

Spassimir Tonkov

The Postglacial Vegetation History in Southwestern Bulgaria

A Paleoecological Approach



The Postglacial Vegetation History in
Southwestern Bulgaria

A Paleoecological Approach

Spassimir Tonkov

The Postglacial Vegetation History in Southwestern Bulgaria

A Paleoecological Approach

Spassimir Tonkov



Sofia, Bulgaria

2021

The Postglacial Vegetation History in Southwestern Bulgaria

A Paleoecological Approach

Spassimir Tonkov

Front cover: A view of Lake Muratovo, Pirin Mountain (Photo P. Ivanov)

Back cover: Coring at Lake Panichishte, Rila Mountain (Photo S. Tonkov)

ISBN 978-619-248-043-1 (Paperback)

ISBN 978-619-248-044-8 (E-book)

Sofia, 2021

Pensoft Publishers

12, Prof. Georgi Zlatarski Str.

1111 Sofia, Bulgaria

e-mail: info@pensoft.net

www.pensoft.net

TABLE OF CONTENTS

PREFACE	6		
1. INTRODUCTION	7		
2. RILA MOUNTAIN	12		
Physico-geographical characteristics and modern vegetation	12		
Northwestern Rila Mountain – Study sites	14		
Vegetation history in the Northwestern Rila Mountain	37		
Central Rila Mountain – Study sites	41		
Vegetation history in the Central Rila Mountain	62		
Southwestern Rila Mountain – Study sites	65		
Vegetation history in the Southwestern Rila Mountain	78		
3. PIRIN MOUNTAIN	82		
Physico-geographical characteristics and modern vegetation	82		
Northern Pirin Mountain – Study sites	83		
Vegetation history in the Northern Pirin Mountain	98		
Southern Pirin Mountain – Study sites	102		
Vegetation history in the Southern Pirin Mountain	105		
4. KONYAVSKA MOUNTAIN	108		
Physico-geographical characteristics and modern vegetation	108		
Study site	109		
Vegetation history in the Konyavska Mountain	116		
		5. OSOGOVO MOUNTAIN	118
		Physico-geographical characteristics and modern vegetation	118
		Study sites	118
		Vegetation history in the Osogovo Mountain	124
		6. MALESHEVSKA MOUNTAIN	127
		Physico-geographical characteristics and modern vegetation	127
		Study site	128
		Vegetation history in the Maleshevska Mountain	129
		7. VLAHINA MOUNTAIN	132
		Physico-geographical characteristics and modern vegetation	132
		Study sites	133
		Vegetation history in the Vlahina Mountain	136
		8. BELASITSA MOUNTAIN	138
		Physico-geographical characteristics and modern vegetation	138
		Study sites	139
		Vegetation history in the Belasitsa Mountain	142
		9. ANTHROPOGENIC IMPACT ON THE NATURAL VEGETATION	145
		10. CONCLUSIONS	153
		REFERENCES	156

PREFACE

This book presents the results from the palynological and paleoecological studies conducted with my participation in Southwestern Bulgaria during the period 1985-2020. The study area has always played a key role in the investigation of the Late Quaternary vegetation history in Bulgaria since the middle of the past century. With the development of the research methods (pollen analysis, determination of plant macrofossils, radiocarbon dating, sediment analysis, computer software, etc.) in the last decades it turned out to be a challenge for me to evaluate critically again and synthesize the paleoecological information. In my opinion, such approach allows to reveal in more details the general trends of the postglacial vegetation development for the last 18000-15000 years, and to take also into account the role of humans in transforming the natural environment after the establishment of agriculture and the practice of stockbreeding in this part of the country along the Struma river.

The content is organized in several chapters starting with introductory notes on the scientific importance and the main purpose of research in the study area, a brief assessment of previous investigations, and a short review of the research techniques applied. The subsequent chapters present the original paleoecological data and the vegetation reconstruction for each montane area in uniform way, starting with the high mountains Rila and Pirin, the Konyavska and the lower west border Osogovo, Maleshevska, Vlahina and Belasitsa mountains. Then follows a summary of the human occupation and the millennial anthropogenic impact on the vegetation cover and the environment since the Neolithic epoch. The final chapter presents to the audience the main conclusions and specifics of the postglacial vegetation history in Southwestern Bulgaria.

