

A CONTRIBUTION TO THE LATE HOLOCENE
VEGETATION HISTORY OF THE NORTHWESTERN RILA
MOUNTAIN, BULGARIA: THE POLLEN RECORD OF LAKE
SKAKAVITSA

Maria Lazarova¹, Spassimir Tonkov^{2✉}, Dimitar Ivanov¹

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Abstract

Pollen analysis was conducted on a Late Holocene sediment core obtained from the peaty shore of Lake Skakavitsa (2170 m) in the Northwestern Rila Mountain. The vegetation reconstruction supported by detailed radiocarbon chronology revealed new information about the forest development and human impact in the study area for the last 4000 years. Dense coniferous forests dominated by *Pinus sylvestris*, *Abies alba*, *Pinus peuce* and some *Picea abies* were distributed between 4000 and 3000 years ago and below them thrived isolated stands of *Fagus*. The subsequent transformations in the forest cover include the invasion of spruce in the coniferous belt between 2500 and 800 years ago and the enlargement of beech communities since 1500 years ago. Evidence of intensive human activities related to livestock-grazing and crop cultivation is registered for the last 700 years.

Key words: pollen analysis, radiocarbon dating, vegetation history, Late Holocene, Northwestern Rila Mountain

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Introduction. In the last decades intensive palynological and paleoecological research was conducted in the Rila Mountain, particularly in its northwestern part, an area which appeared as a key element in resolving important issues after the last glaciation such as the origin and evolution of lakes and peat bogs, the patterns of vegetation and climate changes, the location of plant refugia and the migration routes of the main tree species in the Holocene. As a result the characteristics of the basic stages in postglacial vegetation and paleoenvironment development for the past 18 000 years were outlined, including also evidence of increasing human activities [1, 2]. A peculiar feature of most pollen records recovered from sites in the Northwestern Rila Mountain is their low time resolution for the last 4000–2000 years, i.e. Late Holocene, with few exceptions [3, 4]. In this aspect the aim of the present paper was to expand a preliminary palynological report of a sediment core collected from Lake Skakavitsa which dates back to 4000 years ago [5], and thus to reveal in more details the regional vegetation history based also on a local radiocarbon chronology.

Study area. Rila Mountain is the highest massif on the Balkans (2925 m) located in Southwestern Bulgaria with an area of 2396 km². Deep river valleys following the major fault lines divide the massif into four parts: Eastern (2925 m), Northwestern (2731 m), Central (2716 m), and Southwestern (2630 m). The mountain is built by crystalline rocks of Mesozoic and Pre-Mesozoic age. The granitoids form the central and eastern mountain parts, while the Northwestern Rila and the western fringes of Southwestern Rila are built up mainly of metamorphic rocks, gneisses, schists and amphibolites. Evidence is collected that Rila Mountain was glaciated at least twice in the Pleistocene during the Riss and the Würm glacial stages following the Alpine geochronological scheme of the Quaternary glaciations. The activity of the glaciers has resulted in the formation of glacial relief forms such as cirques, numerous lakes, different types of moraines and trough valleys [6]. The climate above 1000 m is montane and at 1800–1900 m the mean January temperature is –6 °C, and the mean August temperature is +11.4 °C. The highest precipitation, much of it snow, reaches 2000 mm in the 1300–2400 m zone [7].

The altitudinal distribution of the recent vegetation is in six belts. The xerothermic and xeromesophilous oak/hornbeam belts (up to 1000 m) are dominated by different oak (*Quercus cerris* L., *Q. pubescens* Willd., *Q. dalechampii* Ten.) and hornbeam (*Carpinus orientalis* Mill., *C. betulus* L.) species, mixed in places with *Ulmus glabra* Huds., *Acer platanoides* L. and *A. pseudoplatanus* L. The beech forests (1000–1600 m) occupy mostly areas in the northern and western parts of the mountain where the dominant tree *Fagus sylvatica* L. forms also mixed stands with *Abies alba* Mill. and *Picea abies* (L.) Karst. at higher elevations. The coniferous belt (1600–2000 (2200 m)) is composed mainly of forests of *Pinus sylvestris* L. and *P. abies*. Pure or mixed communities of *A. alba*, *Betula pendula* Roth. and *Populus tremula* L. are also found within this belt at

