bogs in mountainous areas, which only occur at distances of at least 100 km. Such 'classical archives' can be found in the eastern (e.g. Fărcaş et al. 1999; Fărcaş and Tanţău 2012; Tanţău et al. 2003, 2009; Feurdean 2004; Magyari et al. 2009, 2018; Geantă et al. 2014; Florescu et al. 2017), western (e.g. Bodnariuc et al. 2002; Feurdean and Willis 2008; Feurdean et al. 2009; Grindean et al. 2015, 2017) and southern Carpathians (e.g. Fărcaş et al. 1999; Rösch and Fischer 2000; Magyari et al. 2009). Fewer studies took place in lower mountain ranges (e.g. Björkman et al. 2002; Tanţău et al. 2003, 2006, 2009, 2011; Feurdean 2004, 2005; Feurdean and Bennike 2004; Feurdean and Astalos 2005; Feurdean et al. 2008; Fărcaş and Tanţău 2012) or the intra-montane basins, for example in Transylvania (Feurdean et al. 2007, 2015; Grindean et al. 2014) or Hungary (Willis et al. 1995; Magyari et al. 2001, 2008, 2010, 2012; Gardner 2002; Jakab et al. 2004; Jakab and Sümegi 2010; Sümegi et al. 2012).

The Holocene climatic history is also based on data from the wider region, mainly isotope studies of speleothems (e.g. Onac et al. 2002; Constantin et al. 2007; Demény et al. 2019), but also on some palaeoenvironmental and palynological evidence (e.g. Feurdean et al. 2007, 2014; Magyari et al. 2010; Cleary et al. 2019). For the Copper Age, it is assumed that temperatures were relatively low and humidity was high, prompting a rise in lake levels and the formation of swamps (e.g. Magyari et al. 2001; Náfrádi et al. 2014; Kiss et al. 2015). In the Middle and the Late Bronze Age (MBA, LBA), conditions were gradually getting more continental (Feurdean et al. 2013; Grindean et al. 2014; Perşoiu 2017). This climatic development in the Pannonian Plain is partly reflected by the Middle to Late Holocene vegetation evolution, which had led to the prevalence of mesothermophilous forests, dominated by oak and hazel (Magyari et al. 2001, 2010). Between ca. 6,000 and 4,000 cal BP, they were gradually replaced by first *Carpinus betulus*, then *Fagus sylvatica*, perhaps caused by dropping temperatures. Soon afterwards (3,700 to 3,000 cal BP), steppe elements increased as a result of both anthropogenic influence and higher aridity (Tomescu 2000; Chapman et al. 2009; Feurdean and Tanţău 2017). A similar development is reported from the Transylvanian lowlands (e.g. Tanţău et al. 2006; Feurdean et al. 2007, 2015).

Studies on the climate and vegetation history of the Banat itself are lacking due to the scarcity of palaeoecological archives. It is all the more remarkable that polliniferous on-site deposits could be detected at Corneşti, where they occur at specific positions within valley bottom profiles, mainly in fossil humic horizons, but also in buried cultural layers. Besides their role as a source of information on vegetation, they also provide general data on landscape evolution which can be used to distinguish morphodynamically active and stable periods sensu Rohdenburg (1970). While activity mainly results in accelerated soil erosion and the deposition of thick colluvia, stability is usually characterised by topsoil development and other pedogenic processes (e.g. Dreibrodt et al. 2009; Emadodin et al. 2011; Houben et al. 2012; Pietsch and Kühn 2014; Henkner et al. 2018). In this paper, 'colluvium'/'colluvial' exclusively refers to products of Middle to Late Holocene settlement activities at Corneşti. They include valley deposits originating from upstream slopes, since it is unrealistic to distinguish between colluvial and alluvial sediments in the very small headwater catchments. It is also acknowledged that there is a causal relationship between instable phases and high population pressure with intensive agricultural practices, just as geomorphic stability is mostly associated with extensive land management.

As isolated features, buried topsoils have been subject to homogenisation processes (Dimbleby 1957, 1985) and can therefore not be interpreted in a pollen-stratigraphical manner (Davidson et al. 1999). The presence of older pollen, either inherited from the colluvia or of syn-sedimentary nature, can potentially cause some metachrony or at least temporal vagueness in the record (Fægri and Iversen 1989). This is further compounded by general problems of age determination, because the time when the dated material was embedded in the sediment is usually already speculative. Since the acquired radiocarbon age is usually a terminus post quem, the detected pollen assemblages will primarily reflect the environmental conditions (including human activities) during the period succeeding the respective date. A later translocation of pollen in the course of pedogenetic processes is possible, but can be largely ruled out within alkaline soils (van Mourik 1999).

The analysis of pollen from terrestrial environments faces a variety of methodological problems, especially regarding chronostratigraphy/mixed spectra as described above, but also the biased preservation of pollen and spores (Davidson et al. 1999). The general processes of oxidation and mineralisation can abrade the tectum and nexine in a way that prohibits the determination of pollen types and/or cause their partly perforation by subsequent microbial attack (Moore et al. 1991; Bunting et al. 2001; Tipping et al. 2009). Post-sedimentary corrosion is usually discussed in the context of taphonomy and depends on many factors, including climatic conditions, pH levels and biological activity (Dimbleby 1961; Havinga 1971; Stanley and Linskens 1974; Zhang et al. 2017). In general, *Lycopodium* and Cichorioideae such as *Taraxacum* are considered to be the most resistant pollen types, whereas most tree pollen show a differentiated behaviour depending on soil pH (Havinga 1967, 1971, 1984).

In our research, we focused on palaeoecological evidence, not only with regard to the natural regional vegetation, but also the characterisation of human–environment interactions (land use and ecosystem change) during the different habitation phases of Corneşti. We used palynological on-site analyses of fossil topsoils for the reconstruction of the local vegetation history and combined them with sedimentological and pedological investigations to assess phases of accelerated erosion, in order to obtain a more detailed picture of land use history. Similar research has already been carried out by Nykamp et al. (2015, 2016, 2017) who concentrated on alluvial fans, describing daub- and charcoal-bearing colluvial layers of up to 3 m thickness. But at that stage of the research, no pollen grains of prehistoric origin had been found (Krause et al. 2019). In order to compare the local to the regional vegetation development, a core from the Apa Mare River system at the town of Vinga (Fig. 1b) has been analyzed as well. As another aspect of archaeobotanical research at Corneşti, plant macro-remains have been investigated in order to draw inferences on food resources and subsistence strategies.

Study area and archaeological site

The Carpathian Basin started to subside in the Miocene, while the surrounding mountains were uplifted and folded. This resulted in first marine (Tethys), then lacustrine (Pannonian) transgressions until sedimentation started to exceed subsidence at the transition of the Pliocene to the Pleistocene. The crystalline basement is consequently covered by up to 1,000 m of marine, limnic, and fluviodeltaic sediments (Ţărău et al. 2014; Kiss et al. 2015). The study site (Fig. 1) is located at about 140 m a.s.l. and includes two NE-SW oriented valleys, incised to depths between 20 and 50 m into a gently dipping plain (Micle et al. 2009). This so-called Vinga High Plain (90–190 m a.s.l.) forms part of the Mureş alluvial fan that was active in the Pleistocene and early Holocene (Kiss et al. 2015). While the eastern section comprises several loess-covered Pleistocene gravel to sand terraces, the western part is dominated by 5 to 15 m of Holocene valley fills, mainly consisting of relatively clayey 'alluvial loess' which also dominates in the lower plains to the West. It most likely originates from Pannonian sediments that have been reworked by aeolian activity during the Pleistocene and frequent river avulsions throughout the Holocene (Ianoş 2002; Grigoraş et al. 2004; Rogobete et al. 2011; Urdea et al. 2012; Dicu et al. 2013).

Haplic Chernozems are still widespread in the northwestern part of the Vinga Plain; some have undergone decalcification and/or leaching, thus transitioning into Phaeozems or Luvisols (Sherwood et al. 2013). They are characterized by very dark brown to black mollic topsoils with humus contents around 2–3.5% (Grigoraş et al. 2004). Eroded subtypes prevail on many slopes, owing to their intensive agricultural use, whereas in the valleys, dark-coloured alluvial soils, termed fluvi-gleyic Chernozems (Grigoraş et al. 2004; Dicu et al. 2012) or Humogleys (Grigoraș and Piciu 2005), are abundant.

The recent climate in the Banat is predominantly temperate (Cfb, according to Köppen), with a north-eastward increase of continental and orographic effects (Dfb), while frequent cyclones from the Mediterranean cause positive precipitation anomalies especially in the western parts. Due to the maritime influence, winters are mild and short, but when north-eastern conditions prevail harsh frosts may occur. Mean annual temperatures range between 12 (with average summer temperatures above 22 °C in July) and 6 °C towards the eastern highlands. Annual rainfall (with spring maxima) in the central and western parts of the Vinga Plain is 500–600 mm/year [Timişoara meteorological station: 601 mm/year, Orţişoara pluviometric point: 544 mm/year (Stanciu 2005)], with a potential evapotranspiration around 700 mm and occasional summer droughts (Rieser 2001; Grigoraş et al. 2004; Ţărău et al. 2010).

