

Juliana Atanassova · Ivanka Stefanova

Late-glacial vegetational history of Lake Kremensko-5 in the northern Pirin Mountains, southwestern Bulgaria

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Abstract The core of Lake Kremensko-5, one of the cirque lakes in the northern Pirin Mountains of southwestern Bulgaria, contains sediments from more than 13,500 years B.P. and a pollen stratigraphy that can be correlated with the interstadial/stadial cycle of the Late-glacial period. *Artemisia* and Chenopodiaceae predominate in the basal part of the sequence, indicating the presence of mountain steppe type vegetation soon after the ice retreat. A sharp increase of *Pinus* diploxylon-type and Poaceae after 12,360 B.P. is followed by a return of *Artemisia* and Chenopodiaceae, marking the Younger Dryas. Its abrupt termination must result from an unconformity, for high values of *Quercetum mixtum*, dated at other sites in the Pirin Mountains as early Holocene, are missing here, perhaps because of erosion at a time of low lake level related to the high insolation maximum during the early Holocene.

Keywords Vegetation history · Late glacial · Holocene · Pirin Mountains · Southwestern Bulgaria

Introduction

The middle and late Holocene vegetational history of the Pirin Mountains of southwestern Bulgaria is known from numerous studies (Bozilova 1975, 1977; Stefanova and

Bozilova 1992, 1995; Stefanova and Oeggl 1993; Panovska et al. 1995; Stefanova 1997, 1998, 1999). At Lake Dalgoto, close to the modern tree line, the early Holocene pollen assemblage of temperate tree taxa is believed to have resulted from long-distance transport of pollen from vegetation at lower elevations, where dated macrofossils indicate the presence of these trees (Stefanova and Ammann 2003). The Late-glacial period, on the other hand, has been little studied, despite its importance in the search for ice age refuges for trees and for the patterns of immigration into glaciated mountains in southern Europe. The abundance of cirque lakes in the Pirin Mountains provides the opportunity to study the pollen record after the ice retreat. At Lake Dalgoto, the Late-glacial sediments are only 20 cm thick. In contrast Lake Kremensko-5, another cirque lake in the northern Pirin Mountains, has more than a metre of Late-glacial sediments, with two radiocarbon dates (13,350±90 B.P. and 12,360±55 B.P.). The pollen stratigraphy can be correlated with the well known Late-glacial interstadial/stadial sequence farther west in Europe. The present paper is a preliminary report on the Late-glacial records.

The study site

Lake Kremensko-5 (41°43'N/23°32'E) is in the highest and most monolithic part of the northern Pirin Mountains, southwestern Bulgaria (Fig. 1), built up of Precambrian metamorphic rocks (Boyadjiev 1959) and possessing typical glacial forms as result of Pleistocene mountain glaciation (Vlaskov 1998). Lake Kremensko-5 at about 2,124 m is the lowest of five lakes in the Kremenski cirque (Ivanov and Sotirov 1964; Fig. 2).

Modern climate and vegetation

The Pirin Mountains belong to the Continental-Mediterranean area of the subtropical climatic zone (Nikolova

J. Atanassova
Department of Botany, Biological Faculty,
Sofia University,
8 Dragan Tzankov, 1164 Sofia, Bulgaria

I. Stefanova (✉)
Institute of Botany,
Bulgarian Academy of Sciences,
23 Acad. G. Bonchev St., 1113 Sofia, Bulgaria
e-mail: stef014@tc.umn.edu

Present address:

I. Stefanova, Limnological Research Center,
University of Minnesota,
310 Pillsbury Drive SE, Minneapolis, MN 55455, USA

Fig. 1 Relief map of the eastern Balkan Peninsula showing the location of the Pirin Mountains