It is my pleasure to dedicate this book to my teacher in the fascinating world of palynology Prof. Elissaveta Bozilova DSc, and also to the members of my family for their support and encouragement during all these years of academic research and

teaching in the Department of Botany at Sofia University St. Kliment Ohridski.

I extend my gratitude to the Director of the Pensoft Publishers Prof. Ljubomir Penev who kindly provided all facilities including financial support. I am also obliged to Teodor Georgiev who was responsible for the preprint and the graphical design.

I will be grateful to all colleagues who are interested in this research topic and share their critical remarks and comments.

Sofia, May 2021 Prof. Spassimir Tonkov DSc, PhD

1. INTRODUCTION

The development of the natural ecosystems is a reflection of global climate changes since the termination of the last glaciation. For paleobotanists and paleoecologists the history of vegetation during the Quaternary, when cold and warm intervals of different duration and amplitude alternated, the changes in the environment are result of the complex interaction of various factors, the most important of which is climate. The concept that vegetation is in equilibrium with climate for a certain period of the Earth's history has been confirmed in different aspects with the application of modern research methods. The dynamic equilibrium has been affected by longer or shorter climatic oscillations in response to changes in orbital factors, as well as the hydrosphere-atmosphere interaction, the formation and disintegration of the continental ice sheets and mountain glaciers.

The use of indicator plants, modern analogues of paleovegetation communities and dynamic computer models, allows to reconstruct the paleoclimate and paleoecological conditions for certain periods of time, as well as to predict the future trends in global changes facing the human society. In this process of learning the history of the Earth from the recent and distant past, it is necessary to take into account the increasing role of the anthropopression, which over time acquires significant proportions in the exploitation of the environmental resources.

The integrated paleoecological research approach provides data on the history, distribution, ecology and relationships between individual plant species and their response to climate and anthropogenic changes. In the study of the past vegetation the main role is assigned to the paleobotanical methods of research, among which pollen analysis and the determination of plant macrofossils are most frequently used. Pollen grains and spores are the most abundant microfossils providing direct information on the past flora and vegetation, and plant macrofossils of local presence as they can often be identified at species

level. The sequence of the identified changes is confirmed by the application of local or regional chronologies, and in the last decades by the study of ice cores from Greenland, Antarctica and other parts of the world.

As a result of the last glaciation, significant changes have occurred in the flora and vegetation - appearance or disappearance of certain plant taxa, changes in the composition and structure of the plant communities as well as in the habitats of a number of species. For Southeast Europe, and the Balkan peninsula in particular, the nature of these dynamic changes is rather diverse, taking into account the complex impact of abiotic and biotic factors.

There is a significant amount of paleobotanical and paleoecological evidence collected for certain regions of Bulgaria regarding the postglacial development of the environment and vegetation in response to climate changes, and, in recent millennia to human activity. The territory of Southwestern Bulgaria is one of these regions that serve as a linkage between the northern parts of the Balkan peninsula with pronounced continental climate and the southern ones, where the mediterranean climatic influence is clearly manifested. This territory comprises a mosaic of high and low mountains, valleys and rivers, an area that was inhabited in the Early Neolithic about 8000 years ago. The highest mountains Rila and Pirin were glaciated during the Quaternary and the neighboring areas have been affected by the periglacial climate.

Traditionally, in this part of the country, the most numerous paleobotanical and paleoecological research on the Late Quaternary history of vegetation and flora is conducted and each subsequent step represents a new direction in this type of investigation.

In Southwestern Bulgaria some of the most suitable sites for paleoecological studies on the postglacial vegetation history are located such as lakes and peat bogs in the Rila and Pirin mountains, and peat bogs and mires in the lower western border mountains. These wetlands are a product of the natural environment and their complex investigation results in acquiring of important information on the historical identification and evolution

of the components of the modern ecosystems and their biodiversity. The sediments that accumulated in the mountain lakes after the retreat of the glaciers provide very good opportunities for paleobotanical, paleoecological and paleogeographical reconstructions.

Lake and peat sediments develop in a certain sequence and constitute a peculiar archive of biotic and abiotic changes in time and space. The climate signal from the sediments is mainly a result of complex interactions in the environment, manifested as variations in the autochthonous organic components, mineral components, and the micro- and macrofossils of plant and animal origin.