Being part of the Pannonian floristic province, the Banat represents an ecotone between the central eastern European and south European vegetation units, comprising numerous intra- and azonal elements. The natural vegetation is believed to consist of a typical forest steppe towards the central parts of the Great Hungarian Plain and open deciduous woodlands at its periphery, similar to the Transylvanian lowlands or large areas of the Ukraine (Magyari et al. 2010; Sümegi et al. 2012). Contemporary woodlands are mostly dominated by *Quercus robur*, mixed with *Fraxinus excelsior/angustifolia/ornus*, *Tilia tomentosa*, *Acer campestre/tataricum*, *Cornus mas/sanguinea* and *Ulmus glabra/laevis*. On drier sites such as loess-covered areas, thermo-/xerophilous (Balkan-type) oak associations (*Quercus pubescens/cerris/frainetto*) can be found (Sümegi et al. 2002; Moskal-del Hoyo et al. 2018). The former extensive floodplain forests composed of *Salix* sp. and *Populus* sp. have largely disappeared due to centuries-long drainage measures (Rieser 2001; Neacşu et al. 2015). Wet meadows with Cyperaceae and patches of *Phragmites australis* are still a common sight in the lowlands and valleys (cf. Fig. 2d), whereas the high plains are nowadays dominated by arable farming (e.g. wheat, maize, sunflowers, or rape).

Already depicted on the military maps of the Habsburg Empire, Corneşti-Iarcuri has historically been attributed to the Avar period, owing to its enormous size. Surrounded by four ramparts with a total length of 33 km, the fortified site covers an area of over 17 km^2 (Szentmiklosi et al. 2011; Heeb et al. 2015). The ramparts were built of earth-filled wooden boxes, reaching 5 m in width and 6 m in height (Heeb et al. 2017). The latest published radiocarbon dates placed them in the LBA and at the transition to the Iron Age (Harding 2017; Lehmphul et al. 2019). Even though the LBA is considered to be the main habitation phase of the site (Szentmiklosi et al. 2011; Lehmphul et al. 2019), human presence has been documented from almost all archaeological periods since the Neolithic. Bronze Age occupation seems to have started in the MBA when many sites are believed to have existed throughout the Banat region. In the

Fig. 2 Coring sites of profiles: **a** Ram-II; **b** LV; **c** Car; **d** Vin

LBA, a centralisation process set in, resulting in the erection of fewer, but fortified sites among which Iarcuri probably stood out as a trans-regional hub (Harding 2017; Heeb et al. 2017; Krause et al. 2019).

Materials and methods

With respect to off-site pollen archives in larger floodplains, material could be retrieved with a manually operated gouge auger, whereas on-site sampling on the predominantly (semi-) terrestrial valley floors inside the fortification necessitated the use of petrol-powered vibracorers (both with chambers of 6 cm in diameter and 1 to 2 m length). Sediment units were subsampled for geochemical analyses at a minimum of 30-cm intervals or less, when lithological or pedological changes were evident. Geochemical laboratory analyses of selected profiles focused on pH (KCl; DIN 19684; 78 samples), soil organic matter (LECO RC-412; DIN ISO 10694; 78 samples) and granulometry (sieve and pipette method after Köhn (Schlichting et al. 1995); n = 33). In six cases, charcoal was radiocarbon-dated by acceleration mass spectrometry (AMS) at the Archaeometry department of the Curt Engelhorn Centre, Mannheim (Table 1). Including off-site profiles, a total of 39 radiocarbon datings has been carried out. Results were calibrated with OxCal 4.3.2 (Bronk Ramsey 2017), using the northern Hemisphere IntCal13 dataset (Reimer et al. 2013).

Fifty seven on-site samples (0.3 to 1 cm^3) from 17 profiles (versus 187 off-site samples from 29 profiles) were prepared for pollen analysis, following the standard procedure after Fægri and Iversen (1989) with addition of *Lycopodium* tablets in order to quantify pollen concentrations (Stockmarr 1971), and subsequently embedded in silicone oil. 14 of the on-site cores proved to be completely sterile, while pollen could be detected inside eight samples from three profiles. They were enriched to three- and sixfold concentrations by density separation. Using a light microscope at magnifications of 480 to 756×, taxa were identified with the aid of our reference collection and respective literature (Punt 1976–2009; Moore et al. 1991; Reille 1992, 1998). Pollen and spores were divided into local (aquatic and wetland plants, including the carr forest representatives *Alnus* and *Salix*, Cyperaceae and spores) and regional taxa (including Poaceae unless specifically identified as *Phragmites*). As *Alnus* and *Salix* were considered to be local constituents in the floodplains of Corneşti, they were excluded from the regional pollen sum. Regional pollen sums range between 200 and 250 grains and pollen concentrations between 396 and 2,598 grains cm^{-3}.

Plant macrofossil analyses included wet-sieving in the field down to a mesh size of 0.315 mm. Sorting and identification were carried out under a low-power stereomicroscope at magnifications of 6 to 40× with the help of the reference collection and respective literature (e.g. Cappers et al. 2006). 291 samples with a total volume of 1,612 l from cultural layers within Rampart I and II, dating to the Copper Age, LBA and Early Iron Age (EIA) were collected during five field campaigns between 2013 and 2017 (Fig. 1b). They contained more than 20,000 mostly charred plant remains (18% of the material was mineralized; some single findings were calcified).

Results

Sediments, soils and chronostratigraphy

The spatio-temporal distribution of floodplain deposits and their sedimentogical and pedological properties have recently been elaborated in Gumnior and Stobbe (2019), based on prior research by Nykamp et al. (2015, 2016, 2017). Most of them consist of silty clay loams that are considered to be derivatives of the 'Pannonian' loess which

Table 1 Radiocarbon datings featured in this study

Profile	Lab.code (MAMS-)	Sample code	^{14}C age (yrs BP)	δ ^{13}C AMS (‰)	Cal age (1σ)	Cal age (2σ)	Material
Ram-II	29748	Cor1 334	4,350 ± 28	− 28.8	3010–2911 BC	3078–2903 BC	Charcoal
LV	32348	CV 1–5/6	2,736 ± 41	− 41.4	913–832 BC	975–809 BC	Charcoal
Car	36327	Caran2 102–104	780 ± 21	− 27.1	AD 1225–1268	AD 1221–1274	Sediment
Car	36328	Caran2 109–111	722 ± 21	− 25.2	AD 1271–1284	AD 1262–1291	Sediment
Vin	32345	VL7–160	1,618 ± 45	− 21.0	AD 393–532	AD 353–540	Seed
Vin	37703	V7-161–162	2,148 ± 20	− 23.9	343–167 BC	350–110 BC	Sediment
Vin	32346	VL7-166–167	3,108 ± 27	− 28.1	1420–1309 BC	1433–1295 BC	Charcoal
Vin	35588	VL7-170.5–171.5	3,988 ± 20	− 23.1	2562–2474 BC	2569–2469 BC	Sediment
Vin	35590	VL7-178–179	4,760 ± 23	− 24.9	3632–3524 BC	3636–3388 BC	Sediment
Vin	36848	VL7-185.5– 187.5	4,941 ± 21	− 26.5	3760–3663 BC	3769–3659 BC	Sediment

has largely been reworked and/or mixed with colluvia. They are commonly covered by reddish, deeply pre-weathered silty clays of Upper Pleistocene origin (termed 'Vinga clays' by Drăgulescu et al. (1968) and Mihailă and Popescu (1987)), probably formed under still water conditions and subsequently translocated by solifluction. Due to their granulometric similarity, Quaternary deposits have often been referred to as loessic and loess-like, with mean silt/clay ratios of 1.4 in suspected Vinga clays and 2 in supposed alluvial loess derivatives (Fig. 3a). Because of an obviously increasing extent of human disturbance, it is especially the younger colluvia that reflect the largest variety of source materials, therefore showing overlapping spectra (Fig. 3b).

Following the taxonomy of the IUSS Working Group (2015), prominent soils on the interfluves are Chernozems and Phaeozems. Carbonate-free A horizons reach average depths of 70 cm, if not eroded. Anthrosols from settlement contexts are also widespread and, unless comprising artefacts, cannot be distinguished visually from the surrounding soils. Clay contents are commonly lower in topsoils, suggesting leaching and the predominance of luvic Phaeozems. Deposits in the valleys have also undergone a variety of pedogenetic processes, particularly pronounced bioturbation and peloturbation (self-mulching), the latter being caused by high contents of smectite-rich clays. Like the slopes, floodplain profiles encompass buried humic horizons, characterised by soil organic matter percentages between 1.6 and 2.7 and lowered pH values, mostly found in the second metre below younger colluvia.

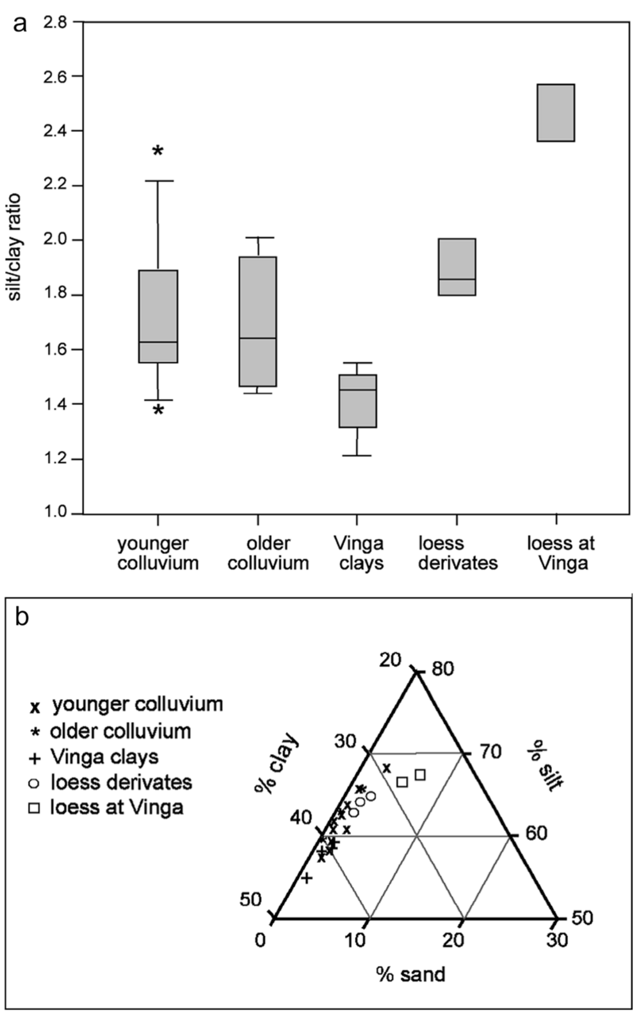


Fig. 3 Grain size distribution of floodplain facies at Corneşti; **a** box-plots (the outlier marked with a star is caused by the reworking of relatively pure loess loam in profile LV, representing the rather serious magnitude of erosion at the given time and position); **b** truncated ternary plot

Profile Ram-II ('Rampart II'; Figs. 2a, 4a) was 400 cm deep and lay immediately below the western part of the second rampart which was still approximately 140 cm high at that point. Underneath the construction material, a fossil topsoil was developed inside 170 cm thick colluvial loams. Below, another, 90 cm thick, silty to clayey colluvium was found which comprised sherds and was partly polliniferous. A piece of charcoal at 194 cm has been dated to 4,350 ± 28 BP (3078–2903 cal BC; 2-σ); i.e. the Late Copper Age. Between 260 and 400 cm, alluvial loess, containing another fossil A horizon, was present.