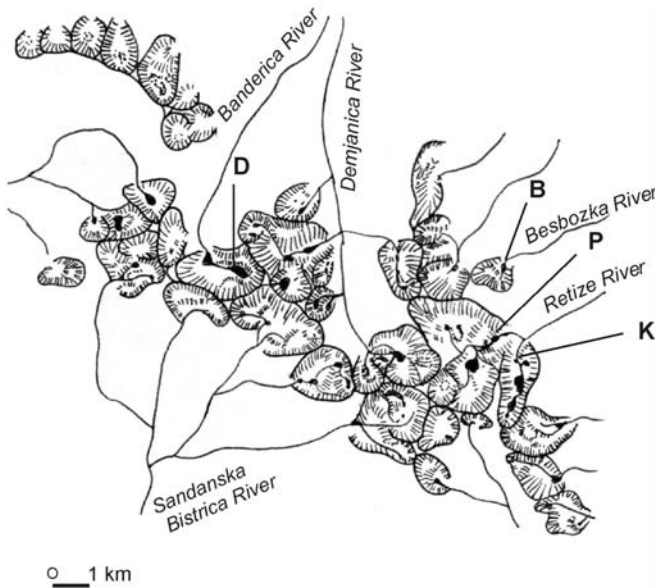


Fig. 2 Map of the Pirin Mountains showing the distribution of glacial cirques and Lake Kremensko-5 (K) and other cirque lakes mentioned in the text (B Besbog, D Dalgoto, P Popovo-6, S Suhodolsko)

1997). The mean annual temperature measured at the weather station situated at 1,970 m (hut Vihren) is 3.7 °C, and above 2,300m it is below zero. The annual precipitation is 800–1,250 mm, with a maximum in November–December (Velev 1997).

The present vegetation of the Pirin Mountains consists of seven altitudinal belts (Bondev 1991; Veltshev 1997). The nomenclature for vascular plants follows the *Flora of the Republic of Bulgaria* (Jordanov et al. 1963–1995).

The lowest belt, up to 500 m a.s.l., found only in the southern part of the mountains, is represented by fragments of communities with the Mediterranean ele-

ments *Quercus coccifera*, *Juniperus excelsa*, *J. oxycedrus*, *Phillyrea latifolia* etc. The xerothermic oak belt (up to 600–700 m a.s.l.) is characteristic of the western and southern slopes but is fragmentary on the eastern and northern slope. It is composed of *Quercus pubescens*, *Q. frainetto*, and *Carpinus orientalis* and also contains *Paliurus spina-christi*.

In the mesophilous and xeromesophilous oak and hornbeam belt (up to 900–1,000 m a.s.l.) are communities of *Quercus dalechampii* and *Carpinus betulus*. Communities of *Pinus nigra* occur on the western and northern slopes.

The beech belt (900–1,000 to 1,500–1,600 m a.s.l.) occurs in the southern and central part of the mountains and as fragments in the northern part. It is composed of *Fagus sylvatica* with limited presence of *Abies alba*, *Pinus nigra* and *Picea abies*.

The coniferous belt (1,500–1,600 up to 2,000–2,200 m a.s.l.) is formed by communities of *Pinus sylvestris* and *Picea abies*. The Balkan palaeoendemic *Pinus peuce* and the Balkan subendemic relict *Pinus heldreichii* also occur in considerable numbers.

In the subalpine belt (2,000–2,500 m a.s.l.) the communities of *Pinus mugo* and *Juniperus sibirica* are dominant. Communities of *Vaccinium myrtillus* are common.

In the alpine belt (2,400–2,500 m a.s.l.) on calcareous areas (marble) *Sesleria coerulea*, *S. korabensis*, *Carex kitaibeliana*, *Dryas octopetala* and *Salix reticulata* are characteristic, and on siliceous terrain there are *Carex curvula*, *Festuca airoides*, *Agrostis rupestris*, *Sesleria comosa*, *Vaccinium uliginosum* and *Empetrum nigrum*.

Lake Kremensko-5 is located within the range of the timberline formed by *Pinus peuce* in this area. The vegetation surrounding the lake is formed by *Pinus mugo*, *Juniperus sibirica*, single trees of *Pinus peuce*, and different species of Poaceae and *Carex*.

