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Late Holocene vegetation changes in the Northern Pirin Mountains (southwestern Bulgaria). Palynological data from Lake Suho Breznishko and Lake Okadensko

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Abstract: The pollen stratigraphies of Lake Suho Breznishko (1963 m a.s.l.) and Lake Okadensko (2475 m a.s.l.) in the Northern Pirin Mountains of southwestern Bulgaria record the vegetation history since about 6000 years ago. An initial open *Betula* forest contained minor *Pinus peuce,* documented by macrofossils, as well as *Abies.* Conifers that had dominated at higher elevations elsewhere then expanded downslope, and after 4300 yr BP *Pinus peuce* was joined by *Pinus* diploxylon-type (including *P. sylvestris, P. mugo,* and *P. heldreichii*) and *Picea.* Maxima of microscopic and macroscopic charcoal, along with increases of *Juniperus, Pteridium,* non-arboreal pollen (including anthropogenic indicators), and algal remains, suggest significant human impact on the vegetation after about 4000 yr BP.

Key words: Holocene, Bulgaria, Pirin Mountains, paleoecology, pollen analysis, microscopic charcoal particles.

Introduction

The numerous glacial lakes and the geographical position of the Pirin Mountains in southwestern Bulgaria within the transitional zone between continental and submediterranean climates provide excellent opportunities for paleoecological investigations and reconstruction of Late Glacial and Holocene vegetation changes, which have been influenced by many factors, including climatic fluctuations, immigration processes, and human impact (Bozilova 1977; Stefanova & Bozilova 1992, 1995; Stefanova & Oeggl 1993; Panovska et al. 1995; Stefanova 1997, 1999; Bozilova et al. 2002; Tonkov et al. 2002; Atanassova & Stefanova 2003; Stefanova & Ammann 2003; Tonkov 2003). However, information is limited concerning human activity as well forest fires, which are one of the most important natural and anthropogenic factors in the distribution of natural vegetation. Today the forests in this area show little human impact, and no records exist concerning fire frequency. To examine these issues, this study includes the analysis of microscopic and macroscopic charcoal particles parallel to pollen analysis in cores from two lakes in the Northern Pirin Mountains. Because the two lakes are at different elevations and are on different types of bedrock, comparison of the pollen profiles could allow evaluation of the effects of these two factors on the forest composition.

Study area

Regional climate and vegetation

The Pirin Mountains (Fig. 1) are composed largely of Precambrian crystalline rocks (Boyagjev 1959), cut by numerous glacial cirques now occupied by small lakes. The northern part of the mountains is the most monolithic, and the highest part extends up to 2914 m a.s.l.

The climate of the mountains below an altitude of 1000 m a.s.l. is transitional continental/submediterranean, and above this altitude it is a typical montane climate. The annual precipitation above 2000 m a.s.l. is 1100–1200 mm, with a maximum in November–December and a minimum in August (Ivanov et al. 1964).

The nature of the vegetation in the Pirin Mountains is determined by the elevation and by the distance from the Mediterranean area. According to Veltshev (1997), several vegetation belts are represented:

— The lowest belt, up to 500 m a.s.l., is locally represented only in southern part of the mountains and consists of communities with the Mediterranean elements *Quercus coccifera*, *Juniperus excelsa, Phyllirea latifolia*, etc.

— The belt of xerothermic oak forest (about 500–700 m a.s.l.) is formed by *Quercus cerris*, *Q. pubescens*, *Q. frainetto,* and *Carpinus orientalis*.

— In the mesophilous and xeromesophilous *Quercus-Carpinus* belt (up to 800–900 m a.s.l. or locally 1000 m a.s.l.) communities *of Quercus dalechampii* and *Carpinus betulus* are typical, but *Pinus nigra*, *Ostrya carpinifolia,* and *Corylus avellana* also occur.

