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REVIEW

Holocene anthropogenic landscapes in the Balkans: the palaeobotanical evidence from southwestern Bulgaria

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Abstract Palaeoecological reconstructions from the region of southwestern Bulgaria were used for inferring the human impact on the vegetation and landscape during the last 8 millennia. They are based on data from pollen analyses of lakes and peat-bogs, plant macrofossils, archaeobotanical finds and radiocarbon dating. During the early Holocene, after 7900 cal. B.P. (5950 cal. B.C.) the climate changed to cooler summers, milder winters and higher precipitation resulting in the formation of a coniferous belt dominated by *Pinus* sp. and *Abies alba*. These favorable environmental pre-conditions had a positive influence on the Neolithisation of the Balkans after the 8200 cal. B.P. (6250 cal. B.C.) cold event, which caused drought in the Eastern Mediterranean. Direct evidence from wood charcoal records from the Neolithic settlement layers in the study area shows a slight modification of the surrounding woodlands and an increase of the light-demanding components, probably expressed through larger forest border zones and thinning out of the wood stands. The increase in the number of settlements in the valleys of southwestern Bulgaria intensified the human activity visible in the palaeobotanical record from 6950 cal. B.P. (5000 cal. B.C.) onwards. Between ca. 5700–5100 cal. B.P. (3800–3200 cal. B.C.) signs of anthropogenic influence on the vegetation are virtually absent. The intensity of human impact increased notably after 3200 cal. B.P. (1400–1250 cal. B.C., approx. Late Bronze Age), documented by a rise of pollen anthropogenic indicators. The final transformations in the natural forest cover after 2750 cal. B.P. (800 cal. B.C. onset of the Iron Age) marked the reduction of the coniferous forests dominated by *Abies alba* and *Pinus* sp. and the expansion of *Fagus sylvatica* and *Picea abies*. These vegetation changes are contemporaneous with increase of the palaeofire activities and the next peak of anthropogenic indicators. The changes in the landscape during the Roman period and the medieval period reflect regional environmental features and were forced by the diversification of anthropogenic activity.

Keywords Pollen · Wood charcoal analysis · Human impact · Climate change · South Eastern Europe

Introduction

Palaeobotanical proxy data can give a comprehensive view of anthropogenic impact on the natural vegetation, providing data on human-environment interactions. In combination with archaeological data, palaeoecological information allows the reconstruction of interactions and/or adaptation of past societies to Holocene climate changes during different historical epochs (Gaillard 2007).

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Southwestern Bulgaria is of special interest for studies on this topic as its natural vegetation has been influenced by anthropogenic activity since at least 8,500 years ago, starting with the introduction of Neolithic farming and continuously increasing through millennia of human occupation. The area is considered as one of the routes for the Neolithisation of southeastern Europe, playing a key role in the prehistory of the region because of its special geographic position linked with the Aegean in the south, the Thracian plain to the east and the Danube valley to the north. This position of the study area makes it very suitable for tracing out various regional land use developments and influences on the vegetation. Its natural conditions have a transitional character from Mediterranean to continental climate and vegetation, and could be crucial for understanding the linkage between the near-eastern and European land use practices.

The main periods of human occupation in the region, if considered against the background of the main palaeoclimatic events during the Holocene, show certain parallels and relationships (for discussion of some of them see Weninger et al. 2009). The Neolithisation in the study area was preceded by the 8200 cal. B.P. (ca. 6200 cal. B.C.) cooling event which influenced the environment and human occupation in the study area (Weninger et al. 2006). Another period of importance is the end of the Holocene climatic optimum, which can be roughly associated with Bond cycle 4: 5400–4800 cal. B.P. (3450–2850 cal. B.C.) (Bond et al. 2001) and which is more or less contemporary with the transitional period between the end of the Chalcolithic period in Bulgaria (ca. 3800–3500 cal. B.C.) and the onset of the Early Bronze Age (3000–2800 cal. B.C.) (Görsdorf and Boyadzhiev 1996). The climatic fluctuations that followed, considered as global, such as Bond Event 3 or the 4200 cal. B.P. (2250 cal. B.C.) event, correspond to the second half of the Early Bronze Age, which was a period of low settlement activity in the study area (Grębska-Kulowa and Kulow 2007). The evidence for the adjacent areas, such as the Aegean and Anatolia (Roberts et al. 2008, 2011), indicate aridity for this period. The rather arid period around 2850 cal. B.P. (900 cal. B.C., corresponding to Bond event 2), was contemporary with the Early Iron Age in the region. The last fairly well globally recorded palaeoclimatic event (Wanner et al. 2008) is the period of ca. 700–500 cal. B.P. (A.D. 1300–1500) corresponding to the Little Ice Age.

In order to evaluate the degree of human impact in the region under consideration, a number of investigations combining pollen analysis, archaeobotanical studies, radiocarbon dating, and information on past climate changes were carried out over a period of 20 years. These studies focused on the introduction of agriculture, the practice of stock-breeding and the collection of plant material for various purposes, as well as the human-environment interactions (e.g. Popova and Bozhilova 1997; Marinova et al. 2002; Kreuz et al. 2005; Marinova 2006; Bozilova and Tonkov 2007; Marinova and Thiebault 2008; Marinova and Popova 2008).

Since at present this information is spread over different publications and partly unpublished, this paper provides the first comprehensive overview and critical evaluation of past vegetation changes in relation to human occupation for the region. As such, it presents evidence on the long term development of the human landscapes in southwestern Bulgaria during the Holocene. The main sources of information for this study are the palynological and anthracological data from south western Bulgaria. Together with this some relevant archaeobotanical information on seed/fruit remains of crops and weeds is also taken into consideration. Possible interpretations for natural and anthropogenic landscape changes are discussed, and the most important stages of these changes are defined. The emphasis will finally be put into a regional context, by comparison with data from the adjacent areas.

Study area

The study area is situated in southeastern Europe and can be divided in two sub-regions corresponding to the main geographical features of southwestern Bulgaria: (1) the Upper and Middle-Struma river valley and its adjoining slopes, and (2) the mountain areas; to the east of the valley the Rila and Pirin mountains, and to the west several smaller mountain ranges (Konjavska, Osogovo and Maleshevska). The locations of the palynological and archaeological sites considered here are shown in Fig. 1.

Natural environment

The climate in the study area, especially its southern part, is under the influence of the Mediterranean, while more continental conditions prevail further north. In general, it can be considered as being transitional between continental and sub-Mediterranean climate. The mean annual temperature in the lowlands varies from 14°C in the south to 10°C in the north. The annual precipitation in the lowlands is from 780 mm in the south to ca. 600 mm in the north. Above 1,000 m the climate changes to mountainous and the mean temperature drops by 0.5°C with each 100 m increase in altitude. The mean annual precipitation is 800–1,000 mm, much of it snow at higher altitudes (Kopralev 2002).

According to Velchev (2002) the natural vegetation in the lowlands of the study area (up to 900 m) is composed of xerothermic and xeromesophilous oak and hornbeam forests dominated by *Quercus cerris*, *Q. pubescens*, *Q. frainetto*, *Q. dalechampii*, *Carpinus orientalis* and *C. betulus*, with an admixture of *Ulmus glabra*, *Acer platanoides* and

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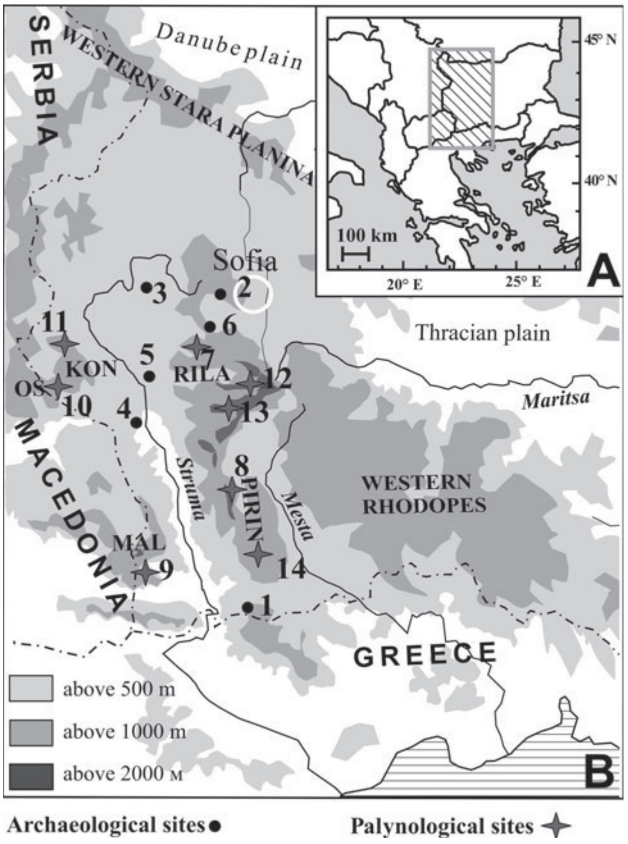

Fig. 1 **a** Overview map with the study area indicated by a hatched rectangle. **b** Detailed map showing the palynological sites under consideration, the three additionally included in the summary given in Fig. 4, and the archaeological sites; *KON* Konjavska Mountain, *OS* Osogovo Mountain, *MAL* Maleshevska Mountain. Archaeological sites: *1* Kovacevo 172 m a.s.l., *2* Slatina 550 m a.s.l., *3* Galabnik 650 m a.s.l., *4* Balgarchevo 368 m a.s.l., *5* Slatino 405 m a.s.l., *6* Kremenik 720 m a.s.l.; *Palynological sites*: *7* Lake Trilistnika 2,216 m, *8* Lake Ribno Banderishko 2,190 m a.s.l., *9* Peat bog Maleshevska 1,700 m a.s.l., *10* Peat bog Osogovo 1,720 m, *11* Tshokljovo marsh 870 m a.s.l., *12* Ostrezki Lakes 2,330 m a.s.l., *13* Dry Lake 1,900 m a.s.l., *14* Peat bog Mutorog 1,700 m a.s.l

A. pseudoplatanus. The sub-Mediterranean floristic elements in these forests increase from north to south. Today human impact has turned many of those forests into secondary communities dominated by sub-Mediterranean species like *Carpinus orientalis* and *Paliurus spina-christi*, and partly by *Juniperus oxycedrus*, *Phillyrea latifolia*, *Quercus coccifera* und *Pistacia terebinthus*. The open habitats created by anthropogenic activities are usually dominated by xerophylous shrubs and herbs mainly of a sub- Mediterranean or steppe character such as *Genista rumelica*, *Astragalua angustifolius*, *Amygdalus nana*, *Artemisia alba*, *Agropyron brandsae* etc. (Bondev 1991).

