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A 5000-year pollen and plant macrofossil record from the Osogovo Mountain, Southwestern Bulgaria: Vegetation history and human impact

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ABSTRACT

Pollen and plant macrofossil analyses were performed on a sequence 105 cm deep obtained from a peat bog (1750 m) that is located above the present timber-line in the Osogovo Mountain, Southwestern Bulgaria. The palaeovegetation reconstruction, supported by a radiocarbon chronology, revealed the vegetation dynamics and human impact during the last 5000 years. The peat bog formed when a coniferous belt of *Abies alba* and *Pinus* (*Pinus sylvestris*, *Pinus nigra*) covered the high mountain slopes. Charcoal fragments indicate the presence of a broad-leaved tree community composed of *Quercus*, *Corylus*, *Carpinus*, *Tilia*, *Acer* and *Ulmus* at lower altitudes. Stands of *Fagus sylvatica* in places with higher air and soil humidity, like river valleys and deep ravines, became established. The pollen assemblages after c. 3200 cal. BP record an important change in the forest composition that led to the replacement of the conifers, mostly *A. alba*, by the invading communities of *F. sylvatica*. The reasons for this replacement included factors related to both climate change and anthropogenic disturbance. During the last centuries a large-scale degradation of the woodlands in the mountain has occurred. On a regional scale the palaeoecological evidence is compared with information from palynological, archaeological and historical sources in Southwestern Bulgaria.

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1. Introduction

The montane part of Southwestern Bulgaria with its diverse vegetation, high and low massifs, is known to be a key area for palynological and palaeoecological research on the postglacial flora history, vegetation development and human impact of the Balkan peninsula (Tonkov, 2003). In the last years numerous investigations have been conducted with the combined application of pollen analysis, determination of plant macrofossils and radiocarbon dating on Lateglacial and Holocene lake and peat bog sequences from the high mountains Rila (2925 m) and Pirin (2914 m), which were glaciated at least twice during the Quaternary (e.g. Bozilova and Tonkov, 2000; Tonkov et al., 2002, 2008, 2013; Tonkov and Marinova, 2005; Stefanova et al., 2006; Marinova and Tonkov, 2012). These studies contributed to the elucidation of the chronological succession of the main vegetation stages, the postglacial climate changes that drove them and the long-term human impact (Lang, 1994; Willis, 1994; Bozilova et al., 1996; Tzedakis, 2004, 2009; Tzedakis et al., 2004; Wagner et al., 2010; Müller et al., 2011; Feurdean et al., 2014; Panagiotopoulos et al., 2014; Sadori et al., 2015, etc.).

Complementary investigations in the western border of the Osogovo–Belasitsa mountain range also provide evidence of Holocene vegetation and environmental changes over the past 9000 years. The outstanding transformation in the vegetation cover has been the replacement of the coniferous *Abies–Pinus* forests by *Fagus* in the Late Holocene (Panovska et al., 1990; Tonkov and Bozilova, 1992a; Tonkov, 1994, 2003; Tonkov et al., 2012; Tonkov and Possnert, 2014). This mountain range stretches longitudinally westwards from the Rila and Pirin mountains along the course of the River Struma and was recognized as one of the main routes for tree migrations in postglacial time from the mountains in Northwestern Greece to the central and northern parts of the Balkan peninsula (Bozilova and Tonkov, 1994; Tonkov, 2007).

Palaeobotanical and archaeological data have been used to infer the anthropogenic impact on the vegetation and landscape and suggest that Southwestern Bulgaria was first inhabited by humans about 8 millennia ago (Bozilova and Tonkov, 1990, 2007; Bozilova et al., 1994; Tonkov et al., 2007; Marinova and Thiebault, 2008; Marinova et al., 2012).

This paper expands on a preliminary study of a peat bog in the Osogovo Mountain that included a pollen diagram (Lazarova et al., 2009). We add the results of plant macrofossil analysis and radiocarbon

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dating to the earlier work and improve our knowledge on the Holocene vegetation pattern and human impact in this part of Southwestern Bulgaria for the last 5000 years.

2. The study area

2.1. Physico-geographical characteristics and modern vegetation

The Osogovo Mountain (peak Ruen, 2251 m) is the highest border massif of the Osogovo–Belasitsa mountain range, which is situated in Southwestern Bulgaria and Northeastern F. Y. R. of Macedonia (Fig. 1A–D). The northern and northeastern slopes on Bulgarian territory are steep and to the south the saddle of Red Rock is the linkage to the Vlahina Mountain (1924 m). The massif is composed mainly of Palaeozoic metamorphic and intrusive rocks. Geomorphological evidence suggests that small valley glaciers existed in the highest parts during the Quaternary glaciations (Velčev, 1995). The present day climate below 1000 m is moderate continental and above this altitude it changes to typically montane. The mean annual precipitation is 700–900 mm with two precipitation maxima in May and November, and a precipitation minimum in August–September. The average annual duration of the stable snow cover is 135 days (Velev, 2002). The basic soils are cinnamomic-forest (*Chromic Cambisols*, *CMx*), above them brown-forest (*Cambisols*, *CM*) and the ridge is occupied by montane-meadow (*Umbrisols*, *UB*) (Ninov, 1997).