— The belt of *Fagus* forest (from 900–1000 to 1500–1600 m a.s.l.) has *Fagus sylvatica* as dominant, but it is represented in the Northern Pirin Mountains only by fragments. Communities of *Abies alba*, *Pinus nigra*, *P. peuce,* and *Picea abies* occur locally.

— In the coniferous belt (between 1500–1600 m and 2000–2200 m a.s.l.) communities of *Pinus sylvestris* and *Picea abies* are most abundant. The Balkan endemic spe-

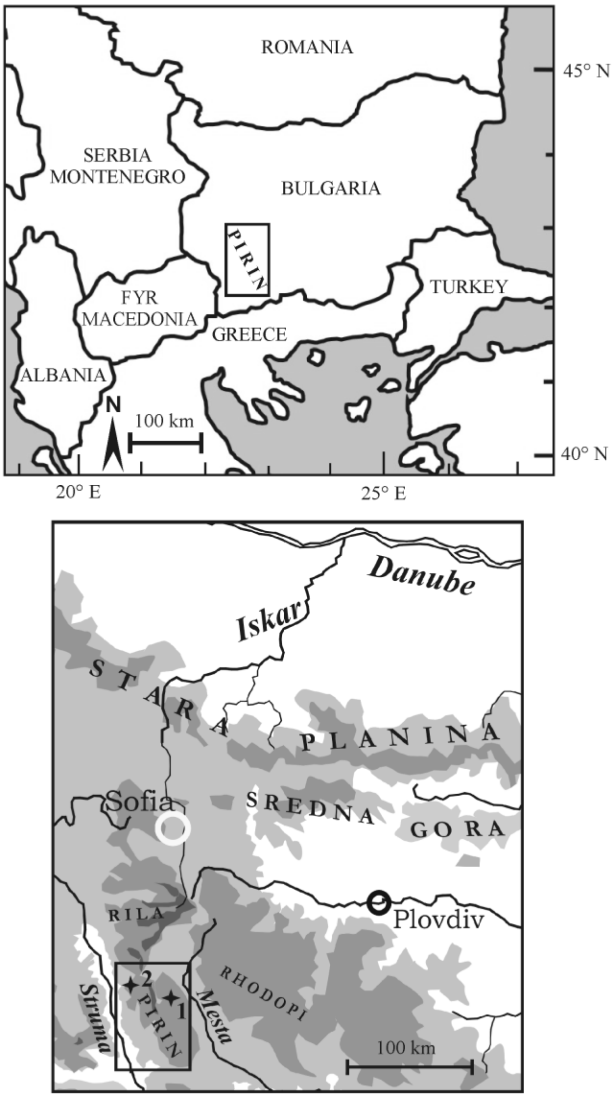

Fig. 1. Location of the investigated sites in Northern Pirin Mts. **1** — Lake Suho Breznishko (1963 m a.s.l.). **2** — Lake Okadensko (2475 m a.s.l.).

cies *Pinus peuce* and the relict subendemic species *Pinus heldreichii* are also present.

— The vegetation in the subalpine belt (about 2000–2500 m a.s.l.) is dominated by *Pinus mugo*, *Juniperus sibirica,* and *Vaccinium myrtillus*.

— The alpine belt (above 2500 m a.s.l.) communities of *Sesleria comosa*, *Festuca airoides*, *Agrostis rupestris,* and *Carex curvula* are common on silicate terrane and *Sesleria coerulans*, *S. corabensis,* and *Carex kitaibeliana* on marble terrane.

Sites of investigations

The two sites of investigation are located in different parts of the Northern Pirin Mountains. Lake Okadensko at 2475 m a.s.l. is situated in the Okadenski cirque in northwestern part of the mountains, where marble occurs in the bedrock. The lake today is less than a meter deep. *Pinus mugo* and *Juniperus sibirica* grow in its surroundings. The upper forest limit in the area is formed by *Pinus heldreichii,* which prefers calcareous substrates. Lake Suho Breznishko at 1963 m a.s.l. lies in the granitic area in the northeastern part of the mountains. As the smallest of the three cirque lakes in the Breznishki cirque, it is 125 m long and 75 m wide and is largely dried out. Subalpine communities of *Pinus mugo* and *Juniperus sibirica* are common in the surroundings, as well as scattered *Pinus peuce* and *Picea abies,* which form the upper forest limit.