In the mountain ranges to the west of the Struma valley the zone between 1,000 and 1,600 m a.s.l. is dominated by forests of *Fagus sylvatica* while in the Rila and Pirin mountains above 1,500 m a coniferous belt exists dominated by *Pinus sylvestris*, *Picea abies* and *Pinus peuce*. The subalpine area (2,000–2,400 m) in the Rila and Pirin mountains is dominated by a thick, impenetrable formation of *Pinus mugo* with *Juniperus sibirica* and *Vaccinium myrtillus*. Above it the alpine area is occupied by various herb communities.

Archaeological background

The development of the prehistoric cultures in southwestern Bulgaria, and particularly along the Struma valley, is a key question in Balkan prehistory. The direct territorial connection of this region with the northern Aegean coast, and from there with Anatolia, influenced the specific dynamics of cultural changes through all prehistoric periods (Pernicheva 1995; Nikolov 2007). The Struma valley is considered as one of the primary routes for the Neolithisation of the Balkan Peninsula (Lichardus-Itten et al. 2006) which according to the available archaeological evidence and radiocarbon dates started around 6200/6100 cal. B.C. (Görsdorf and Bojadziev 1996; Boyadzhiev 2009). The Early Neolithic settlements were situated in the foothills of the mountains, between 400 and 650 m. Quite probably their location reflects favorable climatic and ecological conditions (Todorova and Vaisov 1989). An increase in the number of prehistoric settlements is observed during the Neolithic with a maximum around the last quarter of the 6th millennium B.C. (Grębska-Kulowa and Kulow 2007). During the second half of the Late Neolithic (5200–4900 cal. B.C.) new, larger settlements with surface areas of up to 16 ha were founded. The number of the settlements increased considerably during this period, indicating a strong increase in the population (Grębska-Kulova 2005). By the end of the Late Neolithic and the beginning of the Early Chalcolithic (4900–4850 cal. B.C.) the number of settlements was decreasing and this also continued during the Early Bronze Age (3200–2500 cal. B.C.). The settlements were of limited size and were usually surrounded with palisades or stone walls. This resulted in a chain of protected sites in the Struma valley. A second maximum in the settlement activities in the area was observed during the Late Bronze Age (1400–1200 cal. B.C.) (Grębska-Kulowa and Kulow 2007). Between the Early Bronze Age and the beginning of the Late Bronze Age there is a chronological hiatus of about 600 years from the duration of which no particular sites and cultural content have yet been found (Boyadzhiev 2007).

Subsequently, settlements were founded in the lower parts of the Struma valley, near the river, only during the Late Iron Age probably as a result of the increase in population. During the 6th and in the first half of the 5th century B.C. the broader geographical area around the lower courses of the Mesta (Nestos), Struma (Strymon) and

Vardar (Axios) rivers experienced remarkable economical, political and cultural prosperity. During the 5th–4th century B.C. the area was integrated in the Kingdom of Macedonia, and later on, in the 1st century A.D. it became part of the Roman Empire (Delev 2002). Of importance for the land use strategies is also the fact that woodland-consuming iron production was practiced on a large scale in the mountainous area between the rivers Mesta and Struma during the Medieval. Recent surveys (Athanassov et al. 2010) have found iron slag on numerous sites in the area since from even Late Antiquity. In general, the study area was also involved in transhumance at least from the Late Bronze Age (Leshtakov 2006) until the First World War. This should also be considered when interpreting the palaeoecological evidence for the past landscapes.

Materials and methods

The evidence used for this study was taken first from several palynological profiles considered most appropriate due to their relatively good chronological framework and location. These data [summarized in Fig. 2 and ESM (Electronic Supplementary Material) Figs 1–5] were combined with anthracological evidence gathered from archaeological sites (Fig. 3). The combination and comparison of data coming from natural sediments (pollen) and anthropogenic layers (wood charcoals) allow the creation of a more detailed and complete picture of the past anthropogenic changes in the vegetation. Moreover, in interpreting the palynological and anthracological data, the archaeobotanical evidence on the ancient agriculture and land use in the study area was also taken into consideration (see overview in Valamoti 2004; Borojevic 2006; Marinova 2006; Popova 2009).

Finally, an attempt was made to correlate the palaeobotanical evidence from the study area with information on global rapid climate changes as given by Mayewski et al. (2004), and with the available radiocarbon datasets and archaeological chronology provided by Chohadzhiev (2007), Görsdorf and Bojazhiev (1996), Vajsov (1998), Gatsov and Boyadziev (2009) and Stefanovich and Bankoff (1998). The correlation is presented in Fig. 4.

Palynological data

The palynological data used in this paper originate from investigations already published in Tonkov (1988, 2003), Tonkov et al. (2002, 2008) and Tonkov and Bozilova (1992a, b). Simplified percentage pollen diagrams with selected taxa of importance for the current study are given as ESM Figs 1–5. The exaggeration of the curves is marked by a dotted pattern and is 10× in all of the diagrams. In all these detailed pollen diagrams the sum of the arboreal pollen averages 450–500 grains, with the exception of Tshokljovo Marsh where it was ca. 300 arboreal grains. For the majority of the pollen types the nomenclature of Beug

Fig. 2 Correlation between the local pollen assemblage zones in the pollen diagrams of southwestern Bulgaria (*KON* Konjavska Mountain, *OS* Osogovo Mountain, *MAL* Maleshevska Mountain)

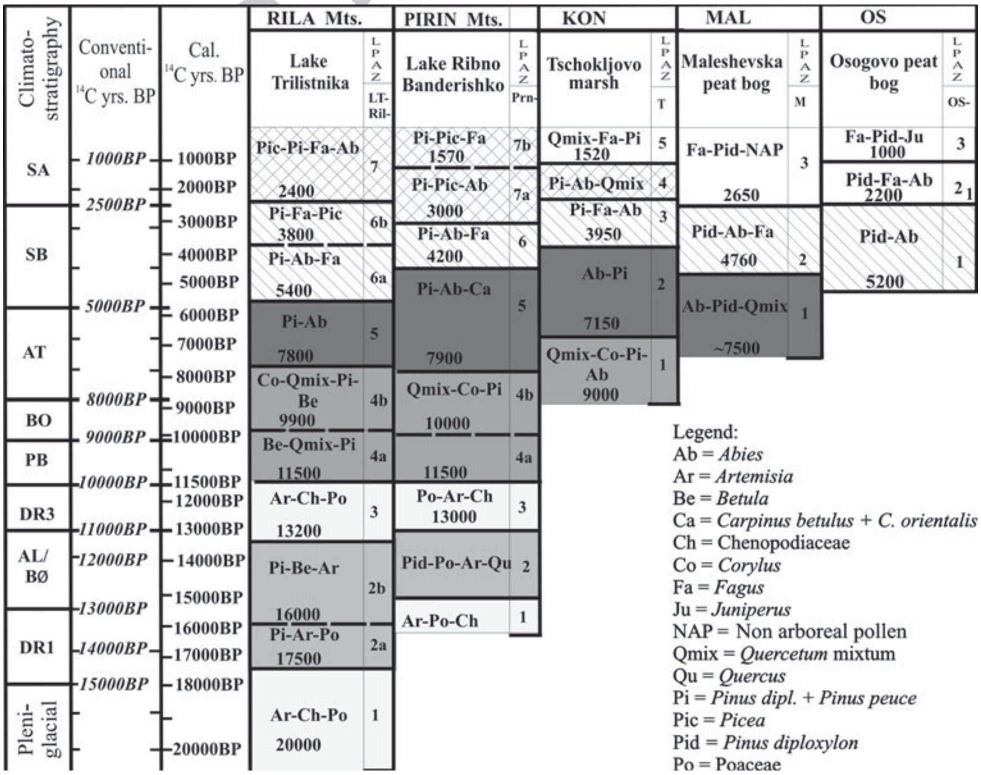

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Fig. 3 Wood charcoal records from archaeological sites in the study area presented in percentage values of the numbers of studied wood charcoal fragments

