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It is our pleasure to dedicate this paper to Professor Magdalena Ralska-Jasiewiczowa on the occasion of her jubilee anniversary and in recognition of her substantial contributions to European postglacial vegetation history.

A contribution to the late Holocene vegetation history of the northern Pirin Mountain, southwestern Bulgaria: palynological study and radiocarbon dating of Lake Muratovo*

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ABSTRACT. Pollen analysis was performed on two cores recovered from Lake Muratovo (2230 m) on the northern Pirin Mountain (southwestern Bulgaria) supplemented by seven ^{14}C AMS dates. The reconstruction of the vegetation history for the last ca. 4300 years shows that during the Subboreal period, coniferous forests composed of *Pinus sylvestris*, *Pinus peuce*, *Pinus heldreichii* and *Abies alba* were widely distributed, with stands of *Pinus mugo* and *Juniperus* within herb vegetation above them in the subalpine zone. Isolated localities with sufficient moisture sheltered groups of *Picea abies* and *Fagus sylvatica.* The Subboreal/Subatlantic transition ca. 3000 cal. BP, when temperatures dropped and precipitation increased, marked the beginning of the late expansion of *Picea* in the coniferous belt and the decline of *Abies*. The last stage in the vegetation development after ca. 1900 cal. BP is connected with the progressively increasing human activities in historical times and the formation of the present-day appearance of the plant cover in the study area.

KEY WORDS: pollen analysis, radiocarbon dating, vegetation history, Lake Muratovo, northern Pirin Mountain, Bulgaria

INTRODUCTION

The postglacial vegetation history the of Pirin Mountain (2914 m), the third highest massif on the Balkan peninsula, has been intensively studied during the last. This mountain with numerous lakes and peat-bogs, located between the moderate continental decades and submediterranean climatic regions, has always been an attractive area for palaeoecological research (Bozilova 1977, 1986, Stefanova & Bozilova 1992, 1995, Stefanova & Oeggl 1993, Panovska et al. 1995, Bozilova et al. 2002, Tonkov et al. 2002, Tonkov 2003, Stefanova & Ammann 2003, Atanassova & Stefanova 2003). These investigations revealed the general trends and phases in vegetation development such as vertical tree migration, forest dynamics, formation of vegetation belts and plant communities dependent on the specific characteristics of the sites studied. It was also established that the dynamic processes in vegetation development came to an end during the late Holocene when anthropogenic activi-

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ties started progressively to increase (Bozilova & Tonkov 1990).

This paper continues the presentation of results from palynological investigations that were undertaken during recent years on lake sediments in one of the largest glacial cirques located in the northern part of the Pirin Mountain (Tonkov et al. 2002, Stefanova & Ammann 2003) and focuses in more detail on the vegetation and climate history during the last ca. 4300 years.

THE STUDY AREA

GEOLOGY, GEOGRAPHY AND CLIMATE

Pirin Mountain constitutes part of the vast Rila-Rhodopes massif and is located between 41°25′ and 41°55′ N, 23°07′ and 23°55′ E in southwestern Bulgaria (Fig. 1). To the west and east it is surrounded by the valleys of the Struma and Mesta rivers, to the north by the Rila Mountains and to the south by the Slavjanka Mountains. Geologically, Pirin Mountain is a large anticline, its granite centre overlain by Palaeozoic metamorphic rocks. From a morphographic point of view Pirin Mountain is divided into three parts. The northern part is the highest and consists of marble and granite. It has been glaciated at least twice during the Quaternary and the glaciations correspond to Riss and Würm in the Alps. Mountain valley glaciers extended down to ca. 1600–1400 m (Glovnja 1963, Velchev 1995).

Fig. 1. Location of Pirin Mountain (solid circle) on the Balkan Peninsula

Pirin Mountain belongs to South-Bulgarian climatic region where the sub-Mediterranean influence penetrates along the rivers in the lowlands and foothills. The climate above 1000 m is typically montane and the annual precipitation amount is 800–1250 mm with a maximum in November – December, much of which is snow above 1500 m (Tishkov 1976).