Comprehensive information on the modern vegetation of Southwestern Bulgaria can be found in the Vegetation Map of Bulgaria (Bondev, 1991), the Map of Vegetation Belts (Bondev, 1986) (Fig. 1E) and in the review of Velčev and Tonkov (1986). Following these basic literature sources the vegetation of Osogovo Mountain is clustered into several vegetation belts. The oak forest belt up to 1000 m on the southeastern slopes is dominated by *Quercus pubescens* Willd., *Quercus cerris* L. and *Quercus dalechampii* Ten. with some *Carpinus orientalis* Mill., *Ostrya carpinifolia* Scop. and *Juniperus oxycedrus* L. Plant communities of *Pinus nigra* Arn. and *Fagus sylvatica* L. are also found. The beech belt (1000–1900 m) is the most well-developed vegetation belt composed mainly of single-dominant communities of *F. sylvatica*. At some areas in the beech belt patches of *Abies alba* Mill. and *P. nigra* are present. Beech forms the upper timber-line between 1500 and 1900 m. Today a compact coniferous vegetation belt does not exist. Stands or isolated trees of *Pinus sylvestris* L. grow close, or just above, the beech timber-line. Remnants of mixed coniferous communities composed of *Picea abies* (L.) Karst. and *A. alba*, highly restricted in distribution, are preserved in the northern part of the mountain between 1100 and 1600 m. The treeless areas in the subalpine belt, above the beech forests, are occupied by plant communities of *Juniperus sibirica* Burgsd., *Vaccinium myrtillus* L., *Bruckenthalia spiculifolia* (Salisb.) Rchb., *Chamaecytisus absinthioides* (Janka) Kuzm., *Nardus stricta* L., etc. In all vegetation zones, the oak and beech forest belts in particular, the negative consequences of the long-lasting human impact, including deforestation with subsequent erosion and ore-mining activities, are easily visible (Zahariev, 1934; Tonkov, 2003).

2.2. The study site

In the treeless mostly flat part of the mountainside between 1600 and 1800 m small peat bogs occur in depressions formed as a result of denudation processes (Velčev et al., 1994). In most of them the thickness of the peat and underlying sediments is less than 1 m. One of these peat bogs, named Begbunar (42°09′ N, 22° 33′ E; 1750 m), located near a freshwater spring on a northwestern slope, which continues into a steep, deep ravine where isolated stands of beech exist was chosen for study (Lazarova et al., 2009) (Fig. 1C).

3. Material and methods

3.1. Pollen analysis

A 105 cm long core was collected from a less densely vegetated area of the bog surface. Sampling for pollen analysis was carried out at 5 cm intervals. The laboratory treatment of the samples followed the standard acetolysis procedure (Faegri and Iversen, 1989) after removal of siliceous particles with cold 60% HF acid for 24 h (Birks and Birks, 1980). The pollen sum (PS) used for percentage calculations was based on AP (arboreal pollen) + NAP (non-arboreal pollen), excluding spores of mosses, pteridophytes and pollen of aquatics and Cyperaceae. On average the PS comprised 1200–1400 pollen grains. The abundance of each taxon identified (pollen or spore) is expressed as percentages of the PS. The identifications of fossil spores and pollen were done using the reference collection at the Institute of Biodiversity and Ecosystem Research and literature sources (Faegri and Iversen, 1989; Moore et al., 1991; Beug, 2004). The percentage pollen diagram was constructed with the



Fig. 1. A. Location of Bulgaria on the map of Europe. B. Southwestern Bulgaria (open square) with Osogovo Mountain (closed circle). C. A view of the peat bog Begbunar in late spring (photo by S. Tonkov) D. Peat bog Begbunar (closed triangle). Location of other sites (•) mentioned in text: I. Peat bog Osogovo-1 (Tonkov, 2003); Konjavska Mountain, II. Tschokljovo marsh (Tonkov and Bozilova, 1992b); Maleshevska Mountain, III. Peat bog (Tonkov and Bozilova, 1992a); Belasitsa Mountain, IV. Mire Gjola (Tonkov et al., 2012; Tonkov and Possnert, 2014), V. Peat bog (Panovska et al., 1990; Tonkov, 2007), VI. Peat bog (Athanasiadis et al., 2003); Rila Mountains, VII. Cirque of the Seven Rila Lakes: Lake Sedmo Rilsko (Bozilova and Tonkov, 2000), Lake Ribno (Tonkov et al., 2013), Lake Trilistnika (Tonkov et al., 2008), VIII. Lake Suho Ezero (Bozilova et al., 1990). E. Vegetation belts in Southwestern Bulgaria (after Bondev, 1986): 1. Xerothermic oak forests of *Quercus cerris* L., *Q. frainetto* Ten, *Q. pubescens* Willd., etc. 2. Xeromesophilous and mesophilous forests of *Quercus dalechampii* Ten., *Carpinus betulus* L., etc. 3. Forests of *Fagus sylvatica* L., *Abies alba* Mill., etc., 4. Coniferous forests of *Picea abies* (L.) Karst., *Pinus sylvestris* L., *P. peuce* Griesb., *P. heldreichii* Christ. 5. Subalpine belt of *Pinus mugo* Turra, *Juniperus sibirica* Burgsd., etc. 6. Alpine grasslands of *Sesleria comosa* Velen., *Carex curvula* All., *Festuca riloensis* (Hack. Ex Hayek) Markgr.-Dann., etc.