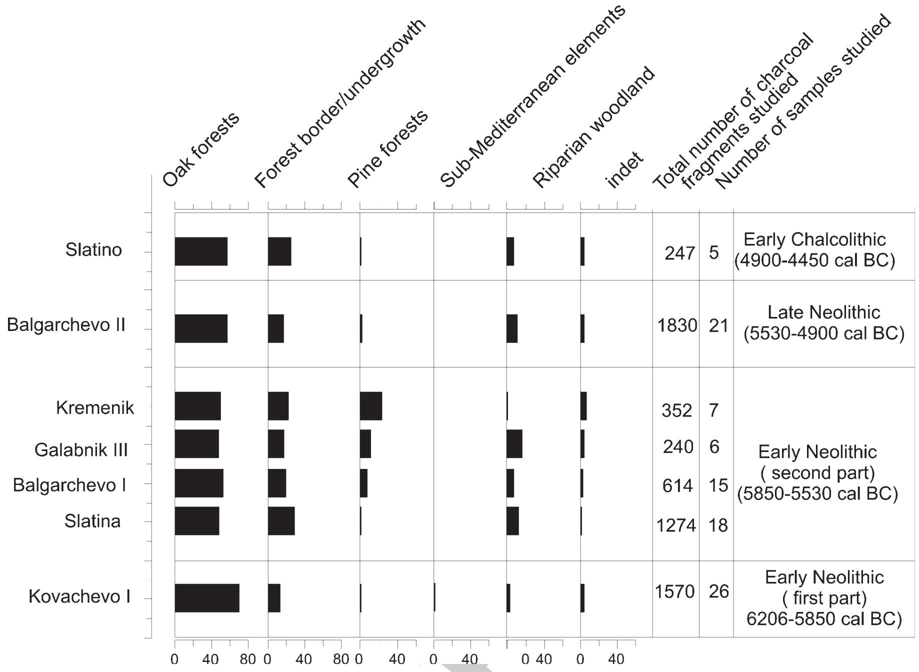
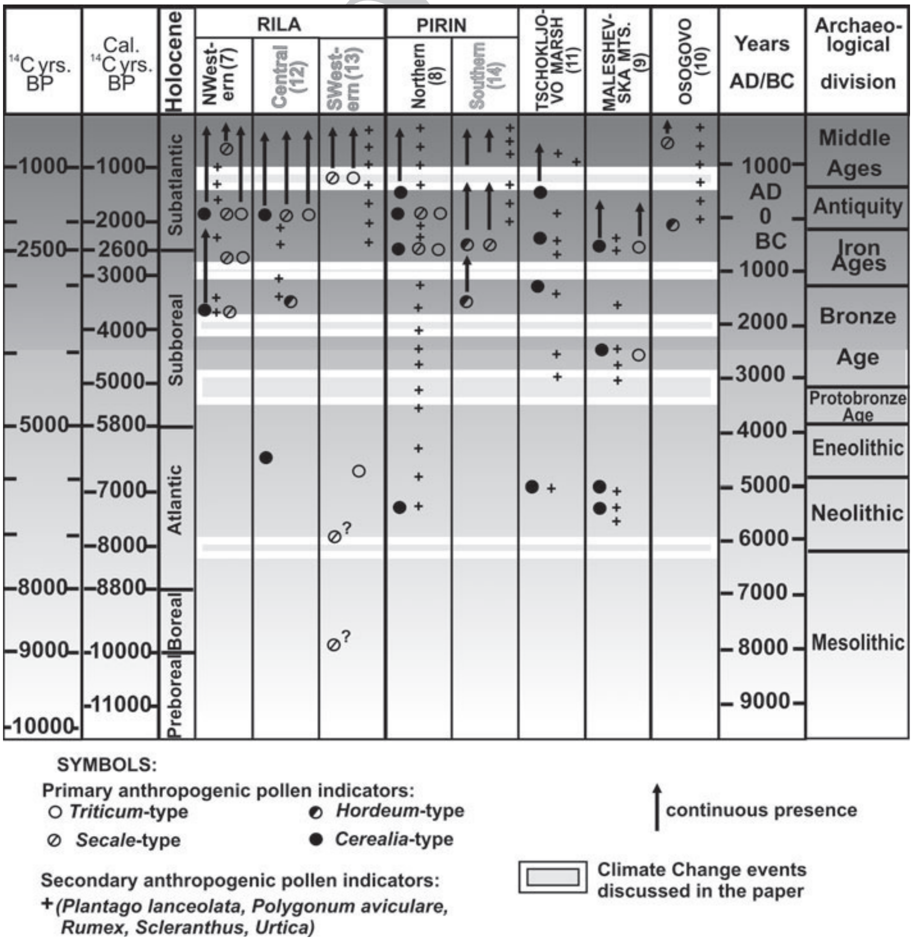


Fig. 4 Summary scheme for the anthropogenic indicators in the pollen diagrams of southwestern Bulgaria. The sites considered in detail in this paper are in *bold black* and further studies included in the summary, not further discussed here, are in *gray*. The numbers in *brackets* after each of the pollen records correspond to those given in Fig. 1. North Western Rila—Lake Trilistnika (7) ESM Fig. 1; Central Rila—Ostrezki Lakes (12) Tonkov and Marinova (2005); South Western Pirin—Dry Lake (13) Bozilova et al. (1986); Northern Pirin—Lake Ribno Banderishko (8) ESM Fig. 2; Southern Pirin—peat bog Mutorog (14) Panovska et al. (1995); Maleshevska Mountain—Peat bog Maleshevska (9) ESM Fig. 3; Osogovo Mountain—Peat bog Osogovo (10) ESM Fig 4; Konjavska Mountain—Tshokljovo marsh (11) ESM Fig. 5



(2004) was used. No hiatuses were detected in any of the pollen records. The age-depth models for each site are given in the corresponding publication referred to above. In the most cases the radiocarbon age control of the records is based on dating of bulk sediment except for the profile from Lake Ribno Banderishko (Tonkov et al. 2002), where AMS-dating on terrestrial plant macrofossils was applied. The lithological units for each of the records are represented in the corresponding diagrams (ESM Figs 1-5). The pollen source area for these palynological archives corresponds to small-medium size basins. As the sites are situated in montane areas transportation of pollen upslope from lower elevations is also considered as shown by studies of surface moss samples from the region (Tonkov 2007).

Palynological indicators for the interpretation of human impact on the vegetation in the study area

In order to understand the nature and extent of human impact on the ancient vegetation and landscape, it is important to define the major indicators for anthropogenic impact. Based on the approach of Behre (1981), the pollen data information is evaluated with special emphasis on the anthropogenic impact on the landscape visible in the palaeoecological records.

The primary anthropogenic indicators of cereal cultivation such as Cerealia-type, *Triticum*-type, *Hordeum*-type, *Avena*-type and *Secale* are also used in the current study for estimation of changes in land use (Faegri and Iversen 1989). The methodological approach for the defining of pollen taxa as “secondary anthropogenic indicators” in the pollen diagrams from Central Europe, the Mediterranean region and Greece has been discussed in detail (Behre 1981, 1988; Bottema 1982; Bottema and Woldring 1990). To a considerable extent these ideas were also applied to the pollen diagrams from Bulgaria (Bozilova and Tonkov 1990; Huttunen et al. 1992; Filipovich and Stefanova 1998; Lazarova 1995; Marinova and Atanassova 2006; Tonkov et al. 2011).

Special attention needs to be given to Cerealia-type as the pollen of several wild-growing grass taxa also shows the morphological features of this type (Beug 2004), which means that it does not necessarily come from cultivated fields, but could have originated from the local wild-growing vegetation. Hence, the records of this type should be considered more cautiously and only in connection with the other indicators for anthropogenic change and considering both the local vegetation and the information on human occupation in the study area (for further discussion on the topic see Behre 2007, 2008). The same is true to great extent for *Hordeum*-type, *Avena*-type and *Secale* as wild-growing representatives of these types could also be found in southeastern Europe. The archaeobotanical evidence from the Neolithic, Chalcolithic and Bronze Age period (from ca. 5900 to 1200 cal B.C.) shows that the main cereal crops of importance for the study area (Popova and Marinova 2007) were hulled wheats (*Triticum monococcum* and *T. dicoccum*) and barley (*Hordeum vulgare*). For this period *Triticum*-type could certainly be considered as a primary anthropogenic indicator, as the genus has no wild-growing representatives in the area under consideration. It is more difficult to consider *Hordeum*-type as a definite indicator of cultivation as several weedy and wild-growing species from the genus *Hordeum* occur in the study area. From the archaeobotanical information from the region of south-eastern Europe (Kroll 1991; Neef 2007; Popova 2009) it is known that cultivated rye (*Secale cereale*) gained importance from the Late Roman period onwards, but had occurred as a weed since the Late Iron Age (6th–4th century B.C.). Considering this, the *Secale* in the pollen diagrams found in sediments of earlier age than the Roman period is more likely to represent non-cultivated rye present as a weed or an element of the natural vegetation. Similarly for cultivated oats (*Avena sativa*) no evidence exists for its cultivation before the Roman age, but as a weed *Avena* sp. is known from the archaeobotanical record since the Late Bronze Age (Popova 2009). However the peaks of *Hordeum*-type, *Avena*-type and *Secale* should be attributed to anthropogenic activities, especially in connection with other evidence for cultivation and human impact.

Another pollen type indicative of anthropogenic activities is *Agrostemma githago*. However it can only really be used as an anthropogenic indicator from the Late Iron Age/Roman Age onwards when this plant becomes a constant element of the weed flora of the study area (Popova 2009). The regular appearance of *Juglans regia* in Mid-Holocene pollen records (Tonkov and Bozilova 1992b; Tonkov et al. 2002) from the study area indicated that this tree should be considered as native for this part of the country. Considering its more extensive occurrence after ca. 1400 cal. B.C. (corresponding to the Late Bronze Age) and the palynological evidence from adjacent regions (Bottema 1974, 2000; Jahns and Van den Bogaard 1998; Eastwood et al. 1998; Kaltenrieder et al. 2010) the pollen of *Juglans regia* could be interpreted as an indicator of anthropogenic activities from 1400 cal. B.C. onwards.

The secondary anthropogenic indicators characteristic of the mountains in southwestern Bulgaria include *Plantago lanceolata*-type, *Polygonum aviculare*-type, *Rumex*, *Scleranthus*, *Urtica*, *Cirsium*-type and *Juniperus*. They reflect permanent human occupation—ruderalization and stock-breeding. Special attention is paid to *Plantago lanceolata*-type, as a taxon that apart from human activity in settlement areas also reflects livestock grazing in the mountain meadows, but is also an important indicator of fallow land.

Quite often after forest clearing the pollen curves of Poaceae, *Artemisia*, Chenopodiaceae, *Plantago major/media*-type, *Urtica* and Cichorioideae (*Taraxacum*- or, according to Beug 2004, *Crepis*-type) increase and by careful evaluation of the dating these can also be used as secondary indicators for interpretation of human impact.

Some of the secondary anthropogenic indicators, for example *Artemisia* sp., Chenopodiaceae, Cichorioideae, *Cirsium*-type, *Plantago major/media*-type, *Rumex* etc. were also elements of the natural open vegetation during the Late Glacial and Early Holocene and for these periods they are not considered to indicate human impact. When occurring in subsequent periods these taxa are considered as anthropogenic indicators mainly only if they show parallel peaks in the pollen diagrams or appear in combination with other primary evidence of human impact on the vegetation.