MODERN VEGETATION

The modern vegetation of Pirin Mountain contains a unique combination of central-european, arctic-alpine and Mediterranean species as a result of the climatic influences and the longitudinal orientation of the mountain. The vegetation is distributed in six vegetation altitudinal belts determined by the contrast between limestone and siliceous habitats (Stojanov 1950, Velchev & Tonkov 1986, Bondev 1991). The xerothermic oak belt (up to 600–700 m) is dominated by *Quercus pubescens*, *Q. frainetto* and *Carpinus orientalis* with numerous Mediterranean and sub-Mediterranean herbs. The xeromesophilous oak and hornbeam belt (600–1000 m) is occupied by the communities of *Quercus dalechampii* and *Carpinus betulus* with an admixture of *Ostrya carpinifolia* and *Fagus sylvatica*. The beech belt (1000–1500 m) is fragmented, identified predominantly in the central and southern parts of the Pirin Mountain by communities of *Fagus sylvatica*, mixed in some areas with *Abies alba*, *Pinus nigra*, and *Picea abies*. The coniferous belt (1500–2000 m) is the most compact and well-developed vegetation belt with a diverse flora. *Pinus sylvestris* grows in both limestone and siliceous areas. The Balkan endemic *Pinus peuce* and *Picea abies* form the upper timber-line in many places. The Balkan subendemic *Pinus heldreichii* occurs exclusively on limestone areas in the northern part. The subalpine belt (2000–2500 m) is dominated by thick stands of *Pinus mugo* (dwarf-pine) with *Juniperus sibirica* and *Vaccinium myrtillus*. The alpine belt (2500–2914 m) in the northern part supports on limestone areas herb communities of *Sesleria caerulea, Carex kitaibeliana, Dryas octopetala* and the dwarf-willow *Salix reticulata*, while on siliceous areas *Carex curvula, Agrostis rupestris, Festuca airoides,* and *Empetrum nigrum* are common. A large group of Balkan and Bulgarian plant endemics, some of them glacial relicts, are predominantly distributed in the uppermost two vegetation belts. The present-day vegetation is influenced to a large extent by anthropogenic activities and intensive tourism.

SITE OF INVESTIGATION

Glacial landforms such as cirques, numerous lakes, trough river beds, hanging valleys and moraines are found in the northern Pirin Mountains. The group of Banderishki Lakes is situated in a large cirque of the same name. Lake Muratovo belongs to this group of lakes at 2230 m and is located on a small secondary cirque (Fig. 2). The lake has almost a circular shape, 133 m long and 114 m wide, with water surface of 1.23 ha, maximum depth of 3.35 m and watershed area of 0.52 km². The slopes near the shores are covered by groups of *Pinus mugo* within patches of herb vegetation (Ivanov 1964).

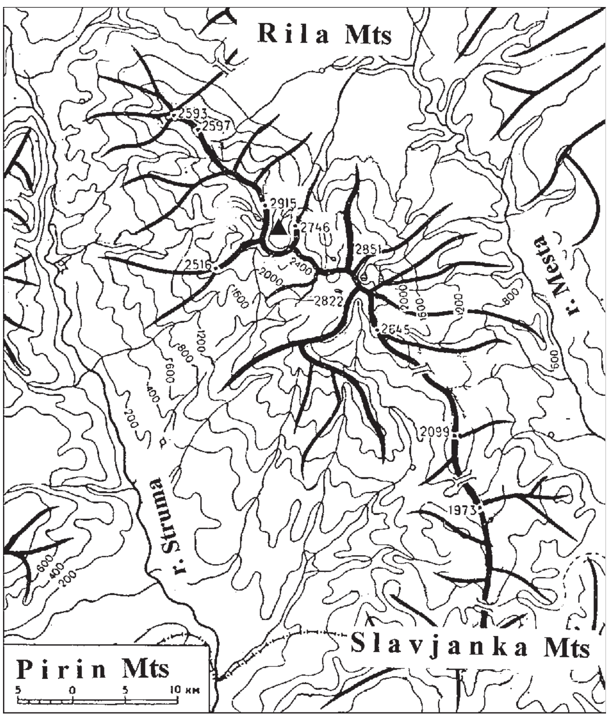

Fig. 2. Map of Pirin Mountain and the location of the Banderishki cirque (solid triangle) with Lake Muratovo