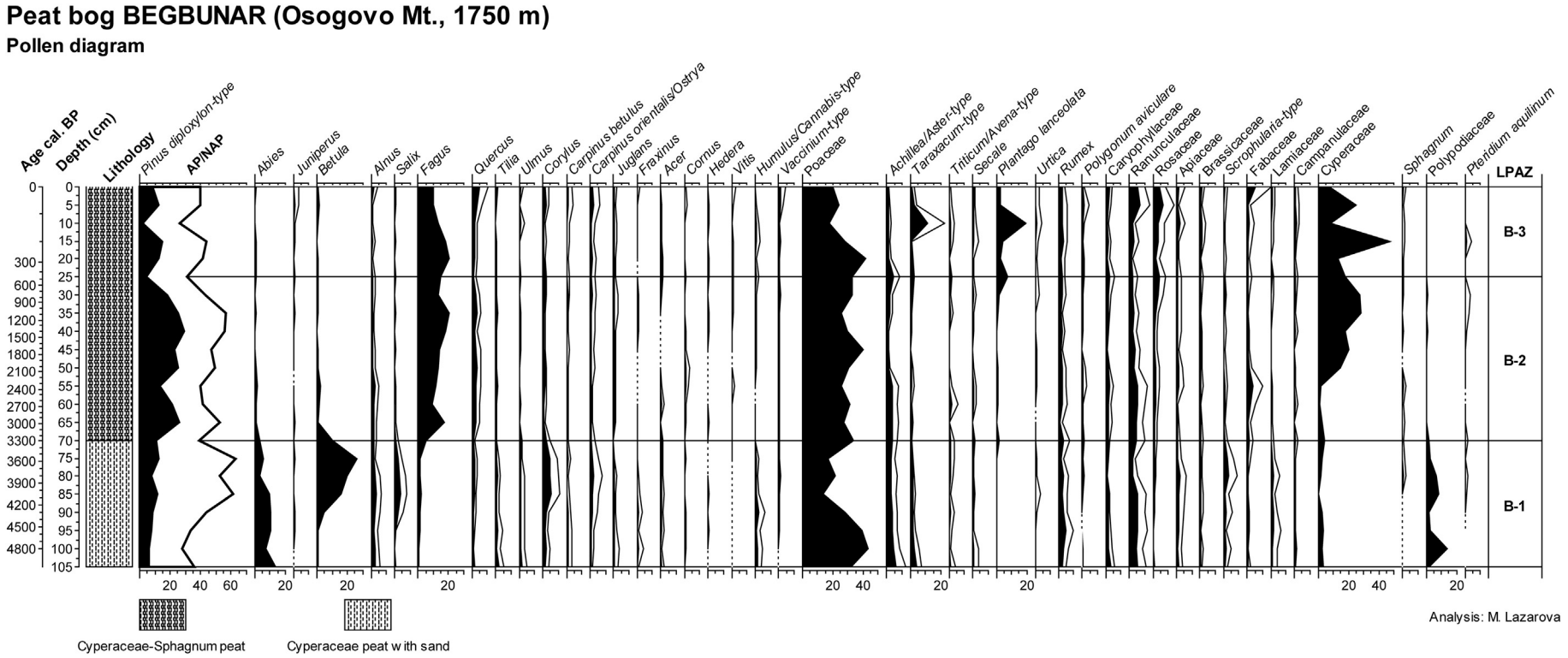


Fig. 2. Percentage pollen diagram from peat bog Begbunar. Lines without filling are exaggerated (2×). LPAZ: Local pollen assemblage zones.

computer software TGView ver. 1.17.6 (Grimm, 2011) (Fig. 2). Taxa with low frequencies are not shown. The pollen diagram is divided into three local pollen assemblage zones (LPAZ) numbered from the base upwards and prefixed by the site designation B taking into consideration important changes in the frequencies of the main pollen taxa.

3.2. Plant macrofossil and charcoal analyses

Sub-samples for macrofossil analysis with a sediment volume of 50 ml were taken at every 5 cm. After soaking for 5–10 min in KOH the material was sieved through meshes of 0.4 and 0.16 mm. The macrofossils were sorted and identified under stereomicroscope with magnification up to 56×. Charred wood fragments (>2 mm) were analyzed under reflecting light microscope. For taxonomical identification they were manually broken along transverse, radial and tangential surfaces. The identification of the material was achieved by comparison to the reference collection from the Department of Botany at Sofia University and relevant literature sources on plant macrofossils (Beijerinck, 1947; Katz et al., 1977; Schweingruber, 1990; Tobolski, 2000). The results of the analysis were plotted on a diagram with the computer program TGView 1.7.16 (Grimm, 2011). The plant macrofossils were represented as absolute numbers of determinable items (needles, seeds, nutlets, etc.) per sample volume of 50 ml. The remains of vegetative parts like stems, leaves and others were not quantified but their presence was also indicated as black dots. Two local macrofossil assemblage zones are distinguished (BMacro-1 and -2) and the boundary between them is placed where the continuous presence of charcoal fragments ends (Fig. 3).

3.3. Radiocarbon dating

The radiocarbon ages of plant macrofossils (*Carex* fruits) and charcoal extracted from three bulk sediment samples were determined in the Radiocarbon Dating Laboratory at the University of Lund, Sweden (Table 1). The calibration ($\pm 2\sigma$ range) was performed with the OxCal v3.10 program (Bronk Ramsey, 2005) using the relevant atmospheric data (Reimer et al., 2013). All dates in the text are cited as cal. BP. The sample ages following an age/depth sedimentation plot with linear interpolation constructed with the computer program TGView 1.7.16 (Grimm, 2011) are indicated on the pollen and plant macrofossil diagrams (Figs. 2, 3).

4. Results

4.1. Radiocarbon dating and chronostratigraphical considerations

The age of the bottom part of the profile is assigned to c. 5000 cal. BP. The two pollen zone boundaries are placed at 3300 and 400 cal. BP, respectively. The sedimentation rate for the interval 105–70 cm (Cyperaceae peat with sand deposit) is estimated to 46 yr/cm, while for the interval 70–20 cm (Cyperaceae–*Sphagnum* peat deposit) which spans c. 3000 years an average sedimentation rate of 60 yr/cm can be estimated. In support of our interpretation the chronological changes in the frequencies of the main pollen taxa for the last 3500 years from the nearest peat bog Osogovo-1 (Tonkov, 2003) were also used for local correlation purposes.