Table 1 Lithology of core taken from Lake Kremensko-5

Depth (cm)	Type
0–20	Cyperaceae peat
20–60	Detritus gyttja
60–100	Dark brown gyttja
100–190	Grey-green silt with sand
190–260	Grey-green silt with sand

Materials and methods

Core lithology

The sediment core was taken from the littoral part of the lake with a Dachnowsky corer (diameter 2 cm and length of the sampling chamber 20 cm). The lithology is presented in Table 1.

Pollen analysis

Samples for pollen analysis were taken at 5-cm intervals (at the most interesting bottom part of the core at 2–3 cm) and were treated with hydrofluoric acid and acetolysis (Fægri and Iversen 1989). The percentage calculations are based on the sum AP (arboreal pollen) + NAP (non-arboreal pollen), excluding spores of Pteridophytes and pollen grains of Cyperaceae, for which percentages were based on the total pollen sum.

The percentage pollen diagram (Fig. 3) is divided into pollen assemblage zones (PK-1 to PK-7) to facilitate description and understanding of the vegetation succession. The zone boundaries were determined by CONISS (Grimm 1992).

Radiocarbon dating

Accelerator mass spectrometry (AMS) ^{14}C dating of organic silt was carried out to establish a local absolute chronology (Table 2).

Results

Vegetation changes and their chronology

The pollen analytical results record the vegetation succession during the last 14,000 years in the vicinity of the Kremenski lakes at an elevation about 2,100–2,200 m a.s.l. The Late-glacial in the Pirin Mountains is poorly dated. Comparison of the Late-glacial chronology is possible only with the peat-filled Dry Lake and Lake Sedmo Rilsko in the Rila Mountains (Bozilova et al. 1990; 1996; Bozilova and Tonkov 2000) and the mire Kupena in the western Rhodopes (Huttunen et al. 1992). The radiocarbon dates for the bottom sediments of Lake Kremensko-5 are the oldest for the Bulgarian mountains and have important implications for the chronology and interpretation of vegetational changes during the interstadial/stadial cycle of the Late-glacial.

Pollen zones PK-1 to PK-4 (Fig. 2) represent the vegetational changes during the Late-glacial and show a sequence that is clearly the equivalent of the interstadial/stadial succession well known from other parts of Europe.

The initial step in the vegetation development (PK-1) began before 13,350 B.P. with wide distribution of open herb communities dominated by *Artemisia* and *Chenopodiaceae*, accompanied by various taxa of *Poaceae*, *Asteraceae*, *Ranunculaceae*, *Lamiaceae*, *Apiaceae*, *Caryophyllaceae*, *Brassicaceae*, *Ephedra distachya*, and *Juniperus*. *Artemisia* and *Chenopodiaceae* most probably included cold-resistant taxa that today grow on open ground and ruderal habitats, or are halophytes.

In one pollen spectrum the relatively high percentage values of *Pinus diploxylon* type (which includes *Pinus sylvestris*, *P. mugo* and *P. heldreichii*) and the presence of *Abies*, *Picea*, and *Betula* as well as single pollen grains of different mesophilous trees (*Quercus*, *Tilia*, *Corylus*, *Fagus*, and *Carpinus betulus*) may result from redeposition from unknown deposits rather than distant transport or contamination during coring. The large numbers of destroyed pollen grains at this level support the latter explanation, but further investigations are necessary.

Zone PK-2, dated 13,350 to 12,360 B.P., also suggests open herb communities of mountain steppe. Increased values of *Ephedra distachya* type and *E. fragilis* type (*E. fragilis* ssp. *campilopoda*) in the pollen spectra imply drier conditions than in PK-1. Neither taxon occurs in the recent vegetation of the Pirin Mountains (Jordanov et al. 1963).