Material and methods

Coring, chemical treatment, and calculations

The sediment cores were taken with a Dachnowsky corer. Samples at 2–3 or 5 cm intervals were treated with HF and acetolysis (Faegri & Iversen 1989). The lowest 10 cm (silt ko contained no pollen grains, but the rest of the core is rich in organic matter and wood fragments, in contrast to the sediments of Lake Okadensko, which consist of gyttja. The pollen sum of AP (arboreal pollen) + NAP (non-arboreal pollen) excludes *Cyperaceae* and fen and aquatic plants and also spores of *Pteridopsida*, and their percentages are calculated on the basis of the pollen sum. At least 1000 AP grains were counted for each level. For calculations and drawing of the pollen diagrams the programmes TILIA and TILIA GRAPH were used (Grimm 1992). Microscopic charcoal particles were counted on the pollen slides without additional preparation (Clark 1982). Microscopic charcoal was identified as black, opaque, angular fragments. The results are expressed as concentration in 1 cc of the sediments (using *Lycopodium* tablets — Stockmarr 1971). Many authors recommend the size-class method (Waddington 1969), which involves measuring the area of each charcoal particle, but Tinner & Hu (2003) point out that it is unnecessary to measure charcoal areas in standard pollen slides. Samples at 5 cm intervals were studied for macroscopic charcoal particles under a binocular microscope (up to 40× magnification), and single seeds of *Pinus mugo, P. peuce*, and fruits of *Carex* were found at different levels in the sediments of lake Suho Breznishko. The macroscopic charcoal particles are presented in the charcoal diagram as absolute numbers. Green algae *Pediastrum* and *Botryococcus* also occur in the pollen slides. Their frequency is presented as a percentage of the pollen sum. *Pediastrum* and *Botryococcus* are usually classified as indicators of eutrophic to mesotrophic conditions (Komarek & Jankovska 2001).

Results and discussion

Lithology of Lake Suho Breznishko sediments

0–10 cm *Polytrichum* sp. mosses;
10–23 cm light brown gyttja;
23–65 cm dark brown gyttja;
65–105 cm black gyttja;

105–115 cm dark grey-brown gyttja;
115–120 cm grey gyttja with an admixture of sand;
120–130 cm light yellowish silt with small stones of granite.

Lithology of Lake Okadensko sediments

0–5 cm organic material;
5–85 cm grey gyttja;
85–100 cm grey gyttja with an admixture of sand.

Radiocarbon dating

Radiocarbon dating was performed at the AMS Lab of the University of Arizona. Radiocarbon dates (uncalibrated) are listed in Table 1 and shown on the pollen diagrams. For Lake Okadensko one sample of gyttja was dated by AMS because macrofossils were not found.

Pollen stratigraphy

To facilitate description and understanding of the vegetation succession, the percentage pollen diagrams (Figs. 2 and 3) are divided into pollen assemblage zones (PBr-1 to PBr-4 in Lake Suho Breznishko and POk-1 to POk-3 in Lake Okadensko). The zone boundaries were determined by CONISS (Grimm 1992). Short descriptions of the pollen zones are presented in Table 2.

Table 1: Radiocarbon dating was performed at AMS Lab of University of Arizona.