MATERIAL AND METHODS

CORES AND LITHOLOGY

In September 1994 two sediment cores were obtained from a platform at the deepest part of the lake with a square-rod piston sampler (Wright 1991). The first core (Pma) is 110 cm long and was collected at a water depth of 3.15 m. The second core (PMb) is 185 cm long and was collected at a water depth of 2.85 m. Both cores, 5 cm in diameter, stopped at very hard clay material and stones. The sediment lithology is given in Table 1.

Table 1. Lithology of the cores taken from Lake Muratovo

Depth (cm)	Type
Core PMa	
0– 20	grey clay
20– 68	grey-brown clay gyttja
68–106	brown hard clay gyttja
106–110	grey silty clay
Core PMb	
0– 30	grey sandy gyttja
30– 70	brown sandy clay gyttja
90–180	grey-brown clay gyttja
180–185	grey silty clay

POLLEN ANALYSIS

Samples for pollen analysis were taken at 5–10 cm intervals. A volume of 2 cm³ for each sample was treated with HF acid and subjected to acetolysis (Faegri & Iversen 1989). The identification of spores and pollen was performed by Bozilova, Atanassova and Tonkov using the reference collection of the Laboratory of Palynology in Sofia, and the keys by Beug (1961), Faegri & Iversen (1989), and Moore et al. (1991). The pollen sum (PS) used for percentage calculations was based on terrestrial pollen (AP + NAP). For calculations and drawing of the pollen diagrams the computer programmes TILIA and TILIA-GRAPH were used (Grimm 1991). The division of the pollen diagrams into Pollen Assemblage Zones (PAZ) and their subsequent correlation were based on important changes in the presence of the main taxa, and by the application of CONISS (Grimm 1987).

RADIOCARBON DATING

Seven AMS radiocarbon dates were obtained from the Dating Laboratory of University of Helsinki, Finland (Tab. 2). The measurements were made on extracted humus as the carbon content of the samples

Table 2. Results of radiocarbon measurements

Lab. No.	Depth (cm)	Age (BP)	Calendar age (cal. BP)	Material dated
Core PMa				
Hela-557	23–25	1695 ± 95	1720–1510	Clay gyttja
Hela-558	63–65	2365 ± 70	2720–2360	Clay gyttja
Hela-559	103–105	3800 ± 75	4300–4080	Clay gyttja
Core PMb				
Hela-692	28–30	1215 ± 35	1180–1060	Sandy gyttja
Hela-693	68–70	1885 ± 35	1880–1730	Clay gyttja
Hela-694	143–150	3485 ± 40	3830–690	Clay gyttja
Hela-695	173–175	3915 ± 45	4420–4280	Clay gyttja

was very low. The dates have been calibrated to calendar years with the computer program OxCal v3.5 (Bronk Ramsey 2000) and INTCAL98 calibration data set (Stuiver et al. 1998). The dates in the discussion are given in cal. yrs BP, unless otherwise stated.

RESULTS

POLLEN STRATIGRAPHY

The pollen diagrams are divided into three pollen assemblage zones (PM-1–PM-3) and their description is briefly presented:

PAZ PM-1, *Abies-Pinus diploxylon* type-*Pinus peuce* (4300–3000 cal. BP)

Core PMa (110–73 cm) and Core PMb (185–110 cm)

Pollen of *Pinus diploxylon* type dominates with 50–68% (Fig. 3) and 35–50% (Fig. 4). A characteristic feature is the high pollen values (above 20%) for *Abies*. The presence of *Pinus peuce* is 5–15%. Pollen grains of *Picea*, *Fagus*, *Betula*, nd *Alnus* are less than 5%. *Quercus*, *Ulmus*, *Tilia*, *Corylus*, and *Carpinus betulus* have low importance. Single pollen grains of *Juglans*, *Fraxinus excelsior* type, *Acer*, *Vitis* are also recorded. The group of NAP is represented by Poaceae with 5%, *Artemisia*, Cichoriaceae, *Achillea* type, *Centaurea jacea* type, *Rumex*, Ranunculaceae, Apiaceae, and Brassicaceae. In core PMa (Fig. 3) the quantity of spores of *Isoëtes* is high (2–6%) compared to the corresponding interval in core PMb (Fig. 4).