Anthracological data

Anthracological analysis permits the reconstruction of the surrounding vegetation on areas where there are no sediments suitable for pollen analysis. In study areas where pollen bearing sediments near prehistoric sites have not yet been recovered, it allows the creation of a relatively good picture of the past vegetation and environments. Moreover, it represents the woodland used directly by the prehistoric population and allows the identification through wood charcoal macro remains of some taxa that could not be revealed by pollen analysis.

The anthracological data used for the current study comes from several archaeological sites from the study area (Fig. 1), all of them situated in the lowlands of the region between ca. 200 and 700 m a.s.l.

Together with the already published information on some of the sites (Marinova et al. 2002; Marinova and Thiebault 2008; Popova and Marinova 2007), additional information was used from samples from Kovacevo collected after 2003 and from further studies in the region (for the sites Balgarchevo, Slatina).

The laboratory study was carried out on charcoal (>2 mm) manually fractured in three anatomical planes (transversal, tangential and radial). The charcoal was examined with a reflected light microscope and counted. Specialized literature (Schweingruber 1990) and a reference collection of modern wood samples were used for the identification. Studies on the sample size required for adequate reconstruction of woodland vegetation in the archaeobotanical assemblages for the Western Mediterranean have shown that the best ca. 400–500 fragments per stratigraphic unit should be used (Chabal 1992). Thus for the sites in southeastern Europe, where the biodiversity is roughly comparable, at least 400 charcoal fragments per stratigraphic layer are needed. In the currently studied material this requirement is met by four of the total of six sites shown in Fig. 3.

The counts of wood charcoal fragments identified for each site were made to calculate percentage proportions between the different vegetation types to which the charcoal taxa most probably belonged and are plotted in chronological order (Fig. 3).

The classification of the different charcoal taxa to vegetation types follows those already published and extensively discussed by Marinova and Thiebault (2008) and is based on the descriptions of the potential natural vegetation in the region given in Bondev (1991) and Bohn et al. (2000/2003). The type defined as "oak forests" includes the wood charcoal fragments identified as *Quercus* sp., *Acer* sp. and *Carpinus* sp. The group defined as "forest border/undergrowth" includes light-demanding taxa like *Cornus* sp., *Corylus avellana*, *Juniperus* sp., Prunoideae, Pomoideae and Rosaceae. The group "pine forests" includes the wood charcoal identified as *Pinus nigra/sylvestris* and coniferous, and finally taxa like *Alnus* sp., *Fraxinus* sp., *Salix/Populus* and *Ulmus* sp. are attributed to the group called "riparian woodland". Being aware that some of these taxa could occur in more than one of the groups defined by us, the decision was made to assign them to the most probable of them.

Results

Palynological evidence

Several pollen diagrams from the mountains of southwestern Bulgaria with relatively good chronological control give information related to anthropogenic impact since the Neolithic.

The correlation of the vegetation development with the palynological data for the region is given in Fig. 2. In the following section the anthropogenic impact on the vegetation will be briefly presented against the background of the general vegetation development for the five selected palynological records.

Lake Trilistnika, Northwestern Rila Mts., ESM Fig. 1

The pollen data span the Late Glacial and the entire Holocene (Tonkov et al. 2008). The palynological record provides some information on the anthropogenic impact. This is not rich bearing in mind the high elevation (2,216 m a.s.l.) of the site studied, but is of importance in tracing human influence in the higher mountain area and on a regional scale.

One of the most important environmental changes for the Holocene occurred at the transition of pollen zones LT-4 and LT-5 (ca. 5900 cal. B.C. corresponding to the Early Neolithic) when the deciduous *Quercus*-forests with *Tilia*, *Ulmus* and *Corylus* declined. Coniferous forests dominated by *Pinus* (*P. sylvestris*, *P. peuce*) and *Abies alba* developed at higher altitudes. The decrease in *Betula* pollen indicates that in many places birch forests gave way to coniferous vegetation. The vertical migration of conifers like *A. alba* and *P. peuce* and the expansion of their areas was probably facilitated by an increase in precipitation and humidity (Davis et al. 2003), taking place after soils with humic horizons had developed (Bennett and Willis 1995). By this time the first sporadic records of *Plantago lanceolata*-type had occurred. From 1400 cal. B.C. (Late Bronze Age) the continuous presence of pollen of *Rumex* and *P. lanceolata*-type begins and the first pollen grains of *Juglans regia* appear. The establishment of *J. regia* pollen and the presence of cereal pollen (*Triticum*-type, *Secale*) points to an expansion of agriculture and cultivation of walnut in the foothills of the mountains, whereas *Rumex*, *P. lanceolata*-type and *Scleranthus* pollen indicate livestock-grazing in the mountain meadows.

Lake Ribno Banderishko, Northern Pirin Mts., ESM Fig. 2

The palynological data cover part of the Lateglacial and the entire Holocene (Tonkov et al. 2002). The site is situated at 2,190 m a.s.l. Comparable to the situation in the Rila Mts. at ca. 5900 cal. B.C. (Early Neolithic) important changes in the forest cover occurred. The mixed deciduous *Quercus*-forests with abundant *Tilia*, *Ulmus* and *Corylus* retreated and were replaced in many places by *Carpinus orientalis/Ostrya carpinifolia*, while further upslope communities of *C. betulus* developed. The favorable climatic and edaphic conditions triggered the formation of a coniferous belt dominated by *Pinus sylvestris*, *P. peuce* and *A. alba*. This is also the period when the first indications of human presence are recorded in the pollen diagram. The beginning of a continuous *P. lanceolata*-type pollen curve and the first appearance of Cerealia-type, *P. major/media*-type and *Polygonum aviculare*-type pollen is noteworthy. Later on, ca. 1000 cal. B.C., the uninterrupted presence of *Scleranthus* pollen begins. The most indicative signs of human impact were present after ca. 700 cal. B.C. with the continuous pollen curve of Cerealia-type and the regular presence of both *J. regia* and secondary anthropogenic pollen indicators.

Peat bog Maleshevska Mts., ESM Fig. 3

The palynological record from this lower mountain, situated in a western direction from the Struma river at about 1,700 m a.s.l., reveals the changes in the natural vegetation since 5500 cal. B.C. (Late Neolithic) (Tonkov and Bozilova 1992a). Three distinct periods are recognized in the pollen diagram.

During the earliest period (5500–2760 cal. B.C., Middle/Late Neolithic-Early Bronze Age) forests of *A. alba* with an admixture of *P. sylvestris* and *P. nigra* dominated above 1,000–1,200 m thus shaping the upper tree-line for more than the next 3,000 years. The wide distribution of the conifers was favored by an increase in precipitation and humidity during the Holocene climatic optimum. Below the coniferous belt, mixed oak forests (*Quercetum mixtum*) with abundant *Tilia*, *Ulmus* and *Corylus avellana* developed. The presence of Cerealia-type pollen observed for the last quarter of the 6th millennium B.C. might reflect increasing settlement activity and, related to this, cereal cultivation in the Struma valley.

During the next period (2760–800 cal. B.C., Early Bronze Age-Early Iron Age) a sharp decline in the areas occupied by *Abies* is observed around 2760 cal. B.C. Quite probably, this was caused by a decrease in humidity (roughly corresponding to Bond event 4) and was reinforced by the intensification of human disturbance in all vegetation belts. By ca. 800 cal. B.C. beech forests replaced the conifers, shaping the present tree-line. The uninterrupted presence of the anthropogenic pollen indicators (Cerealia-type, *P. lanceolata*-type, *Rumex*, *Scleranthus*) clearly indicates the practice of agriculture in the foothills of the mountain and extended sheep/goat and cattle-breeding in the lower mountain areas. The continuous presence of *Juglans* pollen dates back to the Early Bronze age.

The last period (800 cal. B.C.—present) is characterized by a strong anthropogenic influence on the vegetation. At lower elevations the oak forests were anthropogenically disturbed and replaced by secondary communities dominated by *Carpinus orientalis* and *Quercus pubescens*, while at higher elevations beech forests replaced the conifers.

Peat bog Osogovo Mts., ESM Fig. 4

The palynological data from this site provide a reliable basis for a palaeovegetation reconstruction for the last ca. 5000 years (Tonkov 2003). The site is situated at 1,720 m a.s.l. and the oldest pollen spectra reflect a characteristic vegetation pattern dominated by *Pinus* sp. and *Abies alba* which lasted until ca. 200 cal. B.C. The broad-leaved vegetation distributed at lower altitudes was composed of *Quercus* sp., *Carpinus betulus*, *Tilia* sp. and *Corylus avellana*. The first indication of human presence is the appearance of the pollen curves of *Rumex* and *P. lanceolata*-type at ca. 1500 cal. B.C. (transition to Late Bronze Age) synchronously with the decline of the conifers and the rise of the pollen curve of *Fagus sylvatica*. In the course of a thousand years beech has replaced the conifers and in this process the anthropogenic impact should also be taken into consideration. The high values of *Scleranthus* pollen found throughout the entire profile are of local/extra-local origin and are most probably indicative of stock-breeding practiced in the vicinity. The first peak of *Scleranthus* could be assigned to the onset of the Late Bronze Age.

Tschokljovo Marsh, Konjavska Mts., ESM Fig. 5

The study site is nowadays a large marsh (870 m a.s.l.) formed in a depression in the Konjavska Mts. (1,487 m) near to the upper course of the Struma River. The pollen data span the last 9,000 years (Tonkov and Bozilova 1992b; Bozilova and Tonkov 2007).

Indications of human presence are not recorded between 7000 and 5200 cal. B.C. when the mountain slopes surrounding the marsh were covered by mixed oak forests with *Tilia*, *Corylus avellana*, *Ulmus*, some *Carpinus orientalis/Ostrya carpinifolia* and *C. betulus*. On the higher mountain areas stands of *Pinus* sp. and *A. alba* occurred.

The following period of ca. 3,000 years (5200-ca. 2000 cal. B.C.) is characterized by a vast spread of *A. alba* forests. The most interesting feature, however, is the continuous presence of *Juglans* pollen, probably indicating its native distribution in this area rather than cultivation by the local population.