Profile LV ('Lake Valley'; Figs. 2b, 4b) lay in an upstream position outside of Rampart II and comprised a sediment column of 5 m. Beneath 170 cm of colluvial silty clays, a buried topsoil containing pollen was developed inside 50 cm of silty clay loams. Grading into Vinga clays, the loams were also colluvial in nature, albeit macroscopically almost identical with the silty clays underneath. A piece of charcoal at 2 m depth was dated to 2,736 ± 41 BP (975–809 cal BC; 2-σ), viz. the EIA. Below 315 cm, a lighter coloured (10 YR 4/2) loess loam was found down to the maximum coring depth. The fossil A horizon in Profile LV contained pollen.

Profile Car ('Caran'; Figs. 2c, 4c) was located in the northern valley about 2.5 km downstream from the spring of the Caran River between Ramparts III and IV. It mainly served as an example for medieval and contemporary pollen assemblages and consisted of Pleistocene Vinga clays with a fossil topsoil in which pollen has not been preserved. The clays were covered by 145 cm of relatively homogenous, colluvial silty clay loams. Bulk samples from 103 to 110 cm depth both dated to the 13th century AD. Pollen samples from 90, 100 to 110 cm were used as a reference for the Middle Ages (at the time of the Hungarian Kingdom) and a surface sample as evidence for the recent pollen spectrum.

Profile Vin ('Vinga'; Figs. 2d, 4d) originated from a palaeolake around 7 km north of Corneşti. It was used as an off-site example for the Bronze Age which is not conclusively covered by the above-mentioned sediment cores (Table 2). Beneath a partly peaty channel-fill dating to the Migration Period, a thin colluvial layer of Iron Age origin

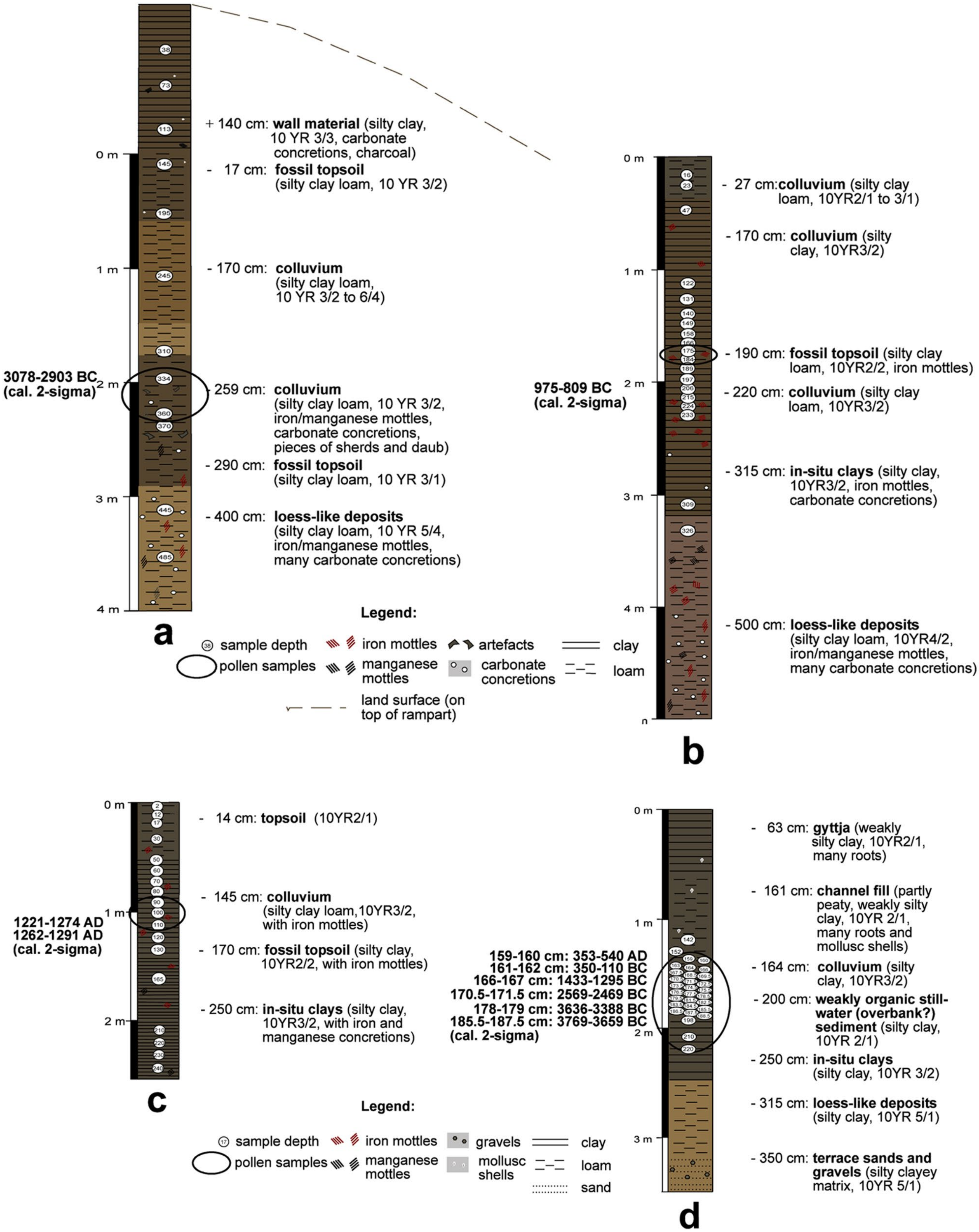


Fig. 4 Sedimentology and chronostratigraphy of profiles: **a** Ram-II; **b** LV; **c** Car; **d** Vin

Table 2 Palaeoenviromental evidence from different archaeological periods

Archaeological period	Off-site ^{14}C datings	Off-site pollen	On-site ^{14}C datings	On-site pollen	Macro-remains[a]
Copper Age	X	X	X	X	X
Early Bronze Age	X	X	–	–	–
Middle Bronze Age	–	X	–	–	–
Late Bronze Age	X	X	–	–	X
Early Iron Age	(X)[b]	–	X	X	X

[a]Early/Middle Bronze Age features have not been excavated; therefore no macro-remains were available

[b]Referring to the colluvial layer at 161–164 cm in profile Vin (cf. Fig. 4d)—since it did not contain sufficient pollen, it is not covered in the presented pollen profile

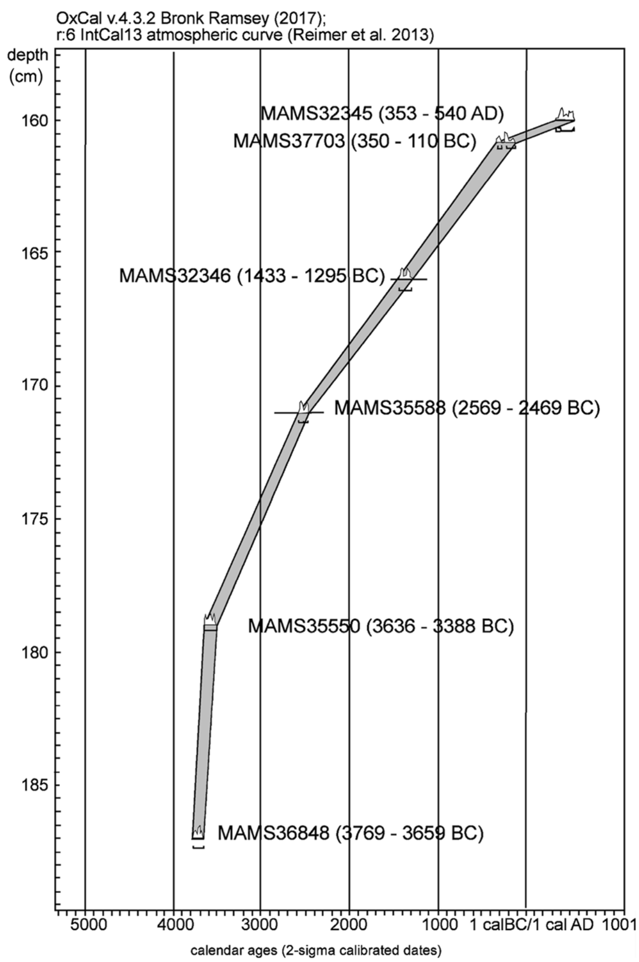


Fig. 5 Age-depth model of Profile Vin

was found; both of these were sterile with respect to pollen (and therefore not covered in the pollen diagram in Fig. 7). They were underlain by an organic-rich still water sediment at 161–190 cm depth, accumulated between the Middle Copper Age and the LBA. The age-depth diagram (Fig. 5) reveals a relatively continuous deposition, well-suited for age interpolations.