PAZ PM-2, *Picea-Pinus diploxylon* type-*Pinus peuce* (3000–1900 cal. BP)

Core PMa (73–38 cm) and Core PMb (120–75 cm)

In this zone the pollen curve of *Picea* rises to 15–20% in both diagrams. A slight increase of *Fagus* is accompanied by a decline of *Abies*. The pollen curve of *Pinus peuce* keeps the same values (5–15%) as in the preceding zone. Pollen grains of deciduous trees are rare. The dominant role of Poaceae, *Artemisia* and Cichoriaceae among the herb pollen types continues

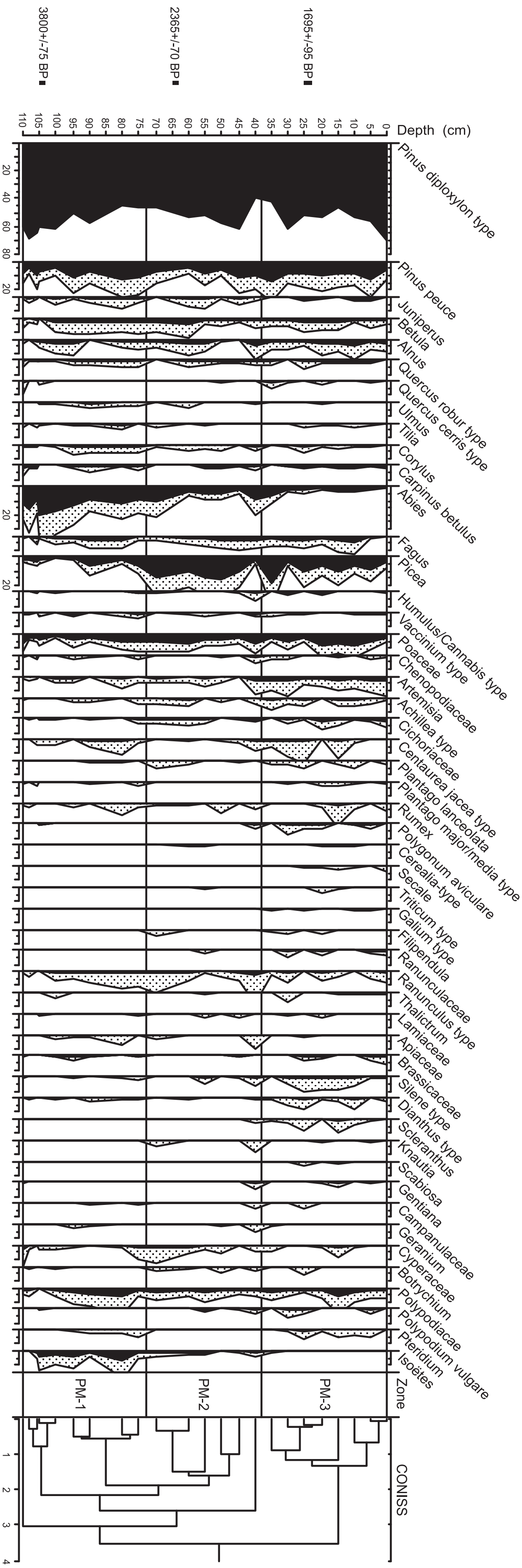

Fig. 3. Percentage pollen diagram of Lake Muratovo (core PMa), northern Pirin Mts (2230 m)