During the subsequent period, which lasted until the start of the Roman occupation (pollen zone transition T-4/T-5), the palynological indications of human presence and activity occur rather sporadically. The coniferous forests composed of *A. alba* and *Pinus* were replaced by forests of *F. sylvatica*, also around the start of the Roman period.

Wood charcoal analysis

The summary of the data from wood charcoal analysis is given in Fig. 3. The dominant vegetation type around the archaeological sites is deciduous oak forest and its representatives dominate the anthracological assemblages. An important characteristic of the wood charcoal assemblages is the increasing proportion of light demanding shrubby forest border and undergrowth elements of the oak forests. At most of the sites this is shown by the rather high percentage proportions of *Cornus* sp. wood (Marinova and Thiebault 2008; Marinova et al. 2002), followed by representatives of Rosaceae, and to a lesser extent, of *Juniperus* sp. and *Corylus avellana*. Many of these small trees and shrubs could not easily be detected by the palynological investigations as they are not wind- but insect-pollinated and/or were growing mainly in the lowlands, far from the palynological sites available in the study area. The anthracological records cover the period when farming started in the study area and thus overcome some of the above mentioned disadvantages of the palynological evidence in tracing the first anthropogenic influence on the vegetation. Figure 3 shows that, starting with the Early Neolithic then until the Early Chalcolithic, the proportions of the light-demanding woodland (given in Fig. 3 under "Forest border/undergrowth") and riparian woodland increase in the anthracological assemblages. It can also be seen that the Neolithic population certainly had access to *Pinus* stands or woodland at lower elevations, most probably those were mainly *P. nigra* stands nowadays greatly diminished by anthropogenic pressure (Bondev 1991).

Discussion

The palynological evidence on the anthropogenic changes of the vegetation is summarized and correlated for the different sub-regions in Fig. 4. This summary is based on the palynological examples closely considered in this paper (ESM Figs. 1-5) and on additional evidence described in detail by Tonkov (2007). The development of the natural landscapes is discussed in the context of the changing human occupation in the area and of the climate change events observed on a global scale discussed in Bond et al. (2001), Mayewski et al. (2004) and Wanner et al. (2008).

First signs of human impact on the vegetation (Neolithic to Early Bronze Age, 6200–2800 cal B.C.)

The up-to-date palynological evidence from southwestern Bulgaria shows the response of the vegetation to the 8200 B.P. event, this response best manifested by the expansion of *Abies alba* in the coniferous belts of Rila and Pirin mountains. (Tonkov et al. 2008). The start of the Holocene climate optimum facilitated the spread of mixed oak forests at low and mid-altitudes, where later the first prehistoric settlements were founded. The palynological records from the area under consideration come from higher altitudes, in most cases above 1,000 m, hence above the main area of activity of the Neolithic population and of limited use for reconstructing human impact on the vegetation for that period. For the only site lower than this limit, Tschokljovo marsh (870 m a.s.l.), the resolution of the palynological record is not high for this period, and shows that oak forests with hazel as a pioneering element were present in the lowlands.

The evidence from wood charcoal analysis is very useful for tracing the woodland use in the initial stages of farming introduction in the region, as this comes directly from the prehistoric settlements. The anthracological as well as the palynological records indicate wide distribution of deciduous forests dominated by *Quercus* sp. These were the

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main woodland resource used by the Neolithic population. In the course of the Neolithic light-demanding trees and shrubs became more important in the oak woodlands. This change is related to the increased disturbance of the woodland by the local people, e.g. establishment of cultivating fields, grazing of animals, collecting fruits, fodder and firewood. This led to an increase of forest edge zones and secondary forests. Similar tendencies are also observed in the palynological records from Slovenia for the period of ca. 5500 cal. B.C., when no forest clearance occurred during the Neolithic period, but small-scale forest modifications, burning and coppicing were detected (Andric and Willis 2003). Moreover, the Neolithic land use strategies, involving coppicing and pollarding and forest pasture of small ruminants, favoured and enlarged such landscapes as is visible in the evidence from Central Europe (Kalis et al. 2003; Kreuz 2008; Bleicher and Herbig 2010; Gardner 2002; Magyari et al. in press). The evidence from Anatolia (Asouti and Hather 2001; Fairbairn et al. 2002; Riehl and Marinova 2008), the Balkans and Central Europe shows quite uniform land use strategies for broad parts of the continent during the Neolithic, resulting in slight modifications of the woodlands and leading to a more patchy character of the forests, with increasing diversity of their composition. Considering also the hypothesis of the uniformity of the Neolithic crop cultivation practices in Central Europe, South Eastern Europe and the Near East proposed by Bogaard (2004), a uniformity of general plant use strategies (including both field cultivation and land use) for this broad area could even be suggested. However palynological records with detailed chronological estimations as well as wood charcoal records concerning all stages of the Neolithic and the Chalcolithic are still needed to reconstruct reliably and more specifically the impact on the vegetation of the agriculture and land use for these periods which span over 1,800 years. Moreover the role of the fire in shaping the vegetation and landscape still needs to be explored by increasingly including micro- and macro-charcoal records, which at present are very scarcely available for the region.

In the pollen diagrams from Northern Pirin, Konjavska and Maleshevska mountains (ESM Figs. 2, 3, and 5) the first sporadic indications of cultivation of cereals (Cerealia-type) and grazing activities (*Cirsium*-type, *P. lanceolata*-type, *Polygonum aviculare*-type, *Rumex*, *Scleranthus*) appear during the Late Neolithic (ca. 5500–5000 cal. B.C.). This is related to more intensive Late Neolithic occupation of the region compared to the previous period. At the beginning of the Late Neolithic there are about 15 recorded settlements, during the second half there are 23, these being situated on the first or second terrace of the river, but higher up as well (Grębska-Kulowa and Kulow 2007). Hence, the first clearly noticeable anthropogenic indicators in the palynological record coincide with the increasing number of settlements. It seems that the signal is rather of extra local character as it is visible in all of the palynological records considered (Fig. 4; ESM Figs. 1–5), including those from the higher mountain sites. The second half of the Late Neolithic is the period contemporary with the expansion of the deciduous and coniferous trees (formation of *Pinus* and *Abies* belt) in the mountains along the Struma valley. The spread of *A. alba* after 5250 cal. B.C. suggests an increase in humidity and temperature (Bozilova and Tonkov 1994). Against this background the indications of increasing light-demanding trees and of the enlarged area for obtaining firewood, present in the wood charcoal assemblages (Fig. 3) should also be interpreted as an indication of anthropogenically-driven opening of the landscape in the surroundings of the sites investigated.

The wood charcoal assemblages from the Early Chalcolithic (ca. 4900–4500 cal. B.C.) show a continued increase in the use of light-demanding and riparian woodland. The settlements decreased in number and moved to hilly areas with defendable locations (Grębska-Kulowa and Kulow 2007).

During the transition between the Late Chalcolithic to the start of the Early Bronze Age (ca. 3800–3200 cal. B.C.) there are almost no indications of anthropogenic impact on the vegetation, except a few weak peaks of secondary anthropogenic indicators such as *P. lanceolata*-type, *Scleranthus*, *Polygonum aviculare*-type and Cichorioideae. Such secondary anthropogenic indicators pointing to pasture activities are also present in the contemporary palynological records from south western Balkans (Sadori 2007). These are usually interpreted as a result of pasture activities. For this period the archaeological evidence also suggests subsistence relying on herding and the presence of fairly mobile groups (Leshtakov 2006).

Large scale human impact on the landscape traceable over the region (Late Bronze Age to Iron Age, 1400–100 cal. B.C.)

After a period with a shift to increasing pastoralism and less permanent settlements around 3200–2200 cal. B.C. the number of settlements in the study area during the Late Bronze Age (1400–1200 cal. B.C.) increased rapidly. For example, in the Middle Struma valley Grębska-Kulowa and Kulow (2007) report about 33 sites (compared with 3 sites for the preceding period). The Late Bronze Age is also the period with the next peak in the indicators of anthropogenic activities. This peak is much more pronounced than that in the Neolithic, and is shown in all of the palynological archives considered. Immediately after this peak the *F. sylvatica* curve starts to increase in the palynological record from the Maleshevska peat bog (ESM Fig. 3).

A similar situation with the rising of *Fagus* percentage values after anthropogenic impact, and also with records of fire activity was observed at the peat bog Beg Bunar in the Osogovo mountains (Lazarova et al. 2009). This evidence indicates clearly that at least in the lower mountain ranges in the study area the spread of *F. sylvatica* was favored by anthropgenic activities. This evidence is in accordance with the estimations of Giesecke et al. (2007) for the lowlands of central Europe and for the southern Prealps (Valsecchi et al. 2008), where disturbance and anthropogenic clearance accelerated the growth of *F. sylvatica* populations during the Holocene. In the higher mountains (Lake Trilistnika, NW Rila; ESM Fig. 1) the appearance of anthropogenic indicators such as *P. lanceolata*-type and *Rumex* is recorded after 1400–1200 cal. B.C. (Late Bronze Age) coinciding with the starting point of increase in *F. sylvatica* and *Picea abies*. But it should be mentioned that this is also a period when an increase of moisture availability favourable for both tree species was reconstructed for the Rila Mountains (Tonkov and Marinova 2005), so climatically driven increase of the *F. sylvatica* population is quite plausible for those higher elevations. However more multi-proxy records with finer chronological resolution from the region are needed to answer this question reliably.