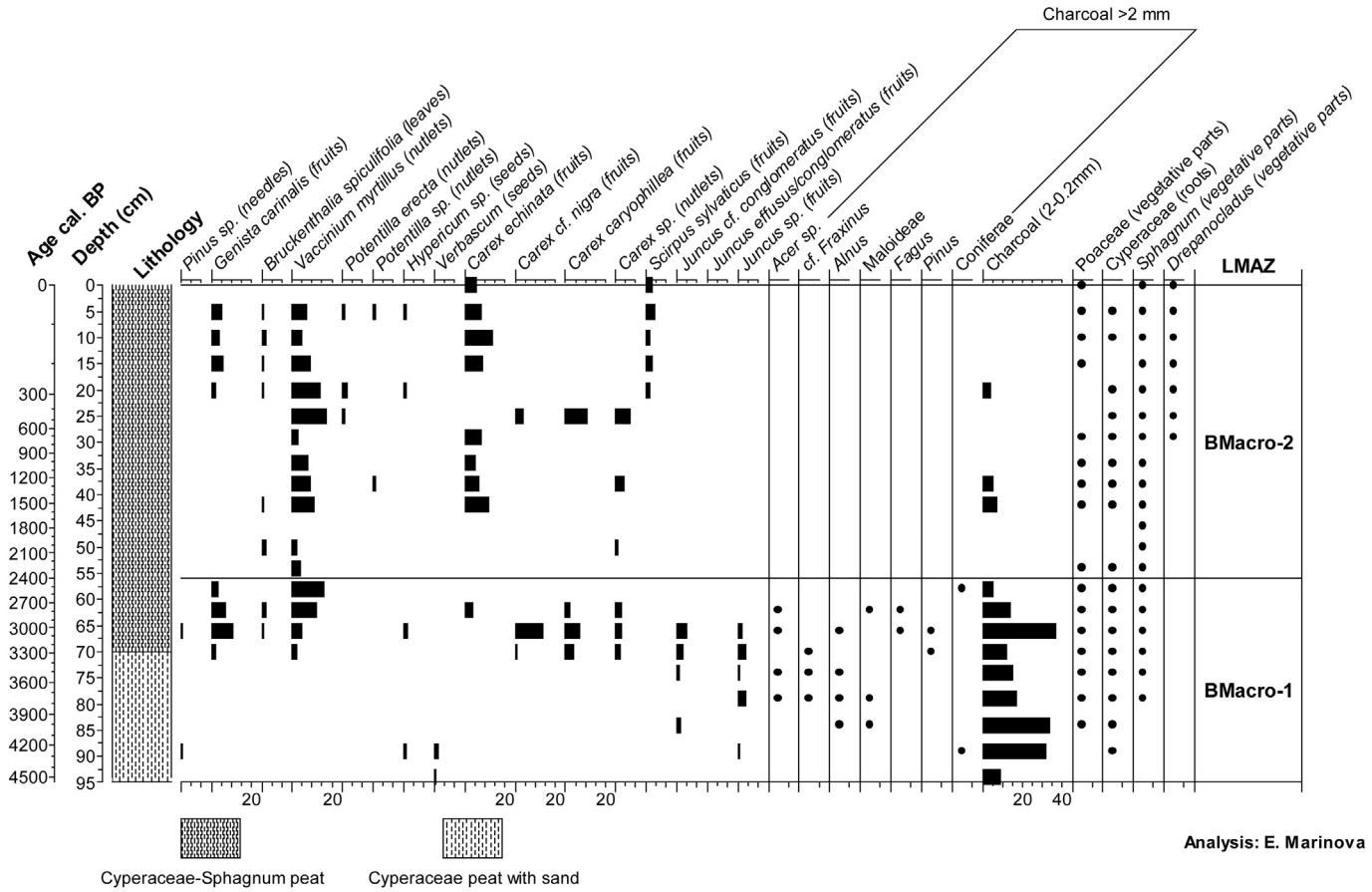


Fig. 3. Plant macrofossil diagram from peat bog Begbunar. LMAZ: Local macrofossil assemblage zones.

Table 1
Results of radiocarbon measurements of peat bog Begbunar.

Lab. code (LuS)	Sample depth (cm)	^{14}C age (BP)	^{14}C age cal. BP, ±2σ (mid-point)	Material dated
6714	20–25	275 ± 70	490–11 (250)	4 mg charcoal
6713	70–74	3190 ± 50	3560–3330 (3450)	5 mg charcoal
6712	84–89	3755 ± 60	4360–3920 (4140)	6 mg *Carex* fruits

4.2. Pollen stratigraphy (Fig. 2)

4.2.1 . LPAZ B-1, 105–70 cm (Abies–Pinus diploxylon–Betula) (~5000–3300 cal. BP)

In this zone pollen of *Abies* (13.3–3%) prevails, followed by *Pinus diploxylon*-type (6.6–12.3%), and *Betula* with a peak of 26% at the transition to the next zone. Deciduous tree pollen is represented also by *Quercus*, *Tilia*, *Ulmus* (1–2% each), *Corylus* up to 5.6%, *Alnus* and *Salix* with 3.2% and 4%, respectively. Minor quantities of pollen are recorded for *Carpinus orientalis*/*Ostrya*, *Carpinus betulus*, *Fagus*, *Fraxinus* and *Acer*. Pollen of *Juglans* is present throughout the entire core. Herb pollen is represented by Poaceae (13–43%), Ranunculaceae (up to 5.7%), *Achillea*/*Aster*-type (up to 6.3%), *Rumex* (5%), *Taraxacum*–type (up to 4%), Caryophyllaceae and Scrophulariaceae (2–3%). The elements of the local vegetation are Cyperaceae (up to 4%), single spores of *Sphagnum*, *Pteridium*, and constant presence of Polypodiaceae spores in all samples between 1.5% and 11%.

4.2.2 . LPAZ B-2, 70–25 cm (Pinus diploxylon–Fagus) (3300–400 cal. BP)

The abundance of *P. diploxylon*-type is between 15% and 29.5%, accompanied by a gradual rise of *Fagus* pollen curve to 20%. Pollen of *Abies* nearly disappears in this zone, but *Quercus* reaches up to 3%. High pollen frequencies (up to 40%) are established for Poaceae. Pollen of Rosaceae, Fabaceae, Ranunculaceae, *Achillea*/*Aster*-type barely reach 3–4%. In this zone begins the rise of Cyperaceae curve reaching 21.6% while the presence of Polypodiaceae spores sharply declines to 1%.