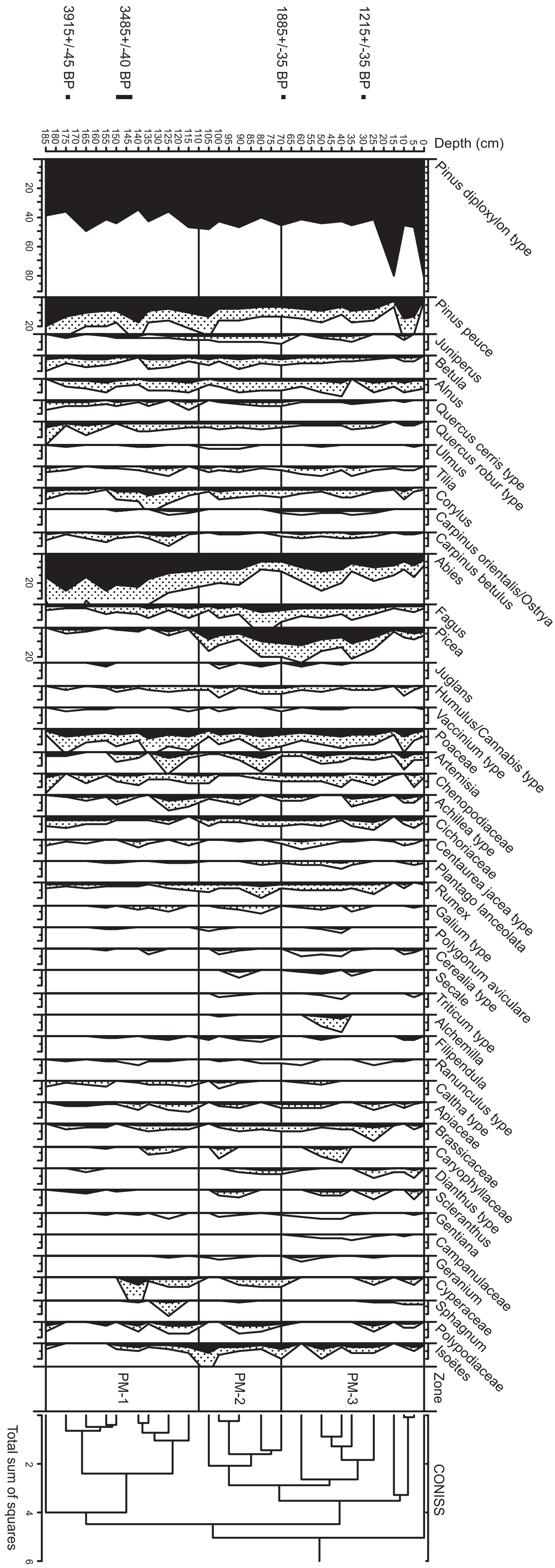

Fig. 4. Percentage pollen diagram of Lake Muratovo (core PMb), northern Pirin Mts (2230 m)

in this zone together with a slight increase in Chenopodiaceae, *Rumex*, *Polygonum aviculare*, *Scleranthus*, and *Plantago lanceolata*. Pollen of cereals (Cerealia type, *Triticum* type) is also noted. The presence of spores of *Isoëtes* in core PMa (Fig. 3) declines while in core PMB (Fig. 4) it is around 1–5%.

PAZ PM-3, *Pinus diploxylon* type-*Pinus peuce-Picea* (1900 cal. BP till the present time)

Core PMa (38–0 cm) and Core PMb (75–0 cm)

The pollen curve of *Pinus diploxylon* type rises up to 60–70%. The presence of *Pinus peuce* is 15–18%. The participation of *Picea* decreases to 5–10% while pollen of *Fagus* increases slightly to 5–6%. The dominant herb pollen taxa are Poaceae, *Artemisia*, *Achillea* type, Cichoriaceae, Chenopodiaceae. Permanent presence of anthropophytes Cerealia type, *Triticum* type, *Secale*, *Polygonum aviculare*, *Plantago lanceolata*, *Scleranthus*, and *Rumex* is characteristic.