For the subalpine zones convincing evidence of human presence is observed in the Rila Mountains in the pollen and plant macrofossil diagrams from the Ostrezki Lakes (Tonkov and Marinova 2005). The pollen curves of taxa such as Cerealia-type, *P. lanceolata*-type, *Rumex*, *Scleranthus* and *Urtica*, along with macro-charcoals, appeared at 1770 cal. B.C., while numerous charcoal fragments indicative of forest fires were found from later, during ca. 800 cal. B.C. After ca. 900–800 cal. B.C. the palynological records from the northern Pirin (this paper, and also Stefanova et al. 2003), Maleshevska and Osogovo mountains also show pronounced peaks of anthropogenic indicators indicating mainly pasture (e.g. *Artemisia*, *Cirsium*-type, *P. lanceolata*, *Rumex*, *Scleranthus*) and a partial deforestation of the area. At many places the upper tree-line was artificially lowered in order to extend the high mountain pasture land. At lower elevations the mixed oak forests were destroyed and communities of *Carpinus orientalis* and *Quercus pubescens*, secondary in origin, were formed. The onset of this period with prominent anthropogenic activities is contemporaneous with the Early Iron Age in the area. It is also marked by the end of a dry climatic interval from approx. 1100 to 900 cal. B.C. also registered in the Hungarian and Thracian plains (Chapman et al. 2009).

The period of ca. 800 B.C. onwards for the Eastern Mediterranean is characterized by an increase in humidity and temperatures (Bar-Matthews et al. 1999; Lamy et al. 2006). Since 800 B.C. and especially around 500–400 B.C. human impact on the vegetation becomes clearly pronounced and continuous on a large scale. This is also clearly visible in the adjacent areas (Andric 2002; Athanasiadis et al. 2000; Eastwood et al. 1998; Feurdean et al. 2010; Jahns 1993; Knipping et al. 2008; Lazarova et al. 2011; Mudie et al. 2007; Triantaphyllou et al. 2010). These changes, except for the cultivation of olive which cannot thrive in the study area, strongly resemble the Beyşehir occupation phase (for more recent discussion on the topic see Bakker et al. 2011). The current evidence confirms the strong element of continuity in land use between the Late Bronze Age settlers and the Early Iron Age communities and the increasing intensity of forest clearance during the Iron Age proposed for the region of southeastern Europe by Chapman et al. (2009).

Roman and medieval landscape management and land use

The trends observed during the Iron Age (800 B.C.–A.D. 100) continued into the Roman period (from ca. A.D. 100–400). The evidence for intensive deforestation and spread of secondary xerothermic vegetation (increases or peaks in *Juniperus*, *Carpinus orientalis/Ostrya carpinifolia*, *Scleranthus*, Cichorioideae, *Cirsium*-type, *Artemisia* etc.) related to stock-breeding as well as to field and tree cultivation is very well manifested in the pollen diagrams under consideration. In most of the lower mountains in the study area, including the records from Maleshevska, Osogovo and Tshokljovo (ESM Figs. 3, 4 and 5) considered here, *Abies alba* played a significant role until the Hellenistic/Roman period. Evaluating the Holocene palaeoecological record of *A. alba* in the study area, Bozilova and Tonkov (1994) consider this reduction to be mainly anthropogenically driven. Similar tendencies for anthropogenically influenced reduction of *A. alba* populations over the last 2,000 years are also observed in North Western Romania (Feurdean and Willis 2008) and in Slovenia (Andric 2002). Arboriculture, a typical element of Roman land use, is only partly traceable by the increase of the *Juglans* curves and in some of the records considered the curves of *Vitis sylvestris* and *Castanea sativa* also rise slightly prior to the Roman period. The finds of *Juglans regia* are also very common and frequent in the archaeobotanical record of the region for the Iron Age and especially the Roman period (Popova 2009). In general, during the Roman period the local agricultural economy flourished as the Romans introduced a broader spectrum of crops, advanced methods of field cultivation and arboriculture (Bozilova et al. 1994).

The palaeoecological records considered here provide little information on medieval land use as most of them end before the start of the Middle Ages, or have no radiocarbon age control for this period. However, further analyses and

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more precise palaeoecological archives for this period are needed to elucidate the medieval human impact on the vegetation and the landscapes in the study area. The only evidence from this time is preserved in the Osogovo peat bog. There, the continuous presence of *Secale* and *Juniperus* pollen since ca. cal. A.D. 1200 indicates the rye cultivation typical of the period and increasing deforestation of the mountain. Here the strong and continuous presence of anthropogenic indicators coincides with an increase in *Fagus* woodlands.

Conclusions

1. The first major human impact, visible on a regional scale in the palynological records, appeared in the final stages of the Neolithic (ca. 5000 cal B.C.), when very sporadic indications of cereal cultivation and grazing occurred.
2. Anthropogenic vegetation change began with a slight modification of the xerothermic oak forests in the lowlands, the main area of activity of the Neolithic population, and with the stimulation of the development of light-demanding and in many cases fruit-producing trees and shrubs like *Cornus* sp., *Corylus avellana*, Maloideae, Prunoideae, *Rosa* sp. etc. The evidence for the Neolithic land use practices is in accordance with that from Anatolia and Central Europe.
3. The first signs of large scale deforestation and more extensive land use are recorded during the Late Bronze Age (ca. 1450–1200 cal. B.C.). In the lower mountains they are followed at many places by the continuous spread of *F. sylvatica* pointing to the favourable influence of the anthropogenic activities on its expansion. They are also marked by the first fairly continuous presence of indicators of pasture and fire activities in the mountainous areas.
4. The continuous presence of *Juglans* pollen from the Early Bronze Age and especially the Late Bronze Age points to its cultivation starting from this period. Its sporadic occurrence in the earlier periods and low percentage values suggest natural occurrence in the area.
5. The next peak of the anthropogenic impact on the vegetation and landscape occurred from 800 cal. B.C. onwards. It reached its maximum during the Roman period when annual crop and tree cultivation, deforestation and selective timber harvesting (*A. alba*) reached a vast extension.
6. The current study shows mainly the general tendencies in the human impact on vegetation and landscape that could be inferred from palaeobotanical data. Many questions on the exact timing and extend of those impacts still remain and only future research focusing on high resolution records with more extended age control will help to gain a detailed and comprehensive picture of the human landscapes formed under the interaction of climate and cultural change.

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References

Andric M (2002) The Holocene vegetation dynamics and the formation of Neolithic to Present-day Slovenian landscape. Doc Praehistorica 28:133–175

Andric M, Willis K (2003) The phytogeographical regions of Slovenia: a consequence of natural environmental variation or prehistoric human activity? J Ecol 91:807–821

Asouti E, Hather J (2001) Charcoal analysis and the reconstruction of ancient woodland vegetation in the Konya Basin, south-central Anatolia, Turkey: results from the Neolithic site Catalhöyük East. Veget Hist Archaeobot 10:23–32

Athanasiadis N, Tonkov S, Atanassova J, Bozilova E (2000) Palynological study of Holocene sediments from Lake Doirani in northern Greece. J Paleolimnol 24:331–342

Athanassov B, Petkov V, Kulow I, Grębska-Kulowa M, Dumanov B, Uzunov Z, Garbov D, Chukalev K, Gercheva D (2010) Expedition struma during 2010 [Ekspedicia Struma prez 2010]. In: Gergova D (ed) Archaeological findings and excavations 2009, pp 676–679

Bakker J, Paulissen E, Kaniewski D, De Laet V, Verstraeten G, Waelkens M (2011) Man, vegetation and climate during the Holocene in the Territory of Sagalassos, Western Taurus mountains, SW Turkey. Veget Hist Archaeobot. doi:10.1007/s00334-011-0312-4 (this volume)

Bar-Matthews M, Ayalon A, Kaufman A, Wasserburg GJ (1999) The Eastern Mediterranean paleoclimate as a reflection of regional events: Soreq cave, Israel. Earth Planet Sci Let 166:85–95

Behre K-E (1981) The interpretation of anthropogenic indicators in pollen diagrams. Pollen Spores 23:225–245

Behre K-E (1988) The role of man in European vegetation history. In: Huntley B, Webb T III (eds) Vegetation history, handbook of vegetation science. Kluwer, Dordrecht, pp 633–672

Behre K-E (2007) Evidence for Mesolithic agriculture in and around central Europe? Veget Hist Archaeobot 16:203–219

Behre K-E (2008) Comment on: Mesolithic agriculture in Switzerland? A critical review of the evidence by W. Tinner, E. H. Nielsen and A. F. Lotter. Quat Sci Rev 27:1,467–1,468

Bennett K, Willis K (1995) The role of ecological factors in controlling vegetation dynamics on long temporal scale. Giornale Botanico Italiano 129:243–354

Beug H-J (2004) Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Pfeil, München

Bleicher N, Herbig CH (2010) Der Federsee: Landschaft und Dynamik im Neolithikum. In: Matuschik I, Strahm C, Eberschweiler B, Fingerlin G, Hafner A, Kinsky M, Mainberger M (eds) Vernetzungen. Aspekte Siedlungsarchäologischer Forschung. Festschrift für Helmut Schlichtherle. Lavori, Freiburg, pp 95–112

Bogaard A (2004) Neolithic Farming in central Europe: an archaeobotanical study of crop husbandry practices. Routledge, Oxon

Bohn U, Gollub G, Hettwer C, Neuheuslova Z, Schlüter H, Weber H (2000/2003) Map of the natural vegetation of Europe. Scale: 1:2,500,000, Parts 1, 2 and 3. Landwirtschaftsverlag, Bonn

Bond G, Kromer B, Beer J, Muscheler R, Evans MN, Showers W, Hoffmann S, Lotti-Bond R, Hajdas I, Bonani G (2001) Persistent solar influence on north Atlantic climate during the Holocene. Science 294:2,130–2136

Bondev I (1991) The vegetation of Bulgaria. Map 1:600,000 with explanatory text. St. Kliment Ohridski University Press, Sofia (in Bulgarian with English summary)

Borojevic K (2006) Terra and silva in the Pannonian Plain: Opovo Agro-Gathering in the Late Neolithic. BAR Internat Ser 1563. Archaeopress, Oxford

Bottema AS (1974) Late Quaternary vegetation history of northwestern Greece. Thesis. Rijksuniversiteit Groningen

Bottema AS (1982) Palynological investigations in Greece with special reference to pollen as an indicator of human activity. Palaeohistoria 24:257–289

Bottema AS (2000) The Holocene history of walnut, sweet-chestnut, manna-ash and plane tree in the Eastern Mediterranean. PALLAS 52:35–59