4.2.3 . LPAZ B-3, 25–0 cm (Fagus-Pinus diploxylon-NAP) (400 cal. BP–till present)

Pollen of *Fagus* attains a maximum of 20.5% while *P. diploxylon*-type declines to 15%. In the uppermost pollen spectra *Quercus*, *Carpinus orientalis*/*Ostrya* and *C. betulus* rise to 5%, 2% and 1.4%, respectively. A slight increase is recorded for *Juniperus*, *Vaccinuim*-type, *Vitis* and *Humulus*/*Cannabis*-type pollen. Characteristic for this zone are the maximal values for Poaceae (42%), *Plantago lanceolata* (19.4%), *Taraxacum*-type (2.2%), Rosaceae and Ranunculaceae (each 7%), Fabaceae pollen. The presence of Cyperaceae pollen is almost 20%, with a maximum of 32%.

4.3. Plant macrofossil content (Fig. 3)

4.3.1 . LMAZ BMacro-1 (95–55 cm)

In the lower part of the profile, where the sediments have a high content of sand, the prevailing macrofossil material is charred wood. In all samples charcoal fragments (>2 mm) were determined to genus level including such from *Acer* sp., cf. *Fraxinus*, *Alnus*, Prunoideae/Maloideae. At a couple of depths charred wood particles from *Fagus*, *Pinus* sp. and from undeterminable conifers were found. The record also appeared rich in unidentifiable charred wood of a smaller size (0.2–2 mm). Charred leaf fragments of *Pinus sp.* were present too. The interval 70–55 cm showed an abundance of fruits/seeds and vegetative parts from several semi-shrubs (*Bruckenthalia spiculifolia*, *Vaccinium* cf. *myrtillus*, *Genista carinalis*) and herbs (*Hypericum*, various *Carex* and *Juncus* species). Vegetative remains from Poaceae, *Carex* and mosses (*Sphagnum*) dominated the macrofossil record.

4.3.2 . LMAZ BMacro-2 (55–0 cm)

The macrofossil content of this zone shows clear differences compared to LMAZ BMacro-1. There are only occasional finds of undeterminable charred wood (0.2–2 mm). Most abundant are nutlets from *Vaccinium* cf. *myrtillus*, fruits from *Carex echinata*, *Genista carinalis* and *Scirpus sylvaticus*, while fruits form *Juncus* are lacking. Nutlets and seeds from *Potentilla* and *Hypericum* species were also determined. Vegetative parts from *Drepanocladus* sp. are present in this zone, in addition to those from Poaceae, Cyperaceae and *Sphagnum*.

5. Discussion

5.1. Vegetation history

The palaeoecological information obtained from the analyzed peat profile, in conjunction with the radiocarbon dates, reveals the vegetation development in the central part of the Osogovo Mountain during the most recent c. 5000 years. The oldest pollen spectra (zone B-1, Fig. 2) indicate that the high mountain slopes and flat ridges were covered by coniferous woods that were dominated by *Abies alba* and pines (*Pinus sylvestris*, *Pinus nigra*) with an undergrowth of ferns and sciophilous herbs. The share of each tree in these forests can be suggested from the analysis of surface moss pollen samples collected from modern coniferous plant communities located between 1650 m and 1800 m in Southwestern Bulgaria, Rila Mountains in particular (Tonkov et al., 2000). *P. sylvestris* and *P. nigra* belong to *Pinus diploxylon*-type which is well known for its high pollen production, effective dispersal and over-representation in surface moss samples. In plant communities where *P. sylvestris* is a subdominant (№2) or represented by single specimens (№3) its abundance in the relevant surface moss samples is considerable, 61% and 15.4%, respectively (Table 2). Pollen grains produced by *Pinus mugo* (dwarf-pine) are included also in the *Pinus diploxylon*-type group but cannot be separated by morphological features. The probable past distribution of dwarf-pine in the highest parts of the Osogovo Mountain could be suggested but definite confirmation requires finds of local macrofossils. Regarding *A. alba*, 18.4% of its pollen recorded in the surface moss sample №3 (Table 2) originated from a coniferous plant community with 40% participation of fir. This result suggests that up to 13% pollen of *Abies*, as recorded in zone B-1 (Fig. 2), appears indicative of a considerable participation of fir in the coniferous forests of Osogovo Mountain c. 5000–4000 years ago. In places with humid air and high soil moisture, such as deep ravines and river valleys, grew small populations of *Fagus sylvatica*, while *Alnus* and *Salix* existed along streams and brooks. The broad-leaved tree vegetation community, composed of *Quercus*, *Corylus*, *Carpinus*, *Tilia*, *Fraxinus*, *Acer* and *Ulmus* species, was distributed at lower altitudes. A local expansion phase of *Betula*, which lasted for c. 1000 years (4200–3300 cal. BP) (Fig. 2) indicates that an opening of the forest took place, which preceded the beginning of the invasion of beech. The palynological reconstruction of the vegetation in the study

Table 2
Percentage values of the main tree taxa in surface moss samples from modern coniferous communities in the Rila Mountains (after Tonkov et al., 2000).

Pollen taxa/Sample №/Composition of plant community	1. Coniferous community (1800 m): *Picea abies* 30%, *Pinus sylvestris* 30%, *Pinus peuce* 30%, *Betula pendula*, *Populus tremula*, etc.	2. Coniferous community (1750 m): *Abies alba*, *Picea abies*, *Pinus peuce*, and *Pinus sylvestris* (each 25%)	3. Coniferous community (1650 m): *Picea abies* 50%, *Abies alba* 40%, *Betula pendula* 10%, *Acer pseudoplatanus*, *Pinus sylvestris*, and *Fagus sylvatica*
Pinus diploxylon-type	30.7%	61.1%	15.4%
Pinus peuce	7.1%	3.7%	2.6%
Abies alba	0.5%	5%	18.5%
Picea abies	12.5%	13%	2.1%
Betula pendula	4.3%	1.2%	46.1%
Fagus sylvatica	2.5%	2.4%	5.6%
Quercus	1.4%	1.4%	1.4%
Corylus	1.9%	2.1%	1.2%
Carpinus betulus	0.6%	0.5%	0.5%
Carpinus/Ostrya	–	2.2%	0.1%

area is supported by the results from the macrofossil analysis — needles and charcoal from *Pinus* sp. and undeterminable charcoal fragments from conifers. The charcoal fragments from some deciduous trees (*Acer* sp., *Fraxinus*, Maloideae) suggest that they had climbed higher compared to the present day situation. The charcoal particles of different size point also to local and regional fires (zone BMacro-1, Fig. 3).