List of taxa with low pollen frequency that are not shown in the diagrams:

Fraxinus ornus, *F. excelsior type*, *Castanea*, *Viburnum*, *Lonicera*, *Sambucus*, *Ribes*, *Bidens* type, *Xanthium* type, *Sanguisorba minor*, *Potentilla* type, *Geum* type, *Agrimonia* type, *Aconitum* type, *Trollius* type, *Helleborus* type, *Epilobium* type, *Scabiosa*, *Helianthemum*, *Hypericum*, *Saxifraga*, *Viola*, *Plantago coronopus*, *P. alpina*, *Polygonum bistorta*, *Mentha* type, *Stachys* type, *Pulmonaria* type, *Onobrychis*, *Rhinanthus* type, *Linum*, *Valeriana*, *Convolvulus*, *Veratrum* type, *Selaginella selaginoides*, *Typha*/*Sparganium* type, and *Potamogeton.*

DISCUSSION

CHRONOLOGY AND SEDIMENTATION

The deposition has started at ca. 3900 BP (4300 cal. BP) during the Subboreal period. This result questions the opinion that Lake Muratovo, like other large lakes in the Banderishki cirque, is of glacial origin (Fig. 5).

Fig. 5. A view of Lake Muratovo (photo H.-J. Beug)

Quite probably, the lake was formed either after a tectonic movement or a landslide, and after that accumulation of clay-gyttja has become possible. The estimates from the radiocarbon measurements (Tab. 2) show for core PMa a sediment accumulation rate of 40 and 23.5 yr/cm for the intervals 104–64 and 64–24 cm, respectively. For the longer core PMb a fairly constant sediment accumulation rate of 24–25 yr/cm was established for the interval 174–69 cm, and 17 yr/cm for the interval 69–29 cm.

VEGETATION HISTORY

The pollen zones reflect the main phases of vegetation development at high altitudes on northern Pirin Mountain after 4300 cal. BP. The palaeovegetation reconstruction for the second part of the Subboreal (zone PM-1) reveals a wide distribution of coniferous forests in the study area not very far away from the lake, composed of *Pinus peuce*, *Pinus sylvestris*, *Pinus heldreichii*, and *Abies alba*. Regrettably, the pollen type *Pinus diploxylon* includes several species (*Pinus sylvestris*, *P. heldreichii*, *P. mugo*), thus making it impossible to evaluate the proportion of each species in the coniferous communities. Groups of *Pinus mugo* and *Juniperus* within herb vegetation dominated by Poaceae species and various representatives of Ranunculaceae, Brassicaceae, Apiaceae, Caryophyllaceae grew in the subalpine zone above the upper forest limit. Along mountain brooks groups of *Alnus* were spread and on poor soils on steep stony slopes *Betula pendula* was growing as a pioneer tree. Probably, by that time, isolated localities with sufficient moisture sheltered *Picea abies* and *Fagus sylvatica*. It is important to point out that the time interval 4300–3700 cal. BP is related to the final phase of the wider distribution of *Abies alba* in the coniferous forests that had existed since the mid-Atlantic, also confirmed by other studies (Stefanova & Bozilova 1995, Tonkov et al. 2002). At the end of the zone, a decrease in the participation of *Abies alba* is observed due to increasing occurrence of *Picea abies*. Meanwhile the dense coniferous forests acted as a filter for the airborne transport of deciduous tree pollen (*Quercus*, *Ulmus*, *Tilia*, *Carpinus*, *Corylus*) from lower altitudes.

The pollen-stratigraphical boundary PM-1/PM-2 coincides with the Subboreal/Subatlantic transition, estimated in both diagrams at ca. 3000 cal. BP. The onset of the Subatlantic is connected with dynamic changes in the vegetation cover of Pirin Mountain, initiated by the expansion of *Picea abies* in the coniferous belt, and the wider spread of *Fagus sylvatica* at lower altitudes, particularly in the southern part of the mountain (Panovska et al. 1995).