Bottema AS, Woldring H (1990) Anthropogenic indicators in the pollen record of the Eastern Mediterranean. In: Bottema AS, Entjes-Nieborg G, Van Zeist W (eds) Man's role in the shaping of the Eastern Mediterranean landscape. Balkema, Rotterdam, pp 231–264

Boyadzhiev Y (2007) Absolute Chronology of the Neolithic and Eneolithic Cultures in the Valley of Struma. In: Todorova H, Stefanovic M, Ivanov G (eds) The Struma/Strymon river valley in prehistory. In the Steps of James Harvey Gaul, volume 2, Sofia, pp 309–316

Boyadzhiev Y (2009) Early Neolithic cultures on the territory of Bulgaria. In: Gatsov I, Boyadzhiev Y (eds) The First Neolithic Sites in Central/South-East European transect volume I: Early Neolithic Sites on the territory of Bulgaria. BAR International Ser 2048, pp 7–44

Bozilova E, Tonkov S (1990) The impact of man on the natural vegetation in Bulgaria from the Neolithic to the middle ages. In: Bottema S, Entjes-Nieborg G, Van Zeist W (eds) Man′s role in the shaping of the Eastern Mediterranean landscape. Balkema, Rotterdam, pp 327–332

Bozilova E, Tonkov S (1994) The postglacial distribution patterns of Abies in Bulgaria. In: Lotter A, Ammann B (eds) Festschrift Gerhard Lang. Beiträge zur Systematik und Evolution, Floristik und Geobotanik, Vegetationsgeschichte und Paläoökologie. Diss Bot 234, Cramer, Berlin Stuttgart, pp 215–223

Bozilova E, Tonkov S (2007) Palaeoecological evidence of the main postglacial vegetation and climate changes in southwestern Bulgaria from the neolithic to modern times. In: Todorova H, Stefanovic M, Ivanov G (eds) The Struma/Strymon River valley in prehistory. In the Steps of James Harvey Gaul, vol 2, Sofia, pp 531–534

Bozilova E, Tonkov S, Pavloa D (1986) Pollen and plant macrofossil analyses of the Lake Sucho Ezero in the south Rila mountains. Annu Sofia Univ Fac Biol 80:48–57

Bozilova E, Tonkov S, Popova TZ (1994) Forest clearance, land use and human occupation during the Roman colonization in Bulgaria. In: Frenzel B (ed) Palaeoclimate research 10. Fischer, Stuttgart, pp 37–44

Chabal L (1992) La représentativité paléo-écologique des charbons de bois archéologiques issus du bois de feu. Bulletin de la Société Botanique de France 139:213–236

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

Chohadzhiev S (2007) Neolithni I halkolitni kulturi v basejna na reka struma [Neolithic and Chalcolithic cultures in the Struma river basin], Veliko Tarnovo University Press, Veliko Tarnovo (in Bulgarian)

Davis B, Brewer S, Stevenson A, Guiot J, Data Contributors (2003) The temperature of Europe during the Holocene reconstructed from pollen data. Quat Sci Rev 22:1,701–1,716

Delev P (2002) The middle Mesta region in antiquity. In: Bozkova A, Delev P (eds) Koprivlen vol 1: rescue archaeological investigations along the Gotse Delchev—Drama Road 1998–1999. NOUS Publishers, Sofia, pp 13–28

Eastwood WJ, Roberts N, Lamb HF (1998) Palaeoecological and archaeological evidence for human occupance in southwest Turkey: the Beyşehir occupation phase. Anatol Stud 48:69–86

Faegri K, Iversen J (1989) Textbook of pollen analysis. In: Faegri K, Kaland PE, Krzywinski K (eds) 4th edn. Wiley, Chichester

Fairbairn A, Asouti E, Near J, Martinoli D (2002) Macro-botanical evidence for plant use at Neolithic Çatalhöyük, south-central Anatolia, Turkey. Veget Hist Archaeobot 11:41–54

Feurdean A, Willis KJ (2008) Long-term variability of *Abies alba* in NW Romania: implications for its conservation management. Divers Distrib 14:1,004–1,017

Feurdean A, Willis KJ, Parr C, Tantau I, Farcas S (2010) Postglacial patterns in vegetation dynamics in Romania: homogenization or differentiation? J Biogeogr 37:2,197–2,208

Filipovich L, Stefanova I (1998) Anthropogenic changes in the vegetation of the Balkan Range according to data obtained from pollen and macrofossil analyses. Phytologia Balcanica 4:37–44

Gaillard M-J (2007) Pollen methods and studies: archaeological applications. In: Elias S (ed) Encyclopedia of quaternary science. Elsevier, Amsterdam, pp 2,571–2,595

Gardner A (2002) Neolithic to Copper Age woodland impacts in northeast Hungary? Evidence from the pollen and sediment chemistry records. Holocene 12:453–541

Gatsov I, Boyadziev Y (2009) The First Neolithic Sites in Central/South-East European transect volume I: Early Neolithic Sites on the territory of Bulgaria. BAR Internat Ser 2048, Archaeopress, Oxford

Giesecke T, Hickler T, Kunkel T, Sykes MT, Bradshaw RHW (2007) Towards an understanding of the Holocene distribution of *Fagus sylvatica* L. J Biogeogr 34:118–131

Görsdorf J, Bojadziev J (1996) Zur absoluten Chronologie der bulgarischen Urgeschichte. Berliner 14C-Datierungen von bulgarischen archäologischen Fundplätzen. Eurasia Antiqua 2: 105–173

Grębska-Kulova M (2005) Cultural changes in the second half of the 6th mill. B.C. in Southwestern Bulgaria. In: Nikolov V, Bačvarov K, Kalchev P (eds) Praehistoric thrace. Proceedings of the international symposium, Stara Zagora, 30.09.-04.10.2003. Bulg Acad of Sci, Sofia, pp 133–145

Grębska-Kulowa M, Kulow I (2007) Prehistorical Sites in the Middle Struma River Valley between the end of the VIIth mill B.C. and the Beginning of the Vth mill. B.C. In: Stefanovic M, Todorova H (eds) The Struma/Strymon River Valley in Prehistory. In the Steps of James Harvey Gaul, vol 2, Sofia, pp 279–296

Huttunen A, Huttunen R-L, Vasary Y, Panovska H, Bozilova E (1992) Late glacial and Holocene history of flora and vegetation in the Western Rhodopes Mountains, Bulgaria. Acta Bot Fennica 144:63–80

Jahns S (1993) On the Holocene vegetation history of the Argive Plain (Peloponnese, southern Greece). Veget Hist Archaeobot 2:187–203

Jahns S, Van den Bogaard C (1998) New palynological and tephrostratigraphical investigations of two salt lagoons on the island of Mljet, south Dalmatia, Croatia. Veget Hist Archaeobot 7:219–234

Kalis AJ, Merkt J, Wunderlich J (2003) Environmental changes during the Holocene climatic optimum in central Europe—human impact and natural causes. Quat Sci Rev 22:33–79

Kaltenrieder P, Procacci G, Vannière B, Tinner W (2010) Vegetation and fire history of the Euganean Hills (Colli Euganei) as recorded by Lateglacial and Holocene sedimentary series from Lago della Costa (northeastern Italy). Holocene 20:679–695

Knipping M, Müllenhof M, Brückner H (2008) Human induced landscape changes around Bafa Gölü (western Turkey). Veget Hist Archaeobot 17:365–380

Kopralev IE (2002) Geography of Bulgaria. Physical geography. Socio-economic geography. ForComPublishers, Sofia

Kreuz A (2008) Closed forest or open woodland as natural vegetation in the surroundings of Linearbandkeramik settlements? Veget Hist Archaeobot 17:51–64

Kreuz A, Marinova E, Schäfer E, Wiethold J (2005) A comparison of Early Neolithic crop and weed assemblages from the Linearbandkeramik and the Bulgarian Neolithic cultures: differences and similarities. Veget Hist Archaeobot 14:237–258

Kroll H (1991) Südosteuropa. In: Van Zeist W, Wasylikowa K, Behre K-E (eds) Progress in old world palaeoethnobotany. Balkema, Rotterdam, pp 161–178

Lamy F, Arz HW, Bond GC, Bahr A, Pätzold J (2006) Multicentennial-scale hydrological changes in the Black Sea and northern Red Sea during the Holocene and the Arctic/North Atlantic Oscillation. Paleoceanography 21, PA1008, doi:10.1029/2005PA001184

Lazarova M (1995) Human impact on the natural vegetation in the region of Lake Srebarna and the Mire Garvan (Northeastern Bulgaria)—palynological and paleoethnobotanical evidence. In: Bozhilova E, Tonkov S (eds) Advances in Holocene palynology in Bulgaria. Pensoft Publishers, Sofia-Moskow, pp 47–67

Lazarova M, Tonkov S, Snowball I, Marinova E (2009) 6. Peat-bog Begbunar (Osogovo Mountains, south-west Bulgaria): four millennia of vegetation history. Grana 48:147–179

Lazarova M, Koutsios A, Kontopoulos N (2011) Holocene vegetation history of the Kotihi lagoon (northwest Peloponnesus, Greece). Quat Int. doi:10.1016/j.quaint.2009.10.036

Leshtakov K (2006) The Bronze Age in the Upper Thracian plain [Bronzovata epoha v gornotrakijskata hizina]. Annuary of the Sofia University—Archaeology vol 3, pp 141–216 (in Bulgarian with English summary)

Lichardus-Itten M, Demoule J-P, Perničeva L, Grębska-Kulova M (2006) Kovachevo, an early Neolithic site in South-West Bulgaria and its importance for the European Neolithization. In: Gatsov I, Schwarzberg H (eds) Aegean-Marmara-Black Sea: the present state of research on the early Neolithic. Schriften des Zentrums für Archäologie und Kulturgeschichte des Schwarzmeeraumes 5, pp 83–94

Magyari E, Chapman E, Francis M, De Guzman M (in press) Neolithic human impact on the landscapes of North-East Hungary inferred from pollen and settlement records. Veget Hist Archaeobot