On-site pollen spectra

Even though sites with hydromorphic conditions could be found at Corneşti (particularly in the Caran Valley), only the three profiles featured in this publication contained significant amounts of pollen at specific positions. Samples were taken from 194 to 220 cm beneath the surface in Profile Ram-II, from the fossil topsoil of Profile LV at 175 and 184 cm depth, and from the colluvium in Profile Car between 90 and 110 cm and 17 cm respectively. Figure 6 shows relative frequencies of selected taxa at the three sites, expressed as percentages of the regional pollen sum.

Representing the Copper Age, Profile Ram-II contains about 41% of woody taxa with *Tilia* as the dominant tree (over 11%), followed by *Quercus* and *Corylus avellana* (both around 9%). *C. betulus* is present, as well as *F. sylvatica* and *Abies alba*. The definition of indicators for human presence mainly follows Feurdean and Tanţău (2017), comprising Cerealia-type, *Plantago lanceolata*, *Polygonum aviculare*-type and *Rumex acetosa*. They reach 11% in the samples, Cerealia-type and *P. aviculare*-type foremost. Among the other herbs, Cichorioideae constitute the major part with 16%, above the value of Poaceae pollen. They are followed by *Artemisia* with 4%. The pollen sum is 253 with three indeterminatae; an additional identified taxon not featured in the diagram is Fabaceae.

In Profile LV, dating to the Iron Age, a distinctly lower percentage of arboreal pollen of around 29% is evident. However, when carr forest species are included, the figure amounts to 41% (versus 44% in Profile Ram-II). This is caused by high *Alnus* values, indicating the existence of alluvial forests outside of Rampart II until this period. The major regional woodland constituent is *Quercus* with 12%, while anthropogenic indicators have risen to almost 18% (*P. lanceolata* is the dominant species with 7%). Other herbs have increased from 32 to 42%; especially Chenopodiaceae show a sharp rise from 1 to 11%, while Cichorioideae reach about the same percentage. The pollen sum amounts to 236, including three indeterminatae;

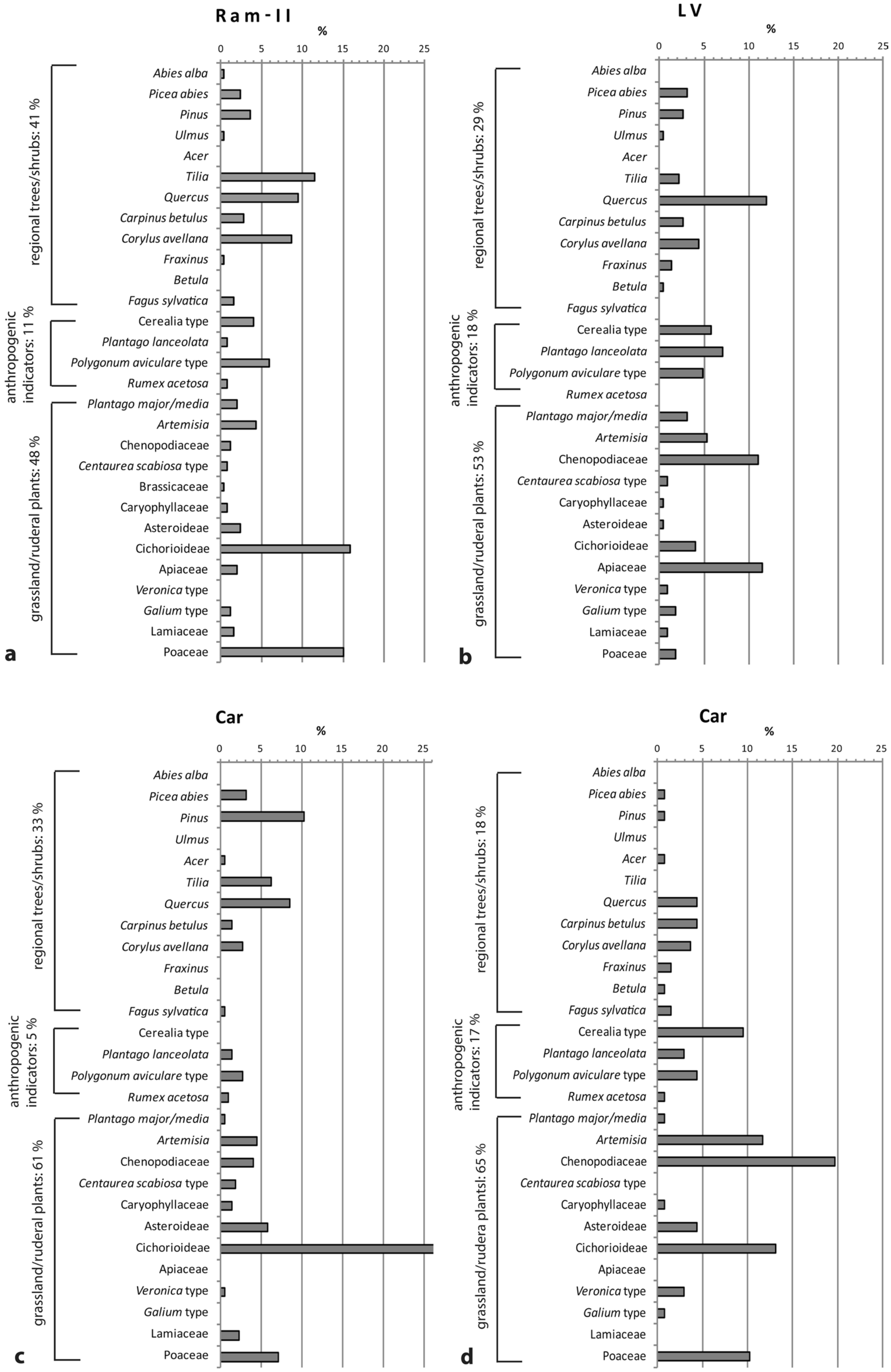
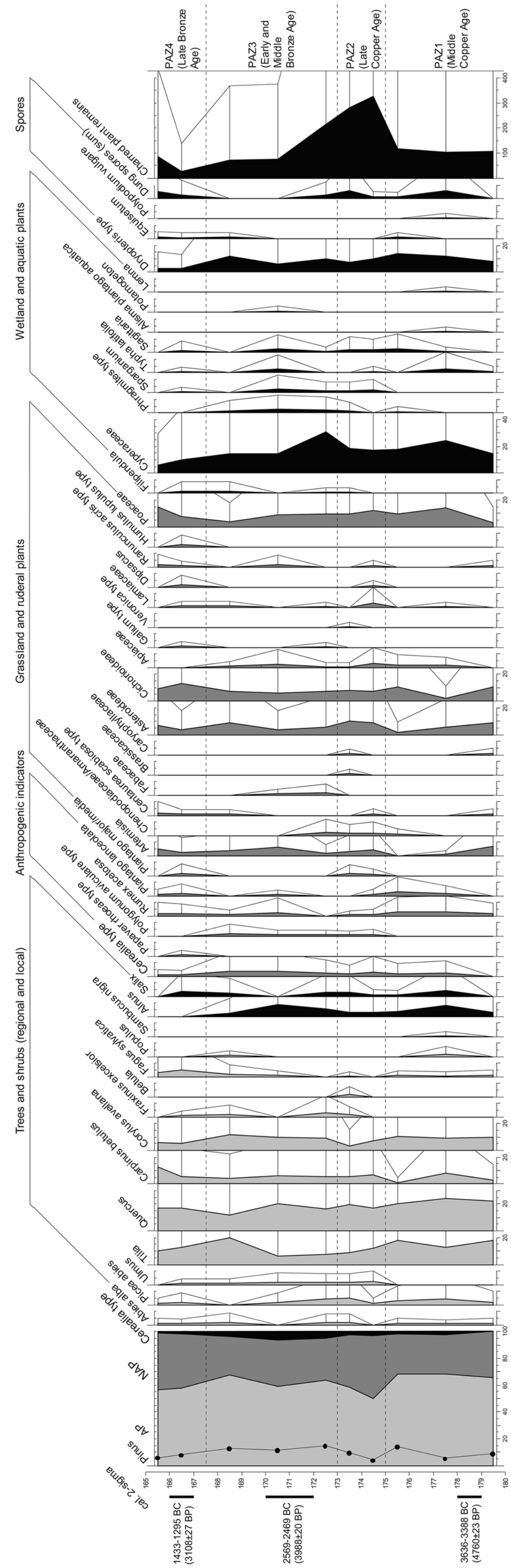


Fig. 6 Selected regional pollen from **a** the Copper Age (profile Ram-II); **b** the Iron Age (profile LV); **c** the medieval; **d** modern times (both the latter profile Car)

not featured in the diagram are *Morus nigra*, *Ranunculus acris*-type, and *Sanguisorba officinalis*.