The late postglacial history of *Picea* in the high Bulgarian mountains, including Pirin Mountain, is of particular interest (Bozilova 1986, Bozilova et al. 1996). The establishment of this coniferous tree in the study area was rather late at ca. 4900–4500 cal. BP (Tonkov et al. 2002), compared for instance with the situation in the mountains of the Carpathian arch. For example, the pollen diagrams for the Polish Carpathians show that spruce is regularly observed from the beginning of the Holocene (Ralska-Jasiewiczowa 1980, Ralska-Jasiewiczowa & Latałowa 1996). Similar results are reported in recent investigations from the western and Eastern Romanian Carpathians where *Picea* was already present around 11 165–10 870 cal. BP (Farcas et al. 1999, Jalut et al. 2003, Tantau et al. 2003). Early appearance of *Picea* in the Ljubljana basin at 14 500–14 000 cal. BP suggests the existence of refugial areas in Slovenia during the last glacial maximum (Culiberg 1991).

In the sediments of Lake Muratovo *Picea* pollen is present, though with low values, since ca. 4300 cal. BP. The reasons for this late establishment and subsequent expansion of spruce are still discussed and are most probably of complex character. The above cited palynological investigations suggest that the closest refugial areas for *Picea* were located in the northernmost parts of the Balkan peninsula – southeastern Alps, Dinaric Mountains and Carpathian Mountains (Lang 1994, Farcas et al. 1999, Björkman et al. 2003) from where it slowly migrated to the south and southeast. The hypothesis that local refugia with residual populations of spruce could have also existed in isolated interior montane areas of the peninsula with sufficient moisture, also deserves attention (Combourieu-Nebout et al. 1999, Ravazzi 2002, Tonkov 2003).

As already mentioned, the beginning of *Picea* expansion in the coniferous belt of northern Pirin Mountain is estimated at ca. 3000 cal. BP. As a main reason for this event a change of climate with lower temperatures and higher precipitation is considered likely in the temperate regions at the Subboreal/Subatlantic transition, synchronous with an abrupt increase in radiocarbon in the atmosphere ca. 850 cal. BC as a result of increased solar activity (van Geel et al. 1998). This climate change also facilitated the enlargement of the coniferous forests in the highest Bulgarian mountains and the formation of numerous peat-bogs. It should be also pointed out that according to de Beaulieu et al. (1994), competition with other trees, notably *Abies*, was the main factor accounting for reduced migration rates of *Picea* after the mid-Atlantic in forest communities in the French Alps. Such a tendency is also recorded in the pollen diagrams from Lake Muratovo.

The last phase in the vegetation development that began after ca. 1900 cal. BP bears the features of increasing anthropogenic activity, although traces of early human impact may have been detected even earlier, during the Late Bronze Age and Hellenistic periods (zones PM-2 and 3). In both pollen diagrams a number of pollen types that are considered as indicators of human presence and disturbance in the natural vegetation are well-documented. The increasing values of *Rumex*, *Plantago lanceolata*, *Scleranthus*, some Asteraceae, indicate the existence of seasonal subalpine pastures, trampling and ruderal communities. The pollen grains of Cerealia, *Triticum* and *Secale* indicate agricultural activity in the mountain foothills. The presence of *Juglans* pollen in this uppermost zone also proves the existence of settlements in the mountain foothills where walnut was introduced.

During this final period of vegetation history, the upper timber-line was formed at many places by *Pinus peuce* and *Picea abies.* The increase in *Pinus diploxylon* type pollen suggests an enlargement of the areas in the subalpine zone occupied by *P. mugo*. It is supported by macrofossil finds of needles and seeds of *P. mugo* in the sediments of Lake Popovo Ezero-6 in the northern Pirin Mountains (Stefanova & Bozilova 1995).

The decline in the pollen of almost all tree taxa, with the exception of *Pinus*, after ca. 1100–1000 cal. BP in the Medieval Ages suggests pronounced human interference in all vegetation belts during the last centuries. As a consequence of this, the present-day appearance of the vegetation cover in northern Pirin Mountain was shaped.

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