lower elevations. The Balkan endemic *Pinus peuce* Griesb. forms a sub-belt and shapes the tree-line at many places, particularly c. 2000 m in the study area. The subalpine belt (2200–2500 m) is dominated by groups of *Pinus mugo* Turra with *Juniperus sibirica* Burgsd. and *Vaccinium myrtillus* L. The highest alpine terrains (2500–2925 m) are occupied by herb communities of *Carex curvula* All., *Festuca airoides* Lam., *F. riloensis* (Hack. ex Hayek) Markgr.-Dann., *Dryas octopetala* L., *Salix herbaceae* L., etc. [8].

The site of the present study Lake Skakavitsa is located in the lower part of the subalpine belt of the Northwestern Rila Mountain (42°12'52" N, 23°18'18" E) at 2170 m above the tree-line. The lake lies in a shallow cirque and is of glacial origin. It has an elongated shape narrowing in its northern part and is about 250 m long, 60 m wide, 3 m deep with a total area of 1 ha. The western shores are rocky and steep, the others are flattened. The lake is surrounded by dense stands of *Juniperus sibirica*, *Pinus mugo*, *Vaccinium uliginosum* L. and herb communities on open areas. The inlet lies to the south and the outlet to the north, where starts the beginning of the river Skakavitsa [9]. The main components of the peaty and the surrounding herb vegetation are *Sphagnum capillifolium* (Ehrh.) Hedw., *Polytrichum commune* Hedw., *Bistorta vivipara* (L.) Delarbre, *Empetrum nigrum* L., *Bruckenthalia spiculifolia* Rchb., *Homogyne alpine* Cass., *Carex rostrata* Michx., *Alopecurus gerardii* Vill., *Nardus stricta* L., *Potentilla erecta* Raeusch., *Geum coccineum* Sibth. & Sm., *Pseudorchis albida* (L.) Á. Löve & D. Löve, *Plantago media* L., *Gentianella bulgarica* (Velen.) Holub, *Primula farinosa* L., etc. [5].

Material and methods. Pollen analysis. The sediment core 120 cm long was taken from a marginal peat land in the shallow south-eastern part of the basin with a Livingstone hand-corer. The lithology of the sediments is: 0–20 cm peat, 20–80 cm decomposed peat, 80–119 cm gyttja and 119–120 cm grey sandy clay. Pollen analysis was performed at 5 cm interval after the application of the acetolysis procedure [10]. The pollen sum (PS) used for percentage calculations is based on AP (arboreal pollen) + NAP (non-arboreal pollen) and includes at average 600–800 pollen grains. The presence of spores of mosses, pteridophytes and pollen of Cyperaceae (local plants) is expressed as percentages of the PS. The determination of pollen and spores was made with the help of a reference collection and the pollen keys in literature sources [11,12]. The percentage pollen diagram includes the most common taxa and the determination of the local pollen assemblage zones (LPAZ) was done with the program Tilia ver. 2.0.41 [13] (Fig. 1). The pollen accumulation rates (PARs; pollen grains deposited $\text{cm}^{-2} \text{yr}^{-1}$) of the main tree/shrub and herb pollen taxa, complimentary to their percentage values, were calculated by addition of two *Lycopodium* tablets (13 911 spores each) per sample of 1 cm^3 before preparation [14]. Unlike percentage data, the PAR value of a given taxon is directly dependent on the abundance of this taxon in the surroundings of the study site and independent of the values of other taxa [15].

[illegible]

The PARs are presented on a separate influx pollen diagram (Fig. 2).