In the medieval strata of Profile Car, tree pollen values amount to 33% (almost 1/3 of which is *Pinus* pollen). Anthropogenic markers are notably low with 5%, and no Cerealia-type pollen is recorded. With 55%, other herbs constitute the majority of the spectrum, among which Cichorioideae are clearly dominant with 35%, followed by Asteroideae, *Artemisia* and Chenopodiaceae. The pollen sum is 235 (two indeterminatae); not shown in the figure are Fabaceae, *Humulus lupulus*-type, *Dipsacus*, *Knautia*, *M. nigra*, *R. acris*-type and *Urtica*. Within the same profile,

Fig. 7 Regional pollen composition (in %) in Copper to LBA strata of the off-site profile Vin; regional trees shown in grey, local trees shown in black ▸



surface samples show minimum arboreal pollen percentages of 18%, while pollen of cultivation indicators has risen to over 17%, half of which is from Cerealia-type. The remaining herbs reach 54%, to which Chenopodiaceae contribute almost 20%. Values of Cichorioideae amount to 13% and those of *Artemisia* to 12%, respectively. With a pollen sum of 206 and four indeterminatae, additional regional taxa not depicted in the diagram are Fabaceae, *R. acris*-type, and *Urtica*.

Off-site data

Copper Age to LBA pollen spectra could be detected in a sediment core from a palaeolake near Vinga (Figs. 1b, 4d). Figure 7 depicts the pollen profile of the relevant strata, with a Copper Age radiocarbon age at its base. The profile was subdivided into four pollen assemblage zones (PAZ).

In PAZ1, arboreal pollen accounts for 68% of the regional pollen sum. Similar to the on-site situation, *Tilia* is predominant, accompanied by *Quercus*, *C. avellana* and *C. betulus*. Among land use indicators, Cerealia-type, *Plantago lanceoloata* and *R. acetosa* are present as well as dung spores.

At approximately 3000 cal BC (PAZ2), in the Late Copper Age, a distinct change in vegetation cover can be observed, evident in a drop in arboreal pollen to 50% and a sharp increase of charred plant micro-remains. Non-arboreal pollen assemblages show a higher diversity, and the percentage of Cerealia-type is slightly increased.

Woodland composition and land use indicators fluctuate throughout PAZ3, i.e. the EBA and MBA. Cerealia-type peaks with over 6% at 170.5 cm (EBA; Fig. 5), and *C. avellana* gains more importance. In the MBA, anthropogenic markers are reduced, while *Tilia* forests become re-established. *Artemisia* and other Asteraceae values are also high; the latter increase towards the top of this pollen zone.

In PAZ4, which largely corresponds to the LBA, *Tilia* becomes less important, while *C. betulus* is increasing once again. Amongst non-arboreal pollen, Asteraceae predominanate, and *Artemisia*, *Plantago major* and *Centaurea scabiosa*-type are also present. An increase in land use indicators such as *P. lanceolata* as well as dung spores can be observed.

Macro-botanical analyses

The analyses of macro-remains from cultural layers dating to the Copper Age show that the principal crops were the glume wheats emmer (*Triticum dicoccon*) and einkorn (*T. monococcum*), while the LBA spectrum encompassed a large variety of domesticated plants, comprising the cereals hulled barley (*Hordeum vulgare*), broomcorn millet (*Panicum miliaceum*), bread wheat (*Triticum aestivum*), emmer, einkorn, spelt (*T. spelta*) and very small quantities of foxtail millet (*Setaria italica*). Furthermore, the pulses garden pea (*Pisum sativum*), lentil (*Lens culinaris*) and field bean (*Vicia faba*), as well as the oil plant gold-of-pleasure (*Camelina sativa*) were identified (Krause et al. 2019). The spectrum of the only investigated EIA feature contained hulled barley, broomcorn millet, bread wheat, einkorn, spelt, garden pea, lentil, broad bean, gold-of-pleasure, flax (*Linum usitatissimum*) and poppy (*Papaver somniferum*).

In the Copper Age samples, more than 1,000 awn fragments and five caryopses of *Stipa*, a representative of dry grassland communities, have been found. In the Bronze and EIA samples, there was an almost complete lack of *Stipa* (13 awn remains). Regarding the ubiquity of this steppe element, the differences were even clearer. Awn fragments have been found in 57% of the features relating to a Copper Age homestead (ditches, pits), but only 11% of Bronze Age and EIA samples contained such material.

Discussion

The combination of geomorphological, chronostratigraphical, pedological and palynological on-site analyses, in context with the results of off-site pollen and macrobotanical investigations enabled us to grasp a multitude of palaeoenvironmental aspects from this exceptional prehistoric mega-site, which would otherwise not have been revealed (Table 2). Through this multi-proxy approach with the principal focus on fossil topsoils in the local floodplains (Fig. 1b), the ecological conditions during the most important habitation sequences at Corneşti-Iarcuri, including the effects of certain agro-pastoral practices, could be detected and evaluated.

Concerning pollen assemblages, one needs to remain aware that selective corrosion has taken place, especially by repeated aeration and subsequent partial to total decay, as documented by the low pollen concentrations and limited spectra with a clear dominance of resistant taxa, although most of them also happen to be common in steppe-like and/or agricultural environments (Bunting et al. 2001). There is also evidence that the bias is rather moderate since pollen that is sensitive to corrosion has been preserved in a relatively good condition—namely *Acer*, *C. avellana*, *Alnus*, *Quercus*, *Fraxinus*, *Ulmus*, *Urtica*, *H. lupulus*-type and *M. nigra*, while indeterminatae are very few (Fig. 6). Only the medieval spectrum in Profile Car with its extreme Cichorioideae values appears to be seriously distorted by selective corrosion, although many of the mentioned delicate pollen types are present as well. There is also an increased percentage of *Pinus* pollen, which according to Havinga (1971) is not necessarily a sign of selective deterioration when the environment is semi-arid and soils are not explicitly acidic. Either long-distance transport or the local occurrence of pine forest appear to be plausible explanations. With a rather overall uniform ecological situation at the presented sites (including the off-site core), pollen assemblages are believed to be interpretable and comparable.

Pre-fortification phase (Middle Copper Age to Middle Bronze Age, ca. 3700-1550 cal BC)

The (Late) Copper Age was definitely a phase of pronounced human impact. This is evident in both off-site and on-site data, where anthropogenic markers were already common at that time, attesting crop cultivation and livestock farming. The composition of arboreal pollen at Profile Vin, 7 km north of Corneşti, shows that a *Tilia*-dominated woodland was prevalent in the Banat region throughout the Copper Age (Fig. 7). This differs substantially from what is described in most former research on regional vegetation history (cf. above), because the majority of this work was conducted in mid- to high-altitude areas. Due to the difficulty of finding undisturbed archives in the plains, the results have subsequently been extrapolated to lowland situations. Most studies from lower altitudes equally stated a general shift from mixed oak to first hornbeam, then beech forests during the Copper and Bronze Age (Willis et al. 1997; Tanţău et al. 2006; Magyari et al. 2010, 2012; Grindean et al. 2014; Feurdean et al. 2015). However, a mixed oak woodland appears to have prevailed at least until 3,700 cal BP in a few areas in NE Hungary (Willis et al. 1998; Sümegi et al. 2002; Magyari et al. 2008). Open woodlands dominated by *Tilia* and *Quercus* have further been reconstructed in the Southern Carpathians by Cleary et al. (2019) during increasingly arid conditions in the last 600 years.

An obvious change in the pollen spectrum of Profile Vin is visible at around 3000 cal BC, before the transition from the Copper to the Bronze Age (starting around 2800 to 2700 cal BC, Gogăltan 2015), probably associated with increasing land use activities (Fig. 7). It is particularly evident in the high number of charred plant remains, correlating with a decline in tree pollen. This points to a massive destruction of the *Tilia* forests due to slash-and-burn practices and was followed not only by a slight increase of disturbance-adapted species such as *Pinus*, *Betula* and especially *C. avellana*, but also a predominance of *Quercus*. The general diversity of non-arboreal pollen, including steppe elements such as *Artemisia* increased accordingly. In the MBA, the intensity of land use became lower, and *Tilia* woodlands partly recovered.

The on-site geomorphodynamics during the Copper Age at the settlement site had considerable effects as well. Copper Age dates from several valley fills and fan deposits

(Nykamp et al. 2016; our own data) show that substantial soil erosion and incision by rills and gullies took place during that time, especially but not exclusively at the centre of the later fortification, where Copper Age villages have been documented (Heeb et al. 2017; Lehmphul et al. 2019). The low arboreal pollen value of the colluvium in Profile Ram-II, together with the high level of anthropogenic indicators suggests a high degree of woodcutting and subsequent land cultivation (Fig. 6a). This is also shown by cereal remains discovered in Copper Age cultural layers. Since *Stipa* as an indicator of a relatively undisturbed feather grass steppe (Walter and Breckle 1986) was abundant in the Copper Age samples, we can conclude that a sparsely wooded steppe under extensive land management (cultivation of cereals such as emmer and einkorn combined with livestock grazing) was predominant during that period. Comparable semi-natural grasslands have been postulated as occurring since the Neolithic (Feurdean et al. 2018).

Fortification phase (Late Bronze Age, ca. 1550–1100 cal BC)

The regional pollen spectrum in Profile Vin shows that, towards the LBA, anthropogenic indicators rose once again (Fig. 7). Congruent with major regional trends (Willis et al. 1998; Gardner 2002; Magyari et al. 2008), *C. betulus*, *Quercus* and *F. sylvatica* became more frequent, and *C. avellana* decreased. However, general tree percentages in the LBA were not significantly lower than in the Copper Age samples. They are further comparable to figures from lowland profiles in the greater region, where tree percentages usually did not drop below 60–65% until approximately 3,000 cal BP (e.g. Magyari et al. 2010; Grindean et al. 2014). Only at Lake Stiucii (Transylvania), reduced levels around 50% have been recorded during the (Middle) Bronze Age (Feurdean et al. 2015). Similar to the EBA and MBA, there is no sedimentary or palynological on-site proof from Corneşti (Table 2).