The possibilities offered by the complex study of lakes and peat bogs in Southwestern Bulgaria remain still not completely utilized. There are issues under discussion about the specifics, chronology and individual stages of the plant paleosuccession during postglacial time, as well as regional manifestation of the climate fluctuations. There are problems related to the localization of glacial refugia of the main tree species, their rates and routes of migration in response to the rapid amelioration of the climate at the beginning of the Holocene. There was practically no information on the sedimentation processes in the glacial lakes as a reflection of the paleoecological situation. From archaeobotanical view of particular interest is the elucidation of the reasons for the early settlement of praehistorical tribes in these lands and the millennial exploitation of the plant and animal resources by humans.

* * *

Paleobotanical and paleoecological studies on the Late Quaternary history of vegetation in Bulgaria have started in the first half of the past century and to this day they are most numerous in Southwestern Bulgaria. The palynological pioneer studies of Late Holocene peat bogs in the Vitosha Mountain are well known as they reflect the alternation of forest phases without establishing their chronology (Stojanov, Georgiev, 1934; Petrov, 1956).

Later on, palynological studies of peat bogs and former lakes were initiated in the Rila and

Northern Pirin mountains. These investigations marked a qualitative leap with the application of radiocarbon dating. As a first step the palynological research in the Rila Mountain was focused on peat bogs located in different parts of the massif, most of which were formed during the Late Holocene (Subboreal and Subatlantic). The age of the sediment cores and the replacement of forest plant communities were determined using a limited number of radiocarbon dates (Bozilova, 1972, 1975, 1976, 1977, 1981). Lateglacial sediments from two sites but without detailed chrono- and biostratigraphical division were studied in the northwestern and southwestern parts of the Rila Mountain (Bozilova, Smit, 1979; Bozilova, 1981, 1986). It was proposed that a number of deciduous and coniferous tree species had survived the harsh glacial conditions at lower altitudes in local refugia with suitable microclimatic conditions with subsequent vertical migration in the Holocene (Bozilova, Tonkov, 1983, 1985, 1985a; Bozilova, 1986; Tonkov, Bozilova, 1988). The fluctuations of the upper timber-line were also discussed in the light of the climatic and anthropogenic changes (Bozilova, 1975a).

The results of the palynological and paleoecological studies in the Pirin Mountain showed many common features with the Rila Mountain in terms of vegetation dynamics and climate change in postglacial time, as well as some site specific features, constrained to the more southern location. Peat bogs located in the northern part of the mountain were studied and it was established that most of them had originated since mid-Atlantic until the beginning of the Subatlantic (Bozilova, 1975b, 1977a; Stefanova, 1991; Stefanova, Bozilova, 1992; Stefanova, Oeggel, 1993; Stefanova, 1997). These studies revealed the basic characteristics of the plant paleosuccession for the last 7000 years. A further progress was achieved with the complex study of lateglacial and Holocene sediments from glacial lakes in the Northern Pirin Mountain by application of pollen analysis, plant macrofossil determination and radiocarbon dating (Stefanova, Bozilova, 1995; Blyakharchuk et al., 2001; Stefanova, Ammann, 2003; Atanassova, Stefanova, 2003, 2005; Stefanova et al., 2003, 2006, 2006a). These

studies revealed the main stages of environmental, vegetation and climate changes after the retreat of the mountain glaciers.

Palynological data supported by radiocarbon dates were obtained from the investigation of peatlands in the Konyavska and Maleshevska mountains (Tonkov, 1985, 1988; Tonkov, Bozilova, 1992, 1992a).

The first summary of the vegetation and environmental changes in Bulgaria in postglacial time, including also several reference sites from the montane area of Southwestern Bulgaria, was published as a separate chapter (Bozilova et al., 1996) within the activities of IGCP Project 158B "Palaeohydrological Changes in the Temperate Zone in the Last 15000 Years: Lake and Mire Environments".