Radiocarbon dating and chronology. Three bulk sediment samples were submitted for AMS radiocarbon dating in the Radiocarbon Dating Laboratory at the University of Lund, Sweden. The calibration (95.4% probability, $\pm 2\sigma$) was performed with OxCal v4.4 program [16] using the relevant atmospheric data [17] (Table 1). A linear interpolation age/depth model was applied [13]. It allows each pollen sample and the zone boundaries to be assigned to the relevant calibrated

Table 1

Results of radiocarbon measurements from Lake Skakavitsa

Lab. code (LuS)	Sample depth (cm)	^{14}C age (BP)	^{14}C age (cal. yr BP, $\pm 2\sigma$)	Material dated
LuS-9333	77–78	2085 ± 50	2300–1890	peat
LuS-9334	88–90	2420 ± 50	2710–2340	gyttja
LuS-9335	117–119	3440 ± 50	3840–3560	gyttja

age in years BP. In the diagrams and the text the dates are cited as cal. yr BP.

Results and discussion. The percentage pollen diagram (Fig. 1) is divided into four LPAZ which reflect successive stages of vegetation history and their brief description includes also information from the influx pollen diagram (Fig. 2).

LPAZ Sk-1 (120–103 cm, *Pinus* – *Abies* – *Picea*) (3780–3070 cal. yr BP)

Arboreal pollen (AP) dominates with 77–80%. Pollen grains of *Pinus diploxylon*-type are present with 31–39%, followed by *Abies* 18–23%, *Picea* up to 9.3%, *Pinus peuce* 3–4%. Deciduous tree pollen of *Quercus*, *Tilia*, *Corylus*, *Carpinus*, *Fagus* is below 5% each. The first pollen grains of *Juglans* are recorded. The main non-arboreal pollen taxa (NAP) are Poaceae up to 6.2%, *Dianthus*-type up to 2.1%, Ranunculaceae 1.3%, *Taraxacum*-type (Cichorioideae) 1.2%, Chenopodiaceae, *Achillea*/*Aster*-type, *Artemisia*, *Plantago*, *Cereal*-type below 1% each. The local elements are pollen of Cyperaceae 1.5%, spores of Polypodiaceae and *Selaginella selaginoides*.

The total PAR of tree taxa (AP) is between 3200 and 8000 grains $\text{cm}^{-2} \text{yr}^{-1}$, contributed by *Pinus diploxylon*-type 1400–4600, *Abies* 900–2000, *Picea* 130–930, *Pinus peuce* 150–490, *Juniperus* up to 530, etc. The total PAR of herbs (NAP) is 1600–2500, with the highest values for Poaceae 180–700.

The first period of vegetation development in the study area lasted between c. 3800 and 3000 cal. yr BP. It was characterized by the spread of coniferous forests dominated by *Pinus sylvestris*, *Abies alba* and *Pinus peuce*, with some *Picea abies*. Isolated stands of *Fagus* were distributed at lower elevations and below them mixed oak forests with *Tilia*, *Ulmus*, *Carpinus*, and *Corylus* on open terrains. In the subalpine area around the lake were growing stands of *Pinus mugo* (dwarf-pine) and *Juniperus* (junipers). The PAR of tree taxa supports this reconstruction, particularly the wider presence of fir and the low participation of spruce. The herb vegetation on open areas was dominated by grasses, sedges and species of *Achillea*, *Aster*, *Dianthus*, *Taraxacum*-type (Cichorioideae), Ranunculaceae, *Rumex*, etc. Almost no indications are recorded for human presence and activities.

LPAZ Sk-2 (103–58 cm, *Pinus* – *Picea* – *Abies* – Poaceae) (3070–1560 cal. yr BP)

The total AP curve slightly declines to 60% (level 100 cm). The participation of *Pinus diploxylon*-type is 24.5–35.5%, *Abies* 10%, *Picea* 14.3%, *Pinus peuce* 2–6%. A characteristic feature is the appearance of the pollen curve of *Fagus* which rises to 3.6%. Pollen of Poaceae reaches a maximum of 13.4%, accompanied by *Cereal*-type with up to 3%, *Taraxacum*-type 2.3%, *Artemisia* and Ranunculaceae 2.2% each, *Dianthus*-type 2%, Apiaceae, *Achillea*/*Aster*-type 1.7% each. Important changes in the frequency and diversity of the local plants are not registered except for the pollen curve of *Sphagnum*.