One of the most relevant questions in terms of woodland composition and density in this particular period is the significance of timber as a crucial constituent of rampart construction. The four enclosures covered 17 km^2 in space or 33 km in total length and consisted of earth-filled wooden boxes (cf. above). Between 6 and 14% of the fortification were made of wood (mostly oak), amounting to an estimated total volume of 493,118 m^3 (Krause et al. 2019). Assuming that all ramparts had been erected more or less simultaneously, a value of 32 m^3/ha was used to assess the available prehistoric wood resources—under these premises, a total of 250 ha (viz. 70.8%) of the habitation site inside rampart IV would have supplied the necessary construction material. As our own results show, local forest clearance had predominantly taken place as early as the Copper Age. Afterwards, arboreal pollen percentages amounted to around one half of what are considered average values in natural forest steppes (Magyari et al. 2010). Nevertheless, we have to assume that the tree cover in the LBA was sufficient to provide the timber needed for the construction of the fortification system. This may imply that some degree of forest recovery had occurred between the EBA and MBA, followed by renewed tree felling in the course of rampart erection.

A large proportion of the cleared area was subsequently used for an intensified and diversified crop cultivation as attested by macro-botanical data, showing that millet had central importance during that period. A fully developed, characteristic LBA agriculture is apparent in the broad variety of cereals, pulses and oil plants, and the general increase of synanthropic species, which corresponds to results from other sites in the Pannonian Plain (e.g. Stika and Heiss 2013). The disappearance of *Stipa* indicates an intensification of animal husbandry, possibly with an increased percentage of sheep and goats. However, the expected erosional impact, resulting in thick colluvial valley fills, could neither be proven anywhere within the fortified site nor further downstream (Nykamp et al. 2016; our own data). The lack of evidence of sediments from the LBA fortification phase may suggest that although the landscape was open at that time, it was geomorphologically rather stable.

Post-fortification phase (Iron Age and later, ca. 1100 cal BC onwards)

Regional pollen spectra are missing from the Iron Age (Table 2). However, the transition from the LBA is documented in archaeological (e.g. Lehmphul et al. 2019) as well as chronostratigraphical data (Fig. 4b). The occurrence of colluvial material in Profile LV shows that human impact was still intensive, but was followed by a prolonged interval of geomorphological stability and soil formation. The incorporated pollen assemblage underlines the continuity in landscape evolution: anthropogenic markers have risen by about 1/3 since the Copper Age to a value almost identical with that of surface samples (Profile Car), even if Cerealia-type pollen did not play an equally dominant role among them (Fig. 6). At the same time, the one investigated macro-botanical feature showed a crop spectrum similar to that of the LBA. Meanwhile, *Quercus* has become the main arboreal genus in the area. This may indicate a recovery of woodland after the abandonment of the fortification system, but could also result from the selective removal of other trees due to the higher economic value of oaks and has been equally observed in many archives from Hungary to Transylvania (e.g. Gardner 2002; Náfrádi et al. 2014; Feurdean et al. 2015). In Profile Car, deciduous tree pollen values were slightly higher in the medieval samples and have dropped to a minimum in modern times (Fig. 6). It may be a sign that land use pressure temporarily decreased in the Middle Ages (also suggested by the lack of Cerealia–type pollen). However, erosion obviously reoccurred at the same time, and the medieval spectrum is also strongly biased towards very resistant taxa.

Conclusions

The cultural landscape at Corneşti-Iarcuri has undergone several habitation phases with intensive land use, separated by times of reduced human interference, leading to the establishment of topsoils that can now serve as palynological archives. Using additional off-site pollen and macrobotanical data as a reference, it is evident that open *Tilia* woodlands with characteristic steppe elements such as *Stipa* dominated the regional vegetation during the Copper Age. In the LBA, *C. betulus* and *Quercus* became slightly more important. This differs from Middle to Late Holocene vegetation scenarios extrapolated from peatbogs and lakes in mountainous environments, where a distinct shift from mixed oak woodlands to *C. betulus*/*F. sylvatica* forests occurred prior to the Bronze Age, and where coniferous trees reach much higher percentages. The rise of *Quercus*, however, is a widely observed phenomenon in the region, because oaks seem to have been selectively preserved due to their economic significance and also produce more pollen in open landscapes.

With respect to on-site palynological results, we were able to gain profound insights into the local vegetation and settlement history by reconstructing the plant cover before and after Corneşti-Iarcuri became the largest known fortified site of the LBA. Arboreal pollen were evidently reduced against regional values, and anthropogenic indicators have progressively increased between the Copper Age and the EIA. Together with the rise of synanthropic species among macro-remains and the disappearance of *Stipa* as a common feature of naturally open woodlands and indicator of low grazing pressure, this confirms considerable land use activities at the site. They started with massive environmental changes at the end of the Copper Age, when local forest clearance and slope erosion processes, such as sheet wash, rill and gully erosion, were most prominent. Possibly promoted by relatively high precipitation, they have led to the accumulation of up to 260 cm of sediment in the main valley. Surprisingly, no deposits originating from the Bronze Age could be pinpointed. The presumably increasing aridity and cultivation patterns in the LBA may in fact have supported landscape stability by minimising erosion, even though settlement dynamics, including severe population pressure and intensive agriculture, obviously reached their peak at that time. The alternation of stable and instable phases as manifest in the form of colluvia, topsoils, and pollen contents partly contradicts the common view that intensive land use triggers soil erosion, whereas extensive resource management is supposedly much more sustainable. The obviously pronounced precipitation regime during the Copper Age promoting slope dissection and deposition of colluvia in the floodplains no longer existed in the Bronze Age. This further led to a more frequent desiccation of this semi-terrestrial environment, inhibiting the preservation of pollen. It may be the crucial factor in why palynological on- and off-site archives from the Bronze Age are extremely rare.

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References

Björkman L, Feurdean A, Cinthio K, Wohlfarth B, Possnert G (2002) Lateglacial and early Holocene vegetation development in the Gutaiului Mountains, northwestern Romania. Quat Sci Rev 21:1039–1059

Bodnariuc A, Bouchette A, Dedoubat JJ, Otto T, Fontugne M, Jalut G (2002) Holocene vegetational history of the Apuseni mountains, central Romania. Quat Sci Rev 21:1465–1488

Bronk Ramsey C (2017) Methods for summarizing radiocarbon datasets. Radiocarbon 59:1809–1833

Bunting MJ, Tipping R, Downes JM (2001) "Anthropogenic" pollen assemblages from a Bronze Age cemetary at Linga Fiold, West Mainland, Orkney. J Archaeol Sci 28:487–500

Cappers RTJ, Bekker RM, Jans JEA (2006) Digital seed atlas of the Netherlands, vol 4. Groningen Archaeological Studies. Barkhuis, Eelde

Chapman J, Magyari E, Gaydarska B (2009) Contrasting subsistence strategies in the Early Iron Age? New results from the Alföld Plain, Hungary, and the Thracian Plain, Bulgaria. Oxf J Archaeol 28:155–187

Cleary DM, Feurdean A, Tanţău I, Forray FL (2019) Pollen, $\delta^{15}N$ and $\delta^{13}C$ guano-derived record of late Holocene vegetation and climate in the southern Carpathians, Romania. Rev Palaeobot Palynol 265:62–75

Constantin S, Bojar A-V, Lauritzen S-E, Lundberg J (2007) Holocene and late pleistocene climate in the sub-mediterranean continental environment: a speleothem record from Poleva Cave (Southern Carpathians, Romania). Palaeogeogr Palaeoclimatol Palaeoecol 243:322–338

Davidson DA, Carter S, Boag B, Long D, Tipping R, Tyler A (1999) Analysis of pollen in soils: processes of incorporation and redistribution of pollen in five soil profile types. Soil Biol Biochem 31:643–653

Demény A, Kern Z, Czuppon G et al (2019) Middle Bronze Age humidity and temperature variations, and societal changes in East-Central Europe. Quat Int 504:80–95

Dicu D, Ţărău D, Borza I (2012) The role of pedological information in agricultural land suitability assessing. Soil Form Factors Proces Temp Zone 11:95–102

Dicu D, Ţărău D, Oncia S, Ţărău A, Câmpean A (2013) Research on stopping the trend of desertification in southwestern Romania (Vinga Plain). Res J Agric Sci 45:61–70