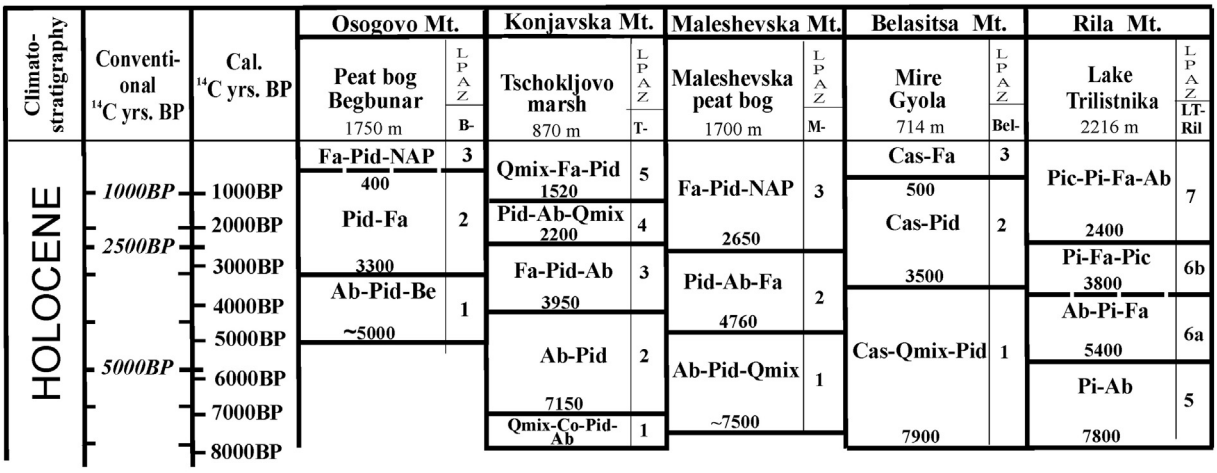
The marshy area of the peat bog seems to be covered by various *Juncus*, *Carex* and *Sphagnum* species. After the second peak of macrocharcoal fragments c. 3200–3000 cal. BP, the appearance of macrofossils from heliophilous taxa such as *Genista carinalis*, *Vaccinium myrtillus* and *Bruckenthalia spiculifolia* was most probably connected with increased opening of the landscape in the surroundings of the peat bog.

A nearly identical picture of the vegetation cover on the high central parts of the mountain for the time interval 5000–3500 cal. BP was obtained from the palynological study of the peat bog Osogovo-1 (Tonkov, 2003) (Fig. 1D, site I). One difference observed is the higher proportion of *P. diploxylon*-type pollen (40–50%) which might reflect a denser forest cover near the site. Another distinction is the absence of a *Betula* peak, which was obviously a local event in the vicinity of the peat bog Begbunar. Birch produces a large amount of pollen with effective possibilities of dispersal as shown in the surface moss samples №1 and №3 (4.3% and 46% pollen) collected from mixed coniferous community with single and 10% participation of *Betula pendula*, respectively (Table 2).

The results of previous palaeoecological investigations from other sites in Southwestern Bulgaria (Fig. 1D) deserve comparison with our new data. In the nearby Konjavska Mountain (1487 m), located northeastwards of the Osogovo massif (Fig. 1D, site II), pollen studies from Tschokljovo marsh (870 m) showed that coniferous forests dominated by *Abies alba* with an admixture of pines (*Pinus sylvestris*, *Pinus nigra*) were stable between 6800 and 3300 cal. BP (Tonkov and Bozilova, 1992b; Bozilova et al., 1996). Subsequently, the disturbance in these forests has led to the formation of mixed coniferous–deciduous communities with an increasing share of beech (Fig. 4).

Further south, in the Maleshevska Mountain (1802 m), the palynological record from a peat bog (1700 m) (Fig. 1D, site III) showed an expansion of *Abies* after 7300 cal. BP (>30% pollen), which resulted in the formation of a coniferous *Abies–Pinus* belt dominated by fir. A second maximum of *Abies* pollen (c. 20%), which represents a reestablishment, occurred between 3400 and 2700 cal. BP (Tonkov and Bozilova, 1992a) and is comparable to the situation in the Osogovo Mountain (Fig. 4).

The most recent palynological study of a small mire (Fig. 1D, site IV) located at 714 m in the sweet chestnut forests of the Belasitsa Mountain (2029 m) revealed that after c. 3500 cal. BP, alongside with the increase



Legend:
Ab = *Abies*
Be = *Betula*
Ca = *Carpinus betulus* + *C. orientalis*
Cas = *Castanea*
Co = *Corylus*
Fa = *Fagus*
NAP = non-arboreal pollen
Qmix = *Quercetum* mixtum
Pi = *Pinus dipl.* + *Pinus peuce*
Pic = *Picea*
Pid = *Pinus diploxylon*

Fig. 4. Regional comparison of the palynostratigraphy for selected sites with consistent radiocarbon chronologies in Southwestern Bulgaria during the last 8000 years. Osogovo Mountain, Peat bog Begbunar (this paper); Konjavska Mountain, site II Tschokljovo marsh (Tonkov and Bozilova, 1992b); Maleshevska Mountain, site III Peat bog (Tonkov and Bozilova, 1992a); Belasitsa Mountain, site IV Mire Gjola (Tonkov et al., 2012; Tonkov and Possnert, 2014); Rila Mountains, site VII Lake Trilistnika (Tonkov et al., 2008).

of *Castanea sativa*, other trees such as *Pinus* sp., *Tilia*, *Carpinus betulus* and *Abies* started to gain importance. These changes in the forest composition suggest an increase in air humidity and soil moisture, which had a favourable effect on the spreading of the forest cover at mid/high altitudes (Tonkov et al., 2012; Tonkov and Possnert, 2014) (Fig. 4).