In Zone PK-3 after 12,360 B.P. the sharp increase in *Pinus diploxylon* type and higher importance of *P. haploxylon* type (*P. peuce*), *Picea*, *Abies* and *Betula* indicate a climatic change leading to enlargement of the coniferous woods around the lake during the Late-glacial/interstadial stage (probably the Bølling/Allerød). In the herb communities *Poaceae*, *Cichoriaceae*, and *Apiaceae* increase in importance at the expense of *Artemisia* and *Chenopodiaceae*. The distinct change in the type of sediments from grey-green silt to brown silty gyttja also suggests increased productivity in the lake or on the land.

The date 12,360 B.P. near the base of PK-3 (14,450 cal B.P.) is close to the date for the beginning of the Bølling/Allerød in the Greenland ice core (GRIP, 14,500 cal B.P.) (Björck et al. 1998). Also, the uncalibrated Kremensko date is similar to that common for western Europe for the beginning of Bølling (12,500 B.P.) (Lang 1994).

In PK-4 the dominance of *Artemisia* and *Chenopodiaceae* and occurrence of the *Juniperus-Ephedra* assemblage indicate increase in aridity, marking the next stadial stage of the Late-glacial (the Younger Dryas). Different taxa of *Asteraceae* (*Achillea*, *Aster*, *Cirsium*, *Jurinea*,

Table 2 Results of radiocarbon measurements of samples from Lake Kremensko-5

Sample ID CURL/NSRL	Depth (cm)	^{14}C dates (B.P.)	Calendar age (cal B.P.)	Material dated
5559/12213	185–190	12,360±55	14,450	Silty gyttja
5560/12213	230–235	13,350±90	15,700	Silty gyttja