Sample ID	Lab. No	Depth (cm)	^{14}C Dates uncal. BP	Material dated
Okaden-100	AA55667	100	4390±300	gyttja
Okaden-83	AA55668	83	2140±150	roots charcoal
Suho Br-1	AA47307	50	4353± 50	wood
Suho Br-2	AA47308	100	5742± 44	wood

Lake Suho Breznishko

PAZ PBr-1 (120–104 cm) represents forest development before 5740 yr BP, when open communities of *Betula pendula* (26–35 %) surrounded the lake, which is the lowest cirque lake in the region. Also at the mire Praso (1900 m) and at Lake Popovo 6 (2190 m) *Betula* was dominant between 7200 and 6500 yr BP (Stefanova & Oeggl 1993; Stefanova & Bozilova 1995). At Suho Breznishko *Abies* (5–7 %), *Pinus* haploxylon-type (*P. peuce* 3–5 %) and *Pinus* diploxylon-type (*P. sylvestris, P. mugo* 20 %) are well represented. They had already expanded at higher elevations by 6500 yr BP, as around Lake Dalgoto at 2310 m (Stefanova & Ammann 2003) and Lake Ribno Banderishko at 2190 m (Tonkov et al. 2002), although at the latter site *P. peuce* is rare. Pollen of *Quercus* (3–5 %), *Tilia* (3–9 %), *Ulmus*, and *Corylus*, believed to have blown up from lower elevations (Stefanova & Ammann 2003), are well represented, because the relatively high values of NAP (35 %) suggest an open landscape with low local pollen production.

In PAZ PBr-2 (104–73 cm) the increase of *Abies* (7–10 %), *Pinus peuce* (6–17 %), and *Pinus* diploxylon-type (up to 50 %) occurred after 5740 yr BP, indicating the lowering of the conifer belt in the mountains, partly replacing *Betula*, which shows fluctuating values (10–25 %). At Lake Suho Breznishko the presence of *P. peuce* is confirmed by the finding

Table 2: Description of the pollen zones.

Lake Suho Breznishko 1963 m a.s.l.			Lake Okadensko 2475 m a.s.l.		
LPAZ	**Depth (cm)**	**Description**	**LPAZ**	**Depth (cm)**	**Description**
PBr-4	0–43	*Picea* (2–5 %) and *Fagus* (up to 3 %) are characteristic. High values for *Pinus* diploxylon-type (45–57 %). Increase in anthropogenic indicators like *Scleranthus*, *Polygonum aviculare*, *Plantago lanceolata*, Chenopodiaceae.	POk-3	0–15	*Pinus* diploxylon-type is the dominant with 50–60 %, *Pinus peuce*, *Abies*, and *Picea* decrease. *Secale* and *Triticum* occur as indicators of human activity increse.
PBr-3	43–73	*Pinus peuce* (up to 23 %), *Abies* (12 %), and *Pinus* diploxylon-type (up to 60 %) have their maximal values. First increase in *Picea* and *Fagus*. Upper border is marked by decrease in *Pinus peuce* and *Abies*.	POk-2	15–85	*Picea* has an absolute maximum of 12 %. *Pinus peuce* (5–20 %) and *Pinus* diploxylon-type (10–60 %) fluctuate. Decrease in *Picea* at the upper border.
PBr-2	73–104	Increase of *Abies* (7–10 %), *Pinus peuce* (6–17 %), and *Pinus* diploxylon-type (25–50 %). *Betula* (10–25 %) is still significant. Sharp decrease in *Betula* characterizes the upper border.	POk-1	85–100	Among the arboreal taxa (AP up to 85 %) dominant are *Abies* (up to 20 %), *Pinus peuce* (10–15 %), and *Pinus* diploxylon-type (up to 50 %). Upper border is marked by decrease of *Abies* and increase of *Picea*.
PBr-1	104–120	*Betula* has maximal values with 20–35 %. *Pinus* diploxylon-type is 10–30 % and *Pinus peuce*, *Abies*, *Quercus*, *Tilia*, and *Corylus* are 3–9 %. Among the herb taxa (NAP up to 35 %) Poaceae, *Taraxacum*-type, *Achillea*-type, *Rumex* and Apiaceae are important. Upper border is marked by decrease of *Betula* and increase of *Pinus peuce*, *Abies*, and *Pinus* diploxylon-type.			