In the Rila Mountains the onset of the formation of a compact coniferous belt dominated by pines (mostly *Pinus sylvestris*, *Pinus peuce*) and *Abies* was precisely radiocarbon dated to 7900/7800 cal. BP from a number of lacustrine sequences (Fig.1D, site VII; see also Fig. 1 in Tonkov et al., 2013). This notable change in the composition of the vegetation cover, when birch, and partly the deciduous oak forests were replaced by conifers, was triggered by a climate seasonality shift to cooler summers and warmer winters with increased precipitation in the Northern Mediterranean region (Davis et al., 2003). The time window 5800–3400 cal. BP which is of most interest to our study was characterized by the vast distribution of fir, together with pines, before the gradual penetration of spruce in the coniferous belt started (Tonkov et al., 2008, 2013) (Fig. 4).

The next stage in the development of the vegetation cover in the Osogovo Mountain existed between 3300 and 400 cal. BP (zone B-2, Fig. 2). Important changes in the forest composition took place as in the course of a thousand years *Fagus sylvatica* populations gradually overcame the conifers (mostly *Abies alba*) on many areas, shaping a belt of single-dominant or mixed communities. The reasons for this replacement were likely of a complex character, including the change towards a more humid and cooler climate with lower average temperatures at the transition Subborreal/Subatlantic (van Geel et al., 1999), but also aided by human interference in the forest cover.

The expansion of *Fagus sylvatica* populations in Europe in Late Holocene often coincides with disturbance events, which may be climatic or anthropogenic in nature (Bradshaw et al., 2010; Bradshaw and Sykes, 2014). For example, the examination of the relationship between pollen percentage values and charcoal data from southern Scandinavia has showed that charcoal values were generally higher immediately prior to local beech establishment (Bradshaw and Lindbladh, 2005). Similarly, the macrofossil diagram from the peat bog Begbunar comprises a peak of charcoal fragments including such identified as *Fagus* c. 3300–3000 cal. BP (the upper part of zone BMacro-1, Fig. 3). These finds just precede the invasion of beech and are supported by a rise of *Fagus* pollen values. Human impact may have been an important local factor in tree population expansion from presence to dominance, but it cannot fully explain the pattern of the Late Holocene beech population expansion in Europe (Giesecke et al., 2007).

The first maximum of beech in the Osogovo Mountain was reached c. 1000 cal. BP and was also confirmed in the pollen diagram from the peat bog Osogovo-1 (Tonkov, 2003). The final advance of *Fagus* has occurred a couple of centuries ago and was quite probably primarily controlled by climatic change. An age of 300 cal. BP for the last widespread of beech which coincides with the Little Ice Age cooling (Grove, 2004) was reported from a young peat profile on Greek territory in the Belasitsa Mountain (Fig. 1D, site VI) (Athanasiadis et al., 2003).

In the Konjavska Mountain the palynological evidence also reveals a replacement of the coniferous forests by beech, which started at c. 3200 cal. BP with two subsequent maxima at 2800 and 1800 cal. BP, respectively (Tonkov and Bozilova, 1992b). Moving southwards, the pollen record from the Maleshevska Mountain showed that *Fagus* started to extend after c. 2700 cal. BP (Tonkov and Bozilova, 1992a) (Fig. 4). In a profile from a high-altitude peat bog (1640 m) in the Belasitsa Mountain (Fig. 1D, site V) which began its existence about 2000 years ago and is located nowadays above the present timber-line shaped by beech, high values of *Fagus* pollen (~25%) were recorded at 1780 cal. BP (Panovska et al., 1990; Tonkov, 2007).

In the Rila Mountains *Picea abies* was the tree species which began to expand in the coniferous belt c. 3400 cal. BP reaching maximal distribution after c. 2600 cal. BP (Fig. 4) in the conditions of a changing climate with lower average temperatures and increase in annual precipitation (van Geel et al., 1999). This expansion was convincingly demonstrated by the abundance of pollen and plant macrofossils of spruce in the sediments of Lake Suho Ezero (Fig. 1D, site VIII) (Bozilova et al., 1990). The final advance of *P. abies*, and partly of *Fagus* in the northwestern part of the mountains, was reached c. 1300 cal. BP and subsequently in some areas beech was replaced by pine (Bozilova et al., 2002; Tonkov et al., 2008, 2013).

The rather uniform content of the macrofossil record from the peat bog Begbunar after c. 2200 cal. BP (zone BMacro-2, Fig. 3) and the nearly complete lack of charcoal fragments suggest that vast areas in the surroundings of the peat bog were already deforested and the openings were colonized by *Vaccinium myrtillus*, *Genista carinalis*, *Bruckenthalia spiculifolia*, and herbs like *Potentilla* sp. and *Hypericum* sp. The marshy area continued to be overgrown by various *Carex* and *Sphagnum* species. The appearance of *Scirpus sylvaticus* signals a reduced water supply to the peat bog.

During the last centuries the general trend of the vegetation development in the Osogovo Mountain witnessed a progressive large-scale degradation of the woodlands. In particular, the destruction of the remnants of the pine forests as shown by the behaviour of *Pinus diploxylon*-type pollen curve reaching minimal values (zone B-3, Fig. 2) culminated in their fragmentary state within the beech belt, above it, or in isolated and inaccessible places. The beech forests were also subjected to exploitation which resulted in the artificial supression of the timber-line at many places to its present day level (Zahariev, 1934). The peat bog Begbunar remained in the treeless zone above the beech forests. The open areas were occupied by diverse herbaceous communities composed of Poaceae, Ranunculaceae, Rosaceae, Fabaceae, Caryophyllaceae and Apiaceae species. Evidence for agricultural activities in the foothills of the mountain is the continuous find of *Triticum*/*Avena* and *Secale* pollen (zone B-3, Fig. 2).