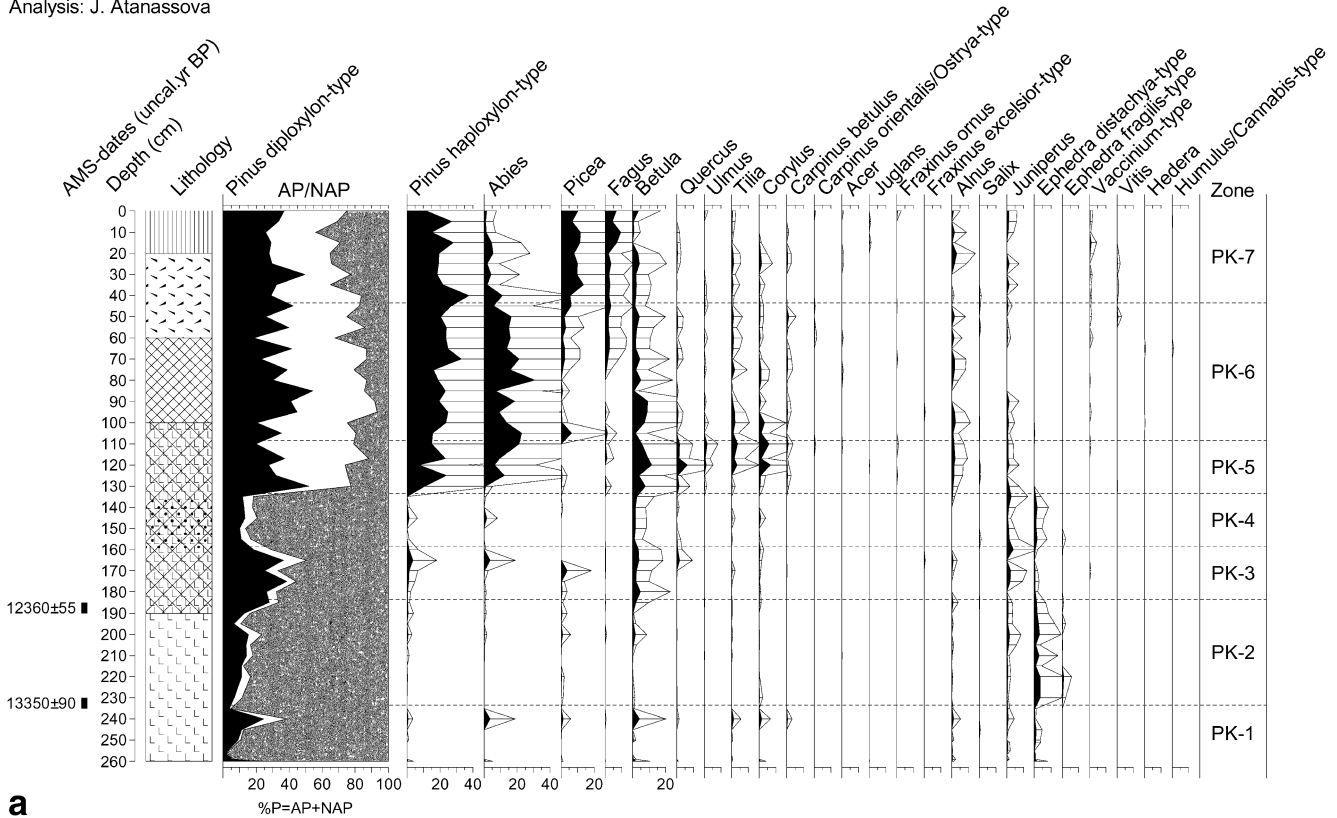


Fig. 3 Pollen percentages of Lake Kremensko-5. *A* Trees and shrubs (*AP*). *B* Herbs and aquatics (*NAP*)

Centaurea), *Apiaceae*, and *Rumex* are characteristic. The persistence of high levels of *Poaceae* implies that the climatic conditions were less severe than in PK-2. Decrease of *Pinus* diploxylon-type percentage values as well as of *Picea*, *Pinus* haploxylon-type, and *Betula* shows that their presence was rather limited.

The Late-glacial pollen records from Lake Kremensko-5, correlated with those from Lake Dalgoto (Stefanova and Ammann 2003) and Lake Ribno Bunderisko (Tonkov et al. 2002) in the Pirin Mountains as well as lakes in the Rila Mountains (Bozilova and Tonkov 2000), and Kupena Mire in the Rhodopes (Huttunen et al. 1992), show that during the Late-glacial period, the herb communities of the mountain steppe had a very similar taxonomic composition at higher elevation in the mountains of southwestern Bulgaria.

The pollen zones PK-5, PK-6, and PK-7 represent the vegetational changes during the Holocene. At the beginning of Zone PK-5 sharp increases of *Pinus* diploxylon-type, *P. haploxylon*-type, *Abies*, and *Betula* are significant. Compared to pollen diagrams from glacial lakes in the Pirin and Rila Mountains (Bozilova et al. 1990; Bozilova and Tonkov 2000; Stefanova and Ammann 2003), the rise of *Pinus* diploxylon-type, *P. peuce*, and *Abies* is more rapid in the pollen diagram from Lake Kremensko-5, but the percentage values of the deciduous trees are much lower. The high Quercetum mixtum values

in the pollen diagrams at the other sites dated as early Holocene are missing here. The rapid change in the profiles at 130 cm may be result of erosion at a time of low lake level related to the high early Holocene insolation maximum.