Dimbleby GW (1957) Pollen analysis of terrestrial soils. New Phytol 56:12–28
Dimbleby GW (1961) Soil pollen analysis. Eur J Soil Sci 12:1–10
Dimbleby GW (1985) The palynology of archaeological sites. Academic Press, London
Drăgulescu A, Hinculov L, Mihailă N (1968) Republica Socialistă România, Harta Geologică: scara 1:200.000. Comitetul de Stat al Geologiei, Institutul Geologic, București
Dreibrodt S, Nelle O, Lütjens I, Mitusov A, Clausen I, Bork H-R (2009) Investigations on buried soils and colluvial layers around Bronze Age burial mounds at Bornhöved (northern Germany): an approach to test the hypothesis of 'landscape openness' by the incidence of colluviation. Holocene 19:487–497
Emadodin I, Reiss S, Bork H-R (2011) Colluviation and soil formation as geoindicators to study long-term environmental changes. Environ Earth Sci 62:1695–1706
Fægri K, Iversen J (1989) In: Fægri K, Kaland PE, Krzywinski K (eds) Textbook of pollen analysis, 4th edn. Wiley, Chichester
Fărcaş S, Tanţău I (2012) Contributions to the European pollen database: 16. Poiana Ruscă Mountains (Romania): Peşteana peat bog. Grana 51:249–251
Fărcaş S, de Beaulieu J-L, Reille M et al (1999) First ^{14}C datings of late glacial and Holocene pollen sequences from Romanian Carpathes. Comptes Rendus Acad Sci Vie 322:799–807
Feurdean A (2004) Palaeoenvironment in north-western Romania during the last 15,000 years. Thesis in Quaternary Geology. Department of Physical Geography and Quaternary Geology, Stockholm University, Stockholm
Feurdean A (2005) Holocene forest dynamics in northwestern Romania. Holocene 15:435–446
Feurdean A, Astalos C (2005) The impact of human activities in the Gutâiului Mountains, Romania. Stud UBB Geol 50:63–72
Feurdean A, Bennike O (2004) Late quaternary palaeoecological and palaeoclimatological reconstruction in the Gutaiului Mountains, northwest Romania. J Quat Sci 19:809–827
Feurdean A, Tanţău I (2017) The evolution of vegetation from the last glacial maximum until the present. In: Radoane M, Vespremeanu-Stroe A (eds) Landform dynamics and evolution in Romania. Springer, New York, pp 67–83
Feurdean A, Willis KJ (2008) The usefulness of a long-term perspective in assessing current forest conservation management in the Apuseni Natural Park, Romania. For Ecol Manage 256:421–430
Feurdean A, Mosbrugger V, Onac BP, Polyak V, Veres D (2007) Younger Dryas to mid-Holocene environmental history of the lowlands of NW Transylvania, Romania. Quat Res 68:364–378
Feurdean A, Klotz S, Mosbrugger V, Wohlfarth B (2008) Pollen-based quantitative reconstructions of Holocene climate variability in NW Romania. Palaeogeogr Palaeoclimatol Palaeoecol 260:494–504
Feurdean A, Willis KJ, Astaloş C (2009) Legacy of the past land-use changes and management on the 'natural' upland forest composition in the Apuseni Natural Park, Romania. Holocene 19:967–981
Feurdean A, Parr CL, Tanţău I, Fărcaş S, Marinova E, Perşoiu I (2013) Biodiversity variability across elevations in the Carpathians: parallel change with landscape openness and land use. Holocene 23:869–881
Feurdean A, Perşoiu A, Tanţău I et al (2014) Climate variability and associated vegetation response throughout central and Eastern Europe (CEE) between 60 and 8 ka. Quat Sci Rev 106:206–224
Feurdean A, Marinova E, Nielsen AB et al (2015) Origin of the forest steppe and exceptional grassland diversity in Transylvania (central-eastern Europe). J Biogeogr 42:951–963
Feurdean A, Ruprecht E, Molnár Z, Hutchinson SM, Hickler T (2018) Biodiversity-rich European grasslands: ancient, forgotten ecosystems. Biol Conserv 228:224–232
Florescu G, Hutchinson SM, Kern Z et al (2017) Last 1000 years of environmental history in Southern Bucovina, Romania; a high resolution multi-proxy lacustrine archive. Palaeogeogr Palaeoclimatol Palaeoecol 473:26–40
Gardner AR (2002) Neolithic to Copper Age woodland impacts in northeast Hungary? Evidence from the pollen and sediment chemistry records. Holocene 12:521–553
Geantă A, Gałka M, Tanţău I, Hutchinson SM, Mîndrescu M, Feurdean A (2014) High mountain region of the Northern Romanian Carpathians responded sensitively to Holocene climate and land use changes: a multi-proxy analysis. Holocene 24:944–956
Gogăltan F (2015) The early and Middle Bronze Age chronology on the eastern Frontier of the Carpathian Basin. Revisited after 15 Years. In: Németh RE, Rezi B (eds) Bronze Age chronology in the Carpathian Basin, vol 8. Bibliotheca Musei Marisiensis, Seria Archaeologica. Cluj-Napoca, Editura Mega, pp 53–95
Grigoraş C, Piciu I (2005) Modifications on the soils map of Vinga Plain due to the application of the Romanian system of soil taxonomy (RSST). Soil Form Factors Process Temp Zone 4:161–167
Grigoraş C, Piciu I, Vlăduţ A (2004) Contributions to the knowledge of the cernisols from the Vinga Plain. Forum Geogr 3:33–42
Grindean R, Tanţău I, Fărcaş S, Panait A (2014) Middle to late Holocene vegetation shifts in the NW Transylvanian lowlands (Romania). Stud UBB Geol 59:29–37
Grindean R, Feurdean A, Hurdu B, Fărcaş S, Tanţău I (2015) Lateglacial/Holocene transition to mid-Holocene: vegetation responses to climate changes in the Apuseni Mountains (NW Romania). Quat Int 388:76–86
Grindean R, Tanţău I, Feurdean A (2017) 37. Doda Pilii, Apuseni Mountains (Romania). Grana 56:478–480
Gumnior M, Stobbe A (2019) Palaeoenvironmental reconstructions at Corneşti-Iarcuri (Southwestern Romania)—Preliminary results from geomorphogical, pedological and palynological on-site studies. In: Hansen S, Krause R (eds) Bronze Age Fortresses in Europe UPA 335 Prähistorische Konfliktforschung 3. Habelt, Bonn, pp 237–251
Harding A (2017) Corneşti-Iarcuri and the rise of mega-forts in Bronze Age Europe. In: Heeb B, Szentmiklosi A, Krause R, Wemhoff M (eds) Fortifications: the rise and fall of defended sites in Late Bronze Age and Early Iron Age of South-East Europe. Berliner Beiträge zur Vor- und Frühgeschichte, vol 21. Staatliche Museen zu Berlin, Berlin, pp 9–15
Havinga AJ (1967) Palynology and pollen preservation. Rev Palaeobot Palynol 2:81–98
Havinga AJ (1971) An experimental investigation into the decay of pollen and spores in various soil types. In: Brooks J, Grant PR, Muir M, van Gijzel P, Shaw G (eds) Sporopollenin. Academic Press, London, pp 446–479
Havinga AJ (1984) A 20-year experimental investigation into the decay of pollen and spores in various soil types. Pollen Spores 26:541–558
Heeb B, Szentmiklosi A, Krause R (2015) Corneşti-Iarcuri—Ergebnisse der archäologischen Untersuchungen 2007 bis 2014 an der größten prähistorischen Befestigung Europas. Mitteilungen der Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte 46:57–68
Heeb B, Szentmiklosi A, Bălărie A, Lehmphul R, Krause R (2017) Corneşti-Iarcuri—10 years of research (2007-2016). Some important preliminary results. In: Heeb B, Szentmiklosi A, Krause R, Wemhoff M (eds) Fortifications: the rise and fall of defended sites in Late Bronze Age and Early Iron Age of South-East Europe, vol 21. Berliner Beiträge zur Vor- und Frühgeschichte. Staatliche Museen zu Berlin, Berlin, pp 217–228
Henkner J, Ahlrichs J, Downey S et al (2018) Archaeopedological analysis of colluvial deposits in favourable and unfavourable areas:

reconstruction of land use dynamics in SW Germany. Royal Soc Open Sci 5:171624

Houben P, Schmidt M, Mauz B, Stobbe A, Lang A (2012) Asynchronous Holocene colluvial and alluvial aggradation: a matter of hydrosedimentary connectivity. Holocene 23:544–555

Ianoş G (2002) General considerations on the soil cover of Banat (Romania). Geogr Pannon 6:13–16

IUSS Working Group (2015) World reference base for soil resources. World soil resources reports 106. FAO, Rome

Jakab G, Sümegi P (2010) Preliminary data on the bog surface wetness from the Sirok Nyírjes-tó peat bog, Mátra Mts, Hungary. Cent Eur Geol 53:43–65

Jakab G, Sümegi P, Magyari EK (2004) A new paleobotanical method for the description of Late Quaternary organic sediments (Mire-development pathways and paleoclimatic records from S Hungary). Acta Geol Hung 47:1–37

Kiss T, Hernesz P, Sümeghy B, Györgyövics K, Sipos G (2015) The evolution of the great Hungarian Plain fluvial system—fluvial processes in a subsiding area from the beginning of the Weichselian. Quat Int 388:142–155

Krause R, Wemhoff M, Szentmiklosi A et al (2019) Vorbericht zu den Feldforschungen der Jahre 2013 und 2014 an der Befestigung Corneşti-Iarcuri im rumänischen Banat. Eurasia Antiqu 22:133–183

Lehmphul R, Heeb B, Szentmiklosi A, Stobbe A, Krause R (2019) The genesis of the fortification of Corneşti-larcuri near the Mureş lower course (Romanian Banat)—a phase model on the chronology of the settlement and fortification structures. In: Hansen S, Krause R (eds) Bronze Age fortresses in Europe. UPA 335, Prähistorische Konfliktforschung 3. Habelt, Bonn, pp 253–278

Magyari EK, Sümegi P, Braun M, Jakab G, Molnár M (2001) Retarded wetland succession: anthropogenic and climatic signals in a Holocene peat bog profile from north-east Hungary. J Ecol 89:1019–1032

Magyari EK, Jakab G, Sümegi P, Szöőr G (2008) Holocene vegetation dynamics in the Bereg Plain, NE Hungary—the Báb-tava pollen and plant macrofossil record. Acta GGM Debrecina 3:33–50

Magyari EK, Braun M, Buczkó K, Kern Z, László P, Hubay K, Bálint M (2009) Radiocarbon chronology of glacial lake sediments in the Retezat Mts (South Carpathians, Romania): a window to Late Glacial and Holocene climatic and paleoenvironmental changes. Cent Eur Geol 52:225–248

Magyari EK, Chapman JC, Passmore DG, Allen JRM, Huntley JP, Huntley B (2010) Holocene persistence of wooded steppe in the northern Great Hungarian Plain. J Biogeogr 37:915–935

Magyari EK, Chapman J, Fairbairn AS, Francis M, de Guzman M (2012) Neolithic human impact on the landscapes of North-East Hungary inferred from pollen and settlement records. Veget Hist Archaeobot 21:279–302