The tendency for an increase of total tree PAR is visible by the maximal values of 15 000–18 000 grains $\text{cm}^{-2} \text{yr}^{-1}$, attributed to *Pinus diploxylon*-type

from 3000 to 7000–8800, *Picea* 2000, *Pinus peuce* 1000, *Quercus* up to 1200, *Fagus* 1000. The total non-arboreal PAR also rises to 5000–9000 and the highest values are recorded for Poaceae 1100–1700, *Cerealia*-type 200–400, *Taraxacum*-type up to 600, Ranunculaceae 600, *Achillea*/*Aster*-type 450, Apiaceae 400.

After 3000 cal. yr BP several important changes in the forest composition are established in the pollen diagram. A short-term partial decrease of the tree cover, accompanied by a rise in the frequency of herb pollen, mainly grasses, was followed by an increase of *Picea abies* and a slight reduction for *Pinus* and *Abies alba*. Spruce started to invade areas in the coniferous belt and gained its first maximum c. 2500 cal. yr BP. This change in the vegetation cover was mainly climatically driven as a shift to lower average temperatures and increase in precipitation that has occurred in the Northern Hemisphere [18]. A similar behaviour of beech at lower elevations led to gradual enlargement of its areas after 2000 cal. yr BP. This period marks an intensification of the human interference in all vegetation belts. Even at high altitudes, like in other palynologically studied lakes from the nearby cirque of the Seven Rila Lakes [2], the find of pollen from *Cerealia*-type and *Juglans* points to well-developed agriculture and cultivation of walnut in the foothills of the mountain. On the other hand, pollen of *Juniperus*, *Rumex*, *Taraxacum*-type, *Plantago*, Chenopodiaceae, *Scleranthus* is indicative of livestock-grazing in the mountain meadows. The higher influx values of deciduous tree taxa (*Quercus*, *Carpinus*, *Corylus*) could be explained by an easier air-transport upslope from lower elevations. The peripheral parts of the lake began to be overgrown with sedges and mosses after 2200 cal. yr BP.

LPAZ Sk-3 (58–28 cm, *Pinus* – *Picea* – *Fagus*) (1560–740 cal. yr BP)

Total tree pollen increases again from 69% to 81.7% contributed mainly by *Pinus diploxylon*-type 23–33.8%, *Picea* with a maximum of 23.3%, *Fagus* up to 4.5%, *Abies* 7.8%, *Pinus peuce* 3.8%. Pollen of deciduous tree taxa slightly rises as shown by *Quercus* up to 5.6%, *Alnus* 2.5%, *Corylus* 2.3%. Pollen of *Juglans* is regularly found. Among the herb pollen taxa a decrease to 3.6% is established for Poaceae. The rest of non-arboreal and local pollen taxa display no significant changes in their participation except a slight increase of *Sphagnum* spores up to 2.3%.

The total tree PAR declines from 18 000 to 12 500 grains cm⁻² yr⁻¹, attributed to *Pinus diploxylon*-type 6500–5000, *Abies* 1800–600, *Pinus peuce* 400, *Alnus* 650–150. Stable values are recorded for *Picea* c. 3000 and *Fagus* 1000–800. The total PAR of herb taxa decreases from 8500 to 2500 as shown by Poaceae 1250–500, *Taraxacum*-type 800–200, *Artemisia* 400–100, etc.