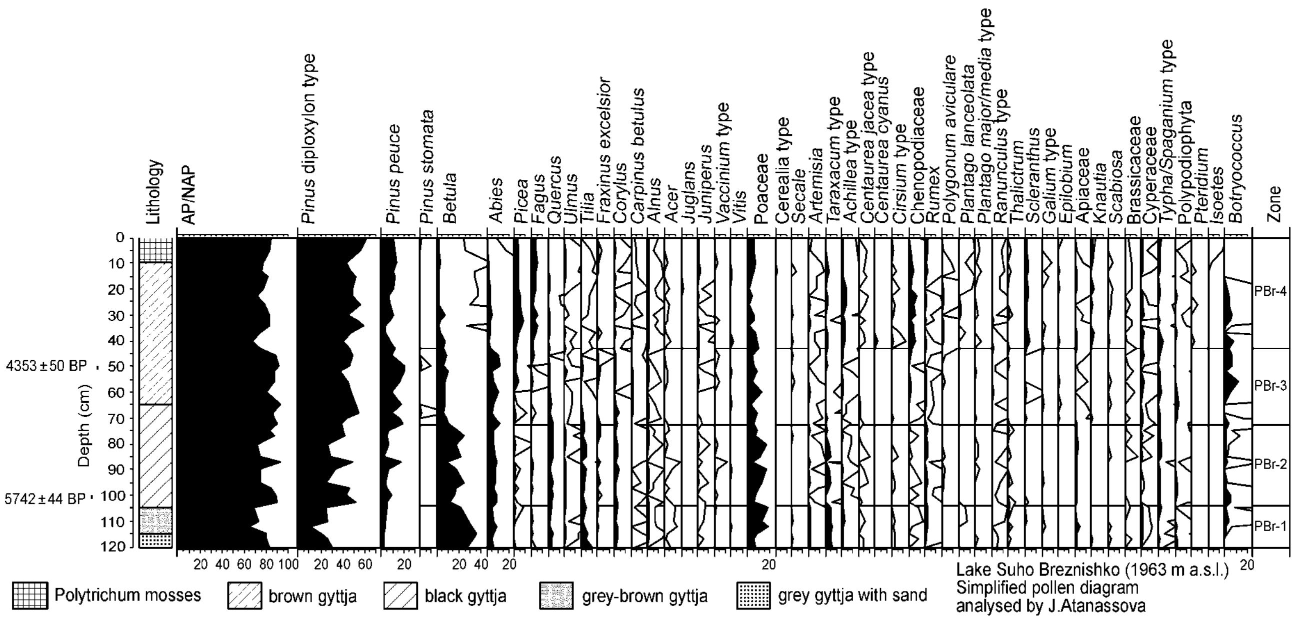

Fig. 2. Simplified percentage pollen diagram of Lake Suho Breznishko.