Until the last two-three decades intensive cattle-breeding was practiced, as proven by the presence of a large number of anthropogenic pollen indicators such as *Taraxacum*-type, *Plantago lanceolata*, *Rumex, Urtica*, etc. Nowadays, the absence of grazing is the main reason for the spontaneous restoration of *Pinus sylvestris* on some terrains. Parallel to these changes, signs of a partial enlargement of *Carpinus* and mixed *Quercus* communities are visible in the beech forest belt at lower altitudes.

5.2. Human impact

The territory of Southwestern Bulgaria where Osogovo Mountain is located appears of special interest for studies of anthropogenic impact on the natural vegetation during the Holocene, which began at least 8500 years ago with the start of the Neolithic farming, although it continuously increased during the subsequent millennia of human occupation. Abundant information has been collected and recently reviewed for inferring the human impact on the landscape in this area based on data from pollen analyses of lakes and peat bogs, plant macrofossils, archaeobotanical finds and radiocarbon dating (Marinova et al., 2012).

The increase in the number of the human settlements in the valleys and in the foothills of the mountains in Southwestern Bulgaria (Grębska-Kulow and Kulow, 2007) is visible in the palaeobotanical records around 6950 cal. BP (roughly fitting to the Late Neolithic/Early Eneolithic in the region). Between c. 5700 and 5100 cal. BP signs of anthropogenic influence on the vegetation are virtually absent. The intensity of human impact increased notably after 3200 cal. BP (approx. Late Bronze Age) as documented by a rise of the pollen anthropogenic indicators (see Fig. 4 in Marinova et al., 2012). The final transformations in the natural forest cover after 2800 cal. BP (the onset of the Iron Age) marked the reduction of the coniferous forests dominated by *Abies alba* and *Pinus* and the expansion of *Fagus sylvatica* or *Picea abies*. These vegetation changes appear contemporaneous with an increase of the palaeofire activities and subsequent peaks of the anthropogenic indicators that point to a diversification of human impact.

Indications of human activity in the pollen diagram from the peat bog Begbunar (Fig. 2) are noticed already c. 5000 cal. BP when pollens of *Secale* and *Triticum/Avena* were deposited, alongside with the presence of pollens from *Rumex* and *Plantago lanceolata*. However, in the peat profile Osogovo-1 (Tonkov, 2003) the appearance of *Secale* pollen starts much later c. 1300 cal. BP. In our opinion this observation reflects local/regional specific features of human activities. For example, high quantities (10–20%) of *Scleranthus* pollen, indicative for stock-breeding, were recorded in the above profile with a first maximum assigned to the onset of the Late Bronze Age. Around 2700 cal. BP (Early Iron Age) a peak in the presence of the anthropogenic indicators is registered. By that time the local Thracian tribes along the River Struma had moved higher up into the surrounding mountains (Bozhkova and Delev, 2002).

Abundant archaeozoological and scarce botanical materials were found in the cultural layers of final Early Neolithic to Early Bronze Age of the prehistoric settlement Vaxevo (600 m) located in the southeastern foothills of the Osogovo Mountain. The bones from cattle, sheep, goats and pigs suggest that stock-breeding was a significant part of the human economy (Chohadziev et al., 2001). The evidence of agriculture from this site shows several storages of cultivated cereals dominated by hulled barley and einkorn (Popova, 2001). The Thracian and Roman periods of occupation witnessed further development of agriculture, vine-growing, stock-breeding and ore-mining. The forests served as an important source for wood used for construction purposes, heating and metallurgy. The local economy flourished as the Romans introduced advanced methods for the cultivation of the fields (Bozilova et al., 1994). Since this period the cultivation of walnut in the area became widespread, as evidenced by the continuous pollen curves of *Juglans*. In Mediaeval times, after 720 cal. BP (Tonkov, 2003), and particularly since 400 cal. BP (Fig. 2) the impact of humans on the natural woods has intensified as demonstrated by the decline of the pollen curves of *Pinus diploxylon*-type and *Fagus* and the rise of Poaceae, *Juniperus*, and *Plantago lanceolata*. The destruction of the woods resulted also in the enlargement of the areas for summer pasture land and the establishment of the present day vegetation cover.

Evidence of human presence is hardly noticeable in the pollen diagrams from Konjavska Mountain. An interesting feature, however, is the continuous presence of *Juglans* pollen already since 7200 cal. BP, probably indicating its native distribution in this area rather than by local cultivation (Bozilova and Tonkov, 2007). Before the onset of the Roman occupation the palynological indications of human presence and activity occur rather sporadically (Marinova et al., 2012). As already mentioned, the replacement of the coniferous forests by beech started c. 3200 cal. BP, most likely as a result of the combined effects of climate change and human interference.

In the Maleshevska Mountain *Abies* decreased twice for the time interval 4760–2800 cal. BP (Early Bronze Age–Early Iron Age) probably due to lower humidity and reinforced by intensification of human disturbance in all vegetation belts. The replacement of the coniferous forests by *Fagus* starting at 2700 cal. BP was accompanied by the uninterrupted presence of anthropogenic pollen indicators such as Cerealia-type, *Plantago lanceolata*, *Rumex* and *Scleranthus* (Tonkov and Bozilova, 1992a).

6. Conclusions

Pollen and plant macrofossil analyses showed that the vegetation cover of the Osogovo Mountain has featured important transformations during the last 5000 years. A coniferous belt composed of *Abies alba* and *Pinus* existed at high altitudes and below it were distributed oak forests with *Carpinus, Tilia*, *Fraxinus*, *Acer* and *Ulmus*. The replacement of the coniferous forests by beech started c. 3200 cal. BP and was of complex character, promoted by factors related to both climate change and anthropogenic disturbance. The remnants of the coniferous forests and also the single-dominant or mixed communities of beech were subjected to destruction during the last two-three centuries. Evidence for pronounced human impact in the study area, including deforestation, stock-breeding and agriculture activities, is available since the Late Bronze Age. On a regional scale the Late Holocene vegetation pattern of the Osogovo Mountain shows parallel developments with other palaeoecological records from the montane area of Southwestern Bulgaria.

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