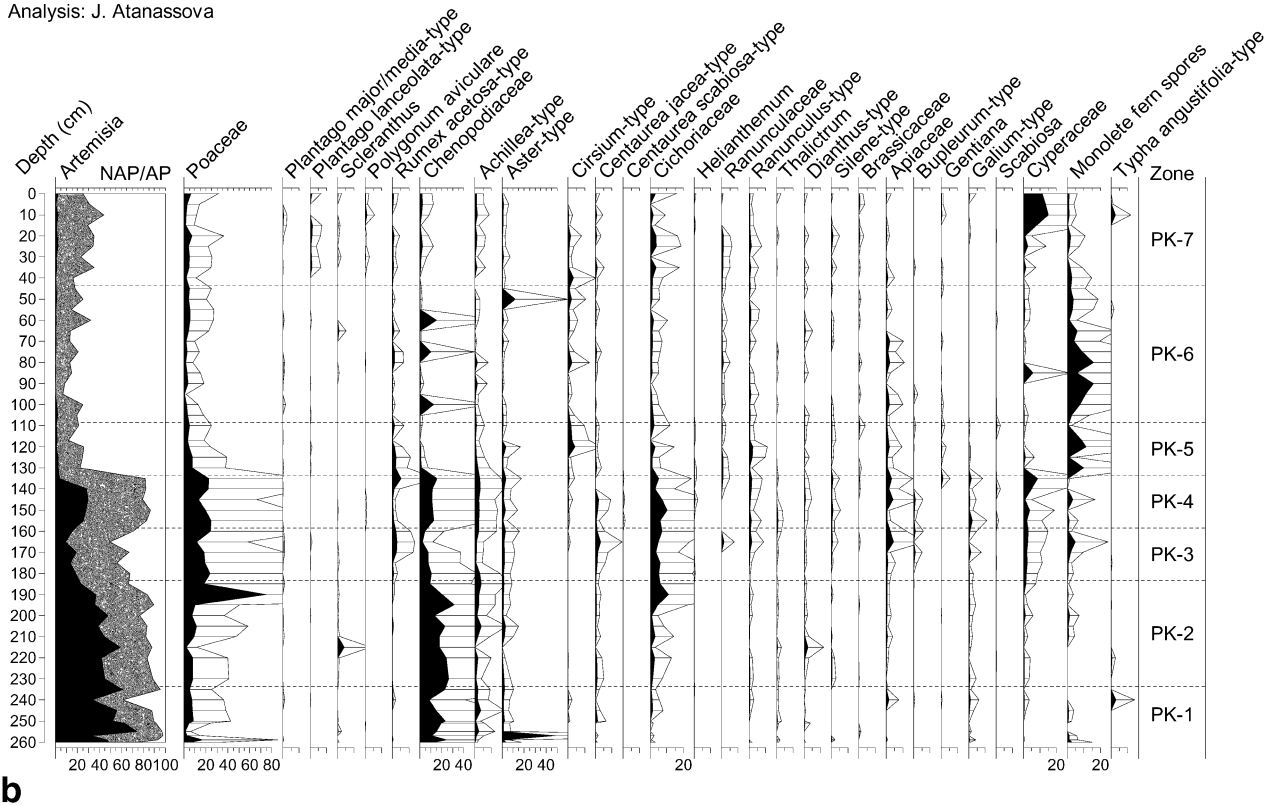
The palynological data for PK-5 indicate the wide extent of coniferous woods with *Pinus peuce* around the lake. *Quercus*, *Ulmus*, *Tilia*, *Corylus*, and *Carpinus betulus* occurred at lower elevations, as seen in other pollen diagrams from the Pirin Mountains for the mid-Holocene (Stefanova and Oeggl 1993; Stefanova and Bozilova 1995; Stefanova and Ammann 2003).

The further increase of *Pinus*, *Picea*, and *Abies* in Zone PK-6 began after 6,500 B.P. (Stefanova and Ammann 2003). Macrofossil data from Praso mire (northern Pirin Mountains) show that about 6,500 B.P. *Pinus peuce* was established as a dominant tree in the upper part of the coniferous belt and rose above 2,200 m a.s.l., where the upper forest limit existed. *Abies* had also its maximum vertical range of distribution between 6,500 and 4,800 B.P. (Stefanova and Oeggl 1993).

PK-7 represents the last step in the vegetational development around the lake. The increase of *Picea* and *Fagus* at lower elevation is characteristic of the last 3,000 years (Stefanova 1997; Stefanova and Oeggl 1993; Stefanova and Bozilova 1992, 1995). Anthropogenic indicators such as *Plantago lanceolata*, *Polygonum*

LAKE KREMENSKO-5 (2124 m asl)

Analysis: J. Atanassova



b

aviculare, *Cerealia*-type and *Triticum*-type show human influence in the region.

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