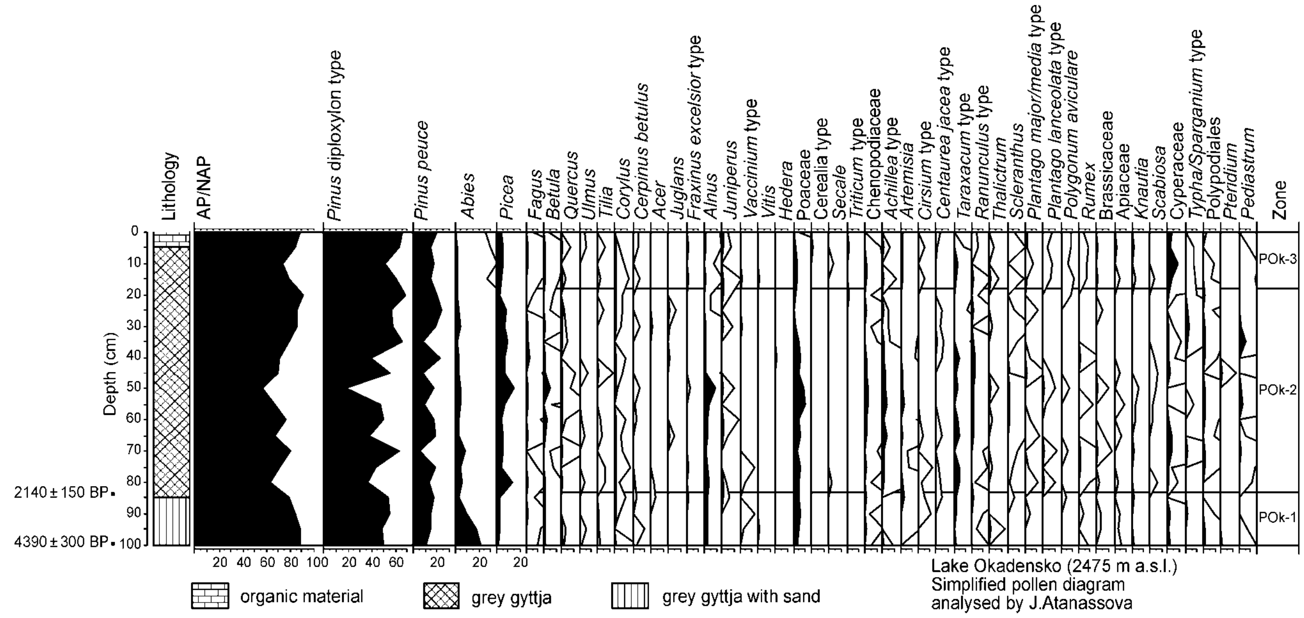

Fig. 3. Simplified percentage pollen diagram of Lake Okadensko.

of two seeds at 85 cm (estimated date 5200 yr BP). Microscopic charcoal has a maximum at 75 cm, where macroscopic charcoal was also found, one piece being 0.5 cm long.

In PAZ PBr-3 (73–43 cm) pollen maxima of *Pinus peuce* (19–23 % and *Abies* 11–12 %) were supplemented by *Pinus* stomata as well as two seeds of *P. mugo* (at 45 and 55 cm) and two seeds of *P. peuce* (at 55 cm).

PAZ PBr-4 (43–0 cm, 4300 yr BP to present) shows high percentages of *Pinus* diploxylon-type (45–57 %). Finding of one seed of *P. mugo* at 35 cm reflects a further expansion of *P. mugo*. *P. peuce* and *Abies* were reduced, as is the case at Dalgoto (Stefanova & Ammann 2003). *Picea* increased, as it became a dominant tree in the upper part of the coniferous belt, along with *P. peuce* (Stefanova 1999; Stefanova & Ammann 2003). *Fagus* also expanded at Lake Suho Breznishko at this time.

Palynological results at Lake Kremensko 5 (Atanassova & Stefanova 2003) indicate possible Late Glacial refugia of *Picea* in the Pirin Mountains, but expansion is rather late in comparison with the Carpathian Mountains (Ralska-Jasiewiczowa 1980), where it became important in the mid-Holocene, and the Gutaiului Mountains in NW Romania (Bjorkman et al. 2003), where it occurred already by 10,750 cal yr BP.

Microscopic charcoal particles show maxima at 32 cm and 23 cm and, macroscopic charcoal was also found at 20 cm and at 25 cm (Fig. 4).

Increase of *Botryococcus* in PAZ PBr-3 and PBr-4 could indicate increased eutrophication of the lake.

Lake Okadensko

The pollen diagram for Lake Okadensko shows that the vegetation changes around the lake for the last about 4300 years are similar to those around Suho Breznishko. PAZ POk-1 shows the last stage of high distribution of *Abies* together with *Pinus peuce* and *P.* diploxylon-type (including *P. sylvestris, P. mugo,* and *P. heldreichii*). The beginning of PAZ POk-2 marks the increase of *Picea* in the region shortly before 2140 BP. Increasing percentages of *Pinus* diploxylon-type are connected with expansion of *P. mugo* around the lake and the dominance of *P. heldreichii* and *P. sylvestris* in the coniferous belt. The higher elevation of Lake Okadensko explains the lower concentration of microscopic charcoal particles in the sediments (Fig. 5). Macroscopic charcoal particles were found at 80 and at 55 cm.