The most characteristic event in the vegetation development after 1500 cal. yr BP was the expansion of *Picea abies* in the coniferous belt replacing at many places *Pinus* and particularly *Abies alba*. Spruce reached a second maximum c. 800 cal. yr BP confirmed also by the influx values. The share of fir in the coniferous communities considerably diminished resulting in its present restricted

distribution. Such a late peak of *Picea* pollen curve was not detected in the pollen diagrams from the other subalpine glacial lakes in this area [2]. Similar tendency for enlargement is recorded for *Fagus* at lower elevations. Around Lake Panichishte (1370 m) located in the same study area coniferous forests dominated by *Pinus sylvestris* and *Abies alba*, with some *Pinus peuce* and few *Picea abies*, were distributed for the period 1900–1200 cal. yr BP. The deciduous forests were composed of oaks with *Carpinus betulus*, *Tilia* and *Corylus*. After 1200 cal. yr BP part of these forests were destroyed and the open areas were colonized by *Betula* and herbs. Later on, spruce has benefited from the optimal ecological conditions for growth in the forest zone 1600–1300 m concurrent with the duration of the Little Ice Age (400–100 cal. yr BP) [4].

LPAZ Sk-4 (28–0 cm, *Pinus* – *Picea* – NAP) (740 cal. yr BP till present)

Arboreal pollen is c. 70%, represented by *Pinus diploxylon*-type 33–36.4%, *Picea* 9.9%, *Quercus* up to 6.4%, *Fagus* 4.3%, *Pinus peuce* up to 3.2%, etc. The participation of herb taxa increases to 37%, contributed by Poaceae 6.9%, *Taraxacum*-type 3.6%, *Cerealialia*-type 2.2%, *Artemisia* 2.8%, *Plantago* 2.2%, Brassicaceae 1.9%, etc. Among the local plants should be mentioned Cyperaceae 3%, *Carex* 1.8% and spores of *Sphagnum* up to 5.3%.

The total arboreal PAR is c. 12 500 grains $\text{cm}^{-2} \text{yr}^{-1}$, a bit lower compared to the previous zone, contributed by *Pinus diploxylon*-type 5000–8000 and a decrease for *Pinus peuce* 600–300, *Abies* 900–250, *Picea* 2000–1000 and *Fagus* 1000–600. Higher values are recorded for *Quercus* 1000–1200. The total PAR of herbs varies between 5000 and 6000, attributed to Poaceae 1000–1250, *Cerealialia*-type 300–500, *Taraxacum*-type c. 500, etc.

In the last centuries the vertical differentiation of the contemporary vegetation took place with a further enlargement of the forests composed of *Picea abies*, *Pinus sylvestris* and *Pinus peuce* after 300 cal. yr BP which shaped the timber line. Plant communities of *Pinus mugo* and *Juniperus* spread in the subalpine zone together with rich grassland composed of Poaceae, *Artemisia*, *Achillea*, *Aster*, *Dianthus*, Ranunculaceae, Brassicaceae species. The increase of anthropogenic indicators such as *Rumex*, *Plantago*, *Scleranthus* and pollen of cereals (*Cerealialia*-type), confirmed also by their influx values, points to intensive human activities such as seasonal livestock-grazing in the mountain meadows and cultivation of cereals in the lowlands. The peripheral peaty parts of the lake continued to enlarge overgrown by sedges, grasses and spots of *Sphagnum*.

Conclusions. The palynological record from Lake Skakavitsa provides new information on the vegetation history, forest development and anthropogenic impact during the Late Holocene in the Northwestern Rila Mountain. The radiocarbon chronology supports the transformations in forest composition which started with the decline of *Abies alba* communities 3000 years ago. Later on, the invasion of *Picea abies* resulted in two maxima at 2500 and 800 cal. yr BP. The enlargement of beech forests at lower elevations began after 2000 cal. yr BP and

they gained wider distribution between 1500 and 500 cal. yr BP. The first indications of human presence pointing to livestock-grazing and crop cultivation in the foothills are recorded after 3000 cal. yr BP. Subsequently, the anthropogenic activities were intensified during the last 700 years. This vegetation reconstruction was facilitated also by the application of the pollen influx values as a perspective methodological approach.

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¹*Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Akad. G. Bonchev St, Bl. 23, 1113 Sofia, Bulgaria*
 e-mails: malazarovam@abv.bg, dimitier@gbg.bg

²*Department of Botany, Faculty of Biology, Sofia University “St. Kliment Ohridski”, 8 Dragan Tsankov Blvd, 1164 Sofia, Bulgaria*
 e-mail: stonkov@abv.bg