Magyari EK, Vincze I, Orbán I, Bíró T, Pál I (2018) Timing of major forest compositional changes and tree expansions in the Retezat Mts during the last 16,000 years. Quat Int 477:40–58

Micle D, Török-Oance M, Măruia L (2009) The morpho-topographic and cartographic analysis of the archaeological site Cornesti "Iarcuri", Timiş County, Romania, using computer sciences methods (GIS and Remote Sensing techniques). Ann Univ Tibiscus Comp Sci Series 7:249–262

Mihailă N, Popescu N (1987) Geologia şi morfogeneza Câmpiei de Vest (sectorul Arad-Vinga-Pecica) şi evoluţia Mureşului în cursul său inferior. Factori şi Procese Pedogenetice din Zona Temperată 74:1–18

Moore PD, Webb JA, Collinson ME (1991) Pollen analysis, 2nd edn. Blackwell Scientific Publications, Oxford

Moskal-del Hoyo M, Lityńska-Zając M, Raczky P, Anders A, Magyari EK (2018) The character of the Atlantic oak woods of the Great Hungarian Plain. Quat Int 463:337–351. https://doi.org/10.1016/j.quaint.2017.02.029

Náfrádi K, Sümegi P, Jakab G, Persaits G, Törőcsik T (2014) Reconstruction of the vegetation and environment during different Climatic and sociotechnical conditions of the last 3000 years in southwestern Hungary. Am J Plant Sci 5:1557–1577

Neacşu AG, Arsene G, Arsene A, Stroia C (2015) Research on several rare phytocoenoses in the Banat vegetation. Res J Agric Sci 42:280–286

Nykamp M, Heeb B, Knitter D, Krause J, Krause R, Szentmiklosi A, Schütt B (2015) Linking hydrological anomalies to archaeological evidences—Identification of Late Bronze Age Pathways at the Fortification Enclosure Iarcuri in Western Romania. In: Knitter D, Bebermeier W, Nakoinz O (eds) Bridging the Gap—Integrated Approaches in Landscape Archaeology. Berlin. Journal for Ancient Studies Special vol 4:77–92

Nykamp M, Hoelzmann P, Heeb B, Szentmiklosi A, Schütt B (2016) Holocene sediment dynamics in the environs of the fortification enclosure of Corneşti-Iarcuri in the Romanian Banat. Quat Int 415:190–203

Nykamp M, Knitter D, Timár G, Krause J, Heeb B, Szentmiklosi A, Schütt B (2017) Estimation of wind-driven erosion of a loess-like sediment and its implications for the occurrence of archaeological surface and subsurface finds—an example from the environs of Corneşti-Iarcuri, western Romania. J Archaeol Sci 12:601–612

Onac BP, Constantin S, Lundberg J, Lauritzen S-E (2002) Isotopic climate record in a Holocene stalagmite from Ursilor Cave (Romania). J Quat Sci 17:319–327

Perşoiu A (2017) Climate evolution during the late glacial and the Holocene. In: Radoane M, Vespremeanu-Stroe A (eds) Landform dynamics and evolution in Romania. Springer, New York, pp 57–66

Pietsch D, Kühn P (2014) Buried soils in the context of geoarchaeological research—two examples from Germany and Ethiopia. Archaeol Anthropol Sci 9:1571–1583

Punt W et al. (ed) (1976–2009) The northwest European Pollen Flora, vol I–IX. Elsevier, Amsterdam

Reille M (1992) Pollen et spores d'Europe et d'Afrique du Nord. Laboratoire de Botanique Historique et Palynologie, Marseille

Reille M (1998) Pollen et spores d'Europe et d'Afrique du Nord, Suppl 2. Laboratoire de Botanique Historique et Palynologie, Marseille

Reimer P, Bard E, Bayliss A et al (2013) IntCal13 and marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55:1869–1887

Rieser H-H (2001) Das rumänische Banat: eine multikulturelle region im Umbruch. Geographische Transformationsforschungen am Beispiel der jüngeren Kulturlandschaftsentwicklung in Südwestrumänien. Thorbecke, Stuttgart

Rogobete G, Ţărău D, Bertici R, Dicu D (2011) Soils in relation to archeology at the tell site of Uivar in the South-west of Romania. Factori şi Procese Pedogenetice din Zona Temperată 10:51–60

Rohdenburg HH (1970) Morphodynamische Aktivitäts- und Stabilitätszeiten statt Pluvial- und lnterpluvialzeiten. Eiszeitalt Ggw 2:81–96

Rösch M, Fischer E (2000) A radiocarbon dated Holocene pollen profile from the Banat mountains (Southwestern Carpathians, Romania). Flora 195:277–286

Schlichting E, Blume H-P, Stahr K (1995) Bodenkundliches Praktikum—Eine Einführung in pedologisches Arbeiten für Ökologen, insbesondere Land- und Forstwirte und für Geowissenschaftler, 2nd edn. Blackwell, Berlin

Sherwood SC, Windingstad JD, Barker AW, O'Shea JM, Cullen Sherwood W (2013) Evidence for Holocene aeolian activity at the close of the Middle Bronze Age in the Eastern Carpathian Basin:

geoarchaeological Results from the Mureş¸ River Valley, Romania. Geoarchaeology 28:131–146
Stanciu E (2005) Precipitaţiile atmosferice din Banat. Eurostampa, Timişoara
Stanley RG, Linskens HF (1974) Pollen: biology, biochemistry, management. Springer, Berlin
Stika H-P, Heiss AG (2013) Plant cultivation in the Bronze Age. In: Fokkens H, Harding A (eds) The Oxford handbook of the European Bronze Age. University Press, Oxford, pp 348–369
Stockmarr J (1971) Tablets with spores used in absolute pollen analysis. Pollen et Spores 13:615–621
Sümegi P, Kertész R, Hertelendi E (2002) Environmental change and human adaptation in the Carpathian basin at the late glacial/postglacial transition. In: Jerem E, Biró KT, Rudner E (eds) Archaeometry 98. Proceedings of the 31th symposium Budapest, April 26–May 3,1998. BAR International Series 1043. Archaeopress, Oxford, pp 171–177
Sümegi P, Gulyás S, Persaits G, Szelepcsényi Z (2012) Long environment change in forest steppe habitat of the Great Hungarian Plain based on paleoecological data. In: Rakonczai J, Ladányi Z (eds) Review of climate change research program at the University of Szeged (2010–2012). SZTE TTIK Földrajzi és Földtani Tanszékcsoport, Szeged, pp 7–24
Szentmiklosi A, Heeb BS, Heeb J, Harding A, Krause R, Becker H (2011) Corneşti-Iarcuri–a Bronze Age town in the Romanian Banat? Antiquity 85:819–838
Tanţău I, Reille M, de Beaulieu J-L, Fărcaş S, Goslar T, Paterne M (2003) Vegetation history in the Eastern Romanian Carpathians: pollen analysis of two sequences from the Mohoş crater. Veget Hist Archaeobot 12:113–125
Tanţău I, Reille M, de Beaulieu J-L, Fărcaş S (2006) Late glacial and Holocene vegetation history in the southern part of Transylvania (Romania): pollen analysis of two sequences from Avrig. J Quat Sci 21:49–61
Tanţău I, Reille M, de Beaulieu J-L, Fărcaş S, Brewer S (2009) Holocene vegetation history in Romanian Subcarpathians. Quat Res 72:164–173
Tanţău I, Fărcaş S, Beldean C, Geanta A (2011) Late Holocene paleoenvironments and human impact in Făgăras depression (Southern Transylvania, Romania). Carpath J Earth Environ Sci 6:171–178
Ţărău D, Dicu D, Oncia S, Ţărău I (2010) Pedological and agrochemical evaluation of degraded lands for their recovery through vineyards, orchards and forest management plans. Res J Agric Sci 42:880–887
Ţărău D, Dicu D, Rogobete G, Constantin M, Ţărău A (2014) The role of pedological information in the definition of land productivity and potential pressures on soil quality from Timiş County. Soil Form Factors Proces Temp Zone 13:45–49
Tipping R, Bunting MJ, Davies AL, Murray H, Fraser S, McCulloch R (2009) Modelling land use around an early Neolithic timber 'hall' in north east Scotland from high spatial resolution pollen analyses. J Archaeol Sci 36:140–149
Tomescu AMF (2000) Evaluation of Holocene pollen records from the Romanian Plain. Rev Palaeobot Palynol 109:219–233
Urdea P, Sipos G, Kiss T, Onaca A (2012) The Maros/Mureş. In: Sipos G (ed) Past, present, future of the Maros/Mureş river. Departmentul de Geografie, Timişoara, pp 159–166
Van Mourik JM (1999) The use of micromorphology in soil pollen analysis: the interpretation of the pollen content of slope deposits in Galicia, Spain. Catena 35:239–257
Walter H, Breckle SW (1986) Ökologie der Erde, Band 3: Spezielle Ökologie der gemäßigten und arktischen Zonen Euro-Nordasiens: Zonobiom VI-IX. Fischer, Stuttgart
Willis KJ, Sümegi P, Braun M, Tóth A (1995) The late quaternary environmental history of Bátorliget, N.E Hungary. Palaeogeogr Palaeoclimatol Palaeoecol 118:25–47
Willis KJ, Braun M, Sümegi P, Tóth A (1997) Does soil change cause vegetation change or vice versa? A temporal perspective from Hungary. Ecology 78:740–750
Willis KJ, Sümegi P, Braun M, Bennett KD (1998) Prehistoric land degradation in Hungary. Antiquity 72:101–113
Zhang W, Lu H, Li C, Dodson J, Meng X (2017) Pollen preservation and its potential influence on paleoenvironmentalreconstruction in Chinese loess deposits. Rev Palaeobot Palynol 240:1–10