Human impact

Archaeological sites in the area of the Northern Pirin Mountains are scarce, but the Early Neolithic settlement of Dobriniste in the foothills indicates that this area was occupied rather early — about 5600–5500 BC (Nikolov 1996). The valley of the Struma River was also a very favourable place for Neolithic people (Grebska-Kulowa 1998). No data exist concerning the prehistoric development of animal husbandry in the Pirin Mountains, but it is known that in historical times some semi-nomadic tribes drove their flocks from high parts of the mountains (Rila, Pirin, Rhodopes) to the Aegean Sea in autumn and back to the high mountains in summer.

In the pollen diagram for Lake Suho Breznishko the first sharp increase of microscopic and macroscopic charcoal particles occurs at 75 cm (upper boundary of PAZ PBr-2) (Fig. 4). A slow increase of *Juniperus* occurs in the PAZ PBr-3. This could be interpreted as the result of a local fire as the first forest clearance in the region. Significant presence of anthropogenic pollen indicators in this PAZ are absent.

Increase in NAP values and significant change in the taxonomic composition of the NAP pollen types in PAZ PBr-4 show features of increasing anthropogenic impact after 4353 BP. Increase in percentages of Chenopodiaceae, *Scleranthus, Plantago lanceolata, Cirsium*-type, *Polygonum aviculare*, and the appearance of *Pteridium* suggest grazing in close vicinity of the lake. Increase of microscopic and macroscopic charcoal at 20–32 cm depth in the sediments indicates possible fire in the surroundings. We suggest that fire was used for forest clearance to open areas for grazing and husbandry.

At the same time after 4353 BP pollen grains of *Secale* and Cerealia-type occur in the sediments, indicating human activity in the lower part of the mountains.

Maximal occurrence of microscopic charcoal particles with single macroscopic charcoal pieces in Lake Okadensko

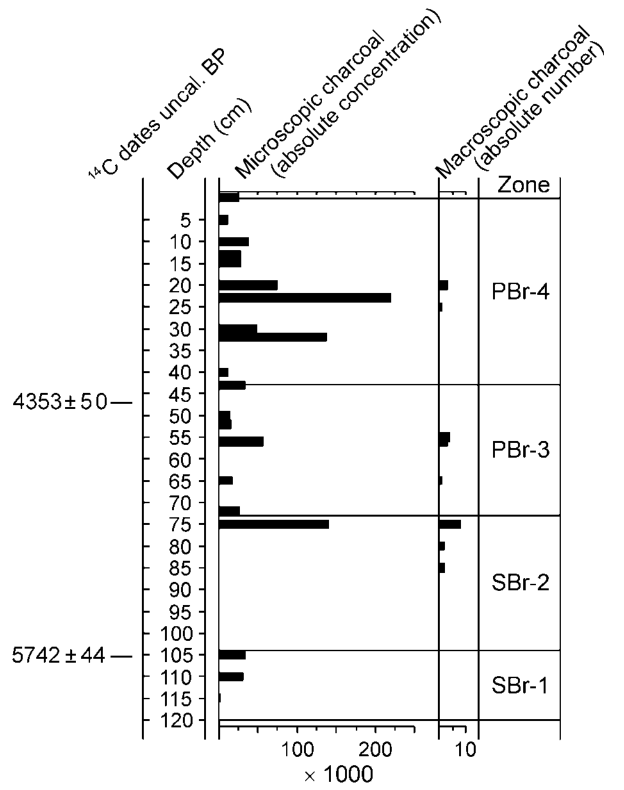

Fig. 4. Charcoal diagram of Lake Suho Breznishko.