Marinova E (2006) Vergleichende palaeoethnobotanische Untersuchung zur Vegetationsgeschichte und zur Entwicklung der prähistorischen Landnutzung in Bulgarien. Diss Bot 401. Cramer, Stuttgart, pp 1–164

Marinova E, Atanassova J (2006) Anthropogenic impact on vegetation and environment during the Bronze Age in the area of Lake Durankulak, NE Bulgaria: pollen, microscopic charcoal, non-pollen palynomorphs and plant macrofossils. Rev Palaeobot Palynol 141:165–178

Marinova E, Popova TZ (2008) *Cicer arietinum* (chick pea) in the Neolithic and Chalcolithic of Bulgaria: implications for cultural contacts with the neighbouring regions? Veget Hist Archaeobot 17(Suppl 1):73–80

Marinova E, Thiebault S (2008) Anthracological analysis from Kovacevo, southwest Bulgaria: woodland vegetation and its use during the earliest stages of the European Neolithic. Veget Hist Archaeobot 17:223–231

Marinova E, Tchakalova E, Stoyanova D, Grozeva S, Dočeva E (2002) Ergebnisse archäobotanischer Untersuchungenausdem Neolithikum und Chalcolithikum in Südwestbulgarien. Archaeol Bulgarica 6:1–11

Mayewski P, Rohling E, Stager C, Karlen W, Maascha K, Meeker D, Meyerson E, Gasse F, Van Kreveld S, Holmgren K, Lee-Thorp J, Rosqvist G, Rack F, Staubwasser M, Schneider R, Steig E (2004) Holocene climate variability. Quat Res 62:243–255

Mudie PJ, Marret F, Aksu AE, Hiscott RN, Gillespie H (2007) Palynological evidence for climatic change, anthropogenic activity and outflow of Black Sea water during the late Pleistocene and Holocene: Centennial- to decadal-scale records from the Black and Marmara Seas. Quat Int 167–168:73–90

Neef R (2007) Archäobotanische Untersuchungen im spätantiken Iatrus/Krivina (Grabungskampagnen 1992–2000). In: Von Bülow G, Böttger B, Conrad S, Döhle B, Gomolka-Fuchs G, Schönert-Geiss E, Stancev D, Wachtel K (eds) Iatrus-Krivina. Spätantike befestigung und frühmittealterliche Siedlung an der unteren Donau. Limesforschungen 28. Philipp von Zabern, Mainz, pp 415–445

Nikolov V (2007) Problems of the early stages of the Neolithisation in the Southeast Balkans. In: Spataro M, Biagi P (eds) A short walk through the Balkans: the first farmers of the carpathian basin and adjacent regions. Società Preistoria Protostoria Friuli-V.G. Trieste Quaderno 12:183–188

Panovska H, Bozilova E, Tonkov S (1995) A palaeoecological investigation on the vegetation history in the Southern Pirin Mts. (Southwestern Bulgaria). In: Bozilova E, Tonkov S (eds) Advances in Holocene palaeoecology in Bulgaria. Pensoft, Sofia, pp 32–46

Pernicheva L (1995) Prehistoric cultures in the middle Struma Valley: Neolithic and Eneolithic. In: Bailey D, Panayotov I (eds) Prehistory of Bulgaria. Monographs in World Archaeology 22, I. Madison, Wiskonsin, pp 99–128

Popova T (2009) Paleobotanic catalogue of the studied sites and studied remains (debries) in the territory of Bulgaria (1980–2008). Interdiscip Stud 20–21:71–165

Popova T, Bozhilova E (1997) Palaeoecological and palaeoethnobotanical data for the Bronze Age in Bulgaria. In: Stefanovich M, Henrieta T, Hauptmann H (eds) In the steps of James Harvey Gaul, vol 1. Sofia, pp 391–397

Popova T, Marinova E (2007) Palaeoethnobotanical data in South-Western Region of Bulgaria In: Todorova H, Stefanovic M, Ivanov G (eds) The Struma/Strymon river valley in prehistory. In the Steps of James Harvey Gaul, vol 2. Sofia, pp 523–532

Riehl S, Marinova E (2008) Mid-Holocene vegetation change in the Troad (W Anatolia): man-made or natural? Veget Hist Archaeobot 17:297–312

Roberts N, Jones MD, Benkaddour A, Eastwood WJ, Filippi ML, Frogley MR, Lamb HF, Leng MJ, Reed JM, Stein M, Stevens L, Valero-Garcés B, Zanchetta G (2008) Stable isotope records of Late Quaternary climate and hydrology from Mediterranean lakes: the ISOMED synthesis. Quat Scie Rev 27(25–26): 2,426–2,441

Roberts N, Eastwood WJ, Kuzucuoğlu C, Fiorentino G, Caracuta V (2011) Climatic, vegetation and cultural change in the eastern

Mediterranean during the mid-Holocene environmental transition. Holocene 21:147–162

Sadori L (2007) Pollen records, postglacial. Southern Europe. Encyclopaedia of quaternary sciences. Elsevier, Amsterdam, pp 2,763–2,773

Schweingruber FH (1990) Anatomie europäischer Hölzer. Ein Atlas zur Bestimmung europäischer Baum-, Strauch- und Zwergstrauchhölzer. Haupt, Bern Stuttgart

Stefanova I, Ognjanova-Rumenova N, Hofmann W, Ammann B (2003) Late Glacial and Holocene environmental history of the Pirin Mountains (SW Bulgaria): a paleolimnological study of Lake Dalgoto (2,310 m). J Paleolimnol 30:95–111

Stefanovich M, Bankoff A (1998) Kamenska Čuka 1993–1995. In: Stefanovich M, Todorova H, Hauptman H (eds) In the steps of James Harvey Gaul, vol 1, Sofia, pp 255–338

Todorova H, Vaisov I (1989) Das Neolithikum in Bulgarien. Nauka i Izkustvo, Sofia (in Bulgarian with German summary)

Tonkov S (1988) Sedimentation and local vegetation development of a reference site in SW Bulgaria. In: Lang G, Schluchter C (eds) Lake, mire and river environments. Balkema, Rotterdam, pp 99–101

Tonkov S (2003) A 5000-year pollen record from Osogovo Mountains, Southwestern Bulgaria. In: Tonkov S (ed) Aspects of palynology and palaeoecology. Pensoft, Sofia-Moscow, pp 233–244

Tonkov S (2007) Paleobotanical and paleoecological investigation on the postglacial vegetation history in southwestern Bulgaria. DSc Thesis, Sofia (in Bulgarian)

Tonkov S, Bozilova E (1992a) Pollen analysis of peat-bog in Maleshevska Mountain (Southwestern Bulgaria). Ann Sofia Univ Fac Biol 83:11–22 (in Bulgarian with English summary)

Tonkov S, Bozilova E (1992b) Paleoecological investigation of Tschokljovo marsh (Konjavska Mountain). Ann Sofia Univ Fac Biol 83:5–16

Tonkov S, Marinova E (2005) Pollen and plant macrofossil analyses of mid-Holocene radiocarbon dated profiles from two subalpine lakes in Rila Mountains, Bulgaria. Holocene 15:663–671

Tonkov S, Panovska H, Possnert G, Bozilova E (2002) The Holocene vegetation history in the Northern Pirin Mountain, southwestern Bulgaria: pollen analysis and radiocarbon dating of core from Lake Ribno Banderishko. Holocene 12:201–210

Tonkov S, Bozilova E, Possnert G, Velcev A (2008) A contribution to the postglacial vegetation history of the Rila Mountains, Bulgaria: the pollen record of Lake Trilistnika. Quat Intern 190:58–70

Tonkov S, Beug H-J, Bozilova E, Filipova-Marinova M, Jungner H (2011) Palaeoecological studies at the Kaliakra area, northeastern Bulgarian Black Sea coast: 6000 years of natural and anthropogenic change. Veg Hist Archaeobot 20:29–40

Triantaphyllou MV, Kouli K, Tsourou T, Koukousioura O, Pavlopoulos K, Dermitzakis MD (2010) Paleoenvironmental changes since 3000 B.C. in the coastal marsh of Vravron (Attiki, SE Greece). Quat Intern 216:14–22

Vajsov I (1998) The typology of the anthropomorphic figurines from Northeastern Bulgaria. In: Stefanovich M, Todorova H, Hauptmann H (eds) In the steps of James Harvey Gaul, vol 1. James Harvey Gaul Foundation, Sofia, pp 107–141

Valamoti S (2004) Plants and people in Late Neolithic and Early Bronze Age Northern Greece an archaeobotanical investigation. BAR International Series 1258, Archaeopress, Oxford

Valsecchi V, Finsinger W, Tinner V, Ammann B (2008) Testing the influence of climate, human impact and fire on the Holocene population expansion of *Fagus sylvatica* in the southern Prealps (Italy). Holocene 18:603–614

Velchev V (2002) Types of vegetation. In: Kopralev I (ed) Geography of Bulgaria. ForCom Publishers, Sofia, pp 324–335 (in Bulgarian)

Wanner H, Beer J, Bütikofer J, Crowley TJ, Cubasch U, Flückiger J, Goosse H, Grosjean M, Joos F, Kaplan JO, Küttel M, Müller SA, Prentice IC, Solomina O, Stocker TF, Tarasov P, Wagner M, Widmann M (2008) Mid- to Late Holocene climate change: an overview. Quat Sci Rev 27:1,791–1,828

Weninger B, Alram-Stern E, Bauer E, Clare L, Danzeglocke U, Jöris O, Kubatzki C, Rollefson G, Todorova H, Van Andel T (2006) Climate forcing due to the 8200 cal yr B.P. event observed at Early Neolithic sites in the eastern Mediterranean. Quat Res 66:401–420

Weninger B, Clare L, Rohling EJ, Bar-Yosef O, Böhner U, Budja M, Bundschuh M, Feurdean A, Gebel H-G, Jöris O, Linstädter J, Mayewski P, Mühlenbruch T, Reingruber A, Rollefson G, Schyle D, Thissen L, Todorova H, Zielhofer C (2009) The impact of rapid climate change on prehistoric societies during the Holocene in the Eastern Mediterranean. Documenta Praehistorica 36:7–59