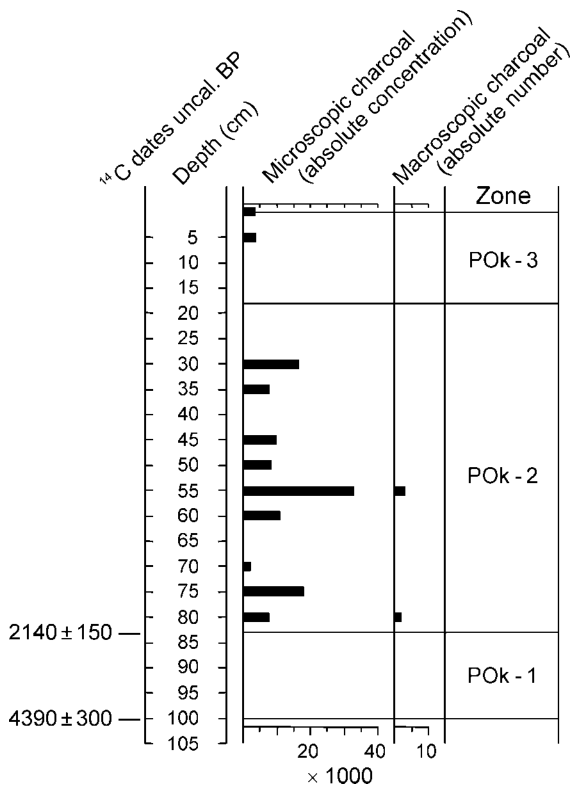

Fig. 5. Charcoal diagram of Lake Okadensko.

(after 2140 BP) is synchronous with the increase of NAP, finds of *Secale* and *Triticum* type, and increases of Cichoriaceae, *Scleranthus*, and Chenopodiaceae. We suggest that forest clearance by fire in the vicinity of Okadensko Lake was also possible at that time. Probably the combination of climatic changes over the last 4000 years and also the human activity in the high mountains forced the spread of *Juniperus* and *Pinus mugo* into the upper forest limit.

These are the first data on the use of fire for forest clearance in the Pirin Mountains, but additional investigations are necessary for more detailed conclusions.

Conclusion

The pollen records of Lake Suho Breznishko and Lake Okadensko provide new information on the Holocene vegetation changes caused by climatic fluctuations but also by forest fire in the Northern Pirin Mountains. The paleoecological reconstruction starts from approximately 6000 years BP with the expansion of *Betula* forests, forming the upper treeline together with *Pinus sylvestris*, *P. peuce*, and *P. mugo*. After 5700 years BP coniferous vegetation expanded, replacing *Betula* forests. At both sites the prominence of *Abies* shifted to that of *Picea*, although at the lower site the change occurred about 2000 years earlier, and the *Abies* phase was accompanied by *Alnus*, *Betula*, *Quercus*, *Tilia*, and *Corylus* and the *Picea* phase by *Fagus*, whereas at the higher site these temperate taxa are poorly represented. Expansion of *Picea* was probably forced by global climatic changes (van Geel et al. 1998) as well as by human activity. Forest disturbance has been shown to favour spruce regeneration in the boreal forest of northern Sweden (Bradshaw & Zackrisson 1990).

The present study illustrates the importance of the analysis of macrofossils and of micro- and macro- charcoal particles parallel to the pollen analysis of mountain-lake sediments. Stomata analysis confirms the presence of important taxa in the surroundings of the investigated sites. Large charcoal particles indicate local fire, which could be an important factor for forest changes. The general conclusion of the present study is that fire was used for forest clearance to open areas for grazing and husbandry in the high Pirin Mountains after 5700 yr BP. Probably not only climatic changes in about the last 4000 years but also the human activity in the high mountains forced the spread of *Juniperus* and *Pinus mugo* at the upper forest limit and the expansion of *Picea*.

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