* * *

The paleoecological results of 28 cores from 26 sites (10 lakes, 13 peat bogs, 3 mires, marshes and swamps) located in the following mountainous areas in Southwestern Bulgaria are presented and discussed (Figs. 1 and 2):

1. Rila Mountain: Northwestern Rila Mountain - Lake Sedmo Rilsko (site 1), Lake Ribno (site 2), Lake Trilistnika (site 3) and Lake Panichishte (two cores) (site 4); Central

Rila Mountain - Lake Manastirsko-2 (site 5), Peat bog Vodniza (site 6), Lake Ostrezko-2 (site 7), Lake Ostrezko-3 (site 8), Lake Suho Ezero-RM (site 9); Southwestern Rila Mountain - Lake Suho Ezero (core 2) (site 10), Peat bog Vapsko-1 (site 11), Peat bog Vapsko-2 (site 12)

2. Pirin Mountain: Northern Pirin Mountain - Lake Ribno Banderishko (site 13), Lake Muratovo (two cores) (site 14), Peat bog Mozgovitsa (site 15); Southern Pirin Mountain - Peat bog Mutorog (site 16), Peat bog Popovi Livadi (site 17)
3. Konyavska Mountain: Tschokljovo Marsh (site 18)
4. Osogovo Mountain: Peat bog Osogovo-1 (site 19), Peat bog Osogovo-2 (site 20), Peat bog Begbunar (site 21)
5. Maleshevska Mountain: Peat bog (site 22)
6. Vlahina Mountain: Peat bog Kadiytza (site 23), Swamp Obel (site 24)
7. Belasitsa Mountain: Mire Gjola (site 25), Peat bog Belasitsa-1 (site 26)

The sediment cores were recovered with hand-operated equipments (Dachnowsky, Livingstone, Hiller) and motor Streif sampler, with different length of the chambers (0.2 m, 0.5 m and 1 m), and stored in plastic tubes in refrigerator.

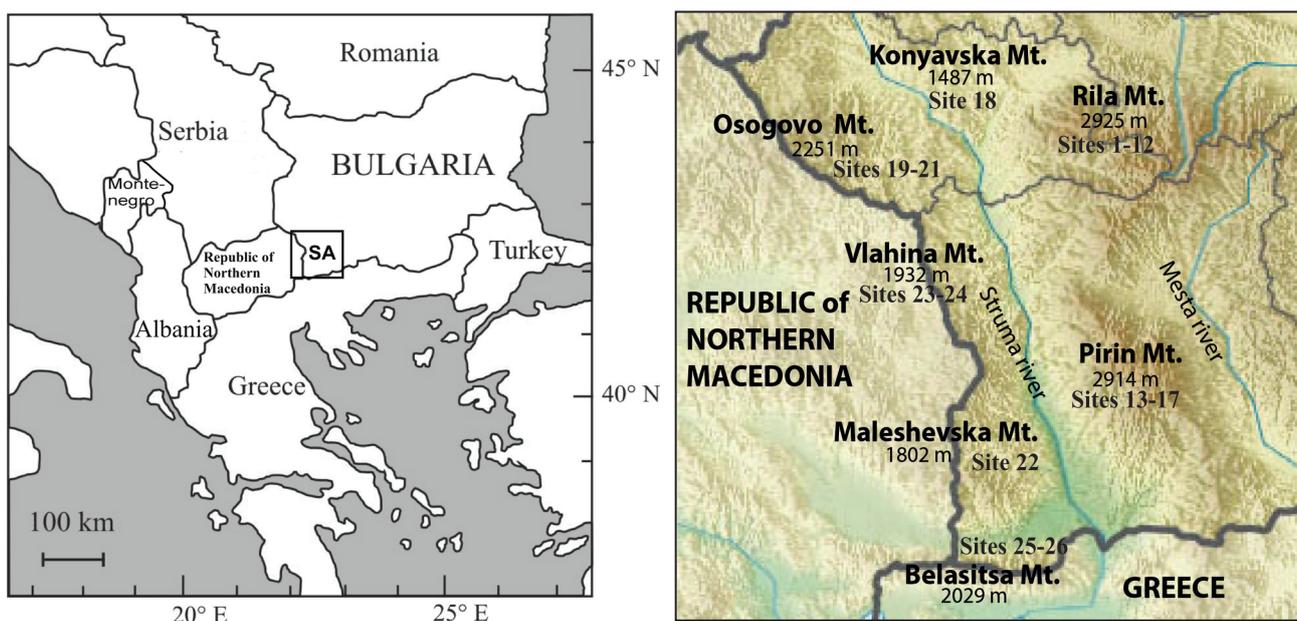


Figure 1. A. Map of Bulgaria on the Balkan peninsula with the study area (SA). B. Map of Southwestern Bulgaria with the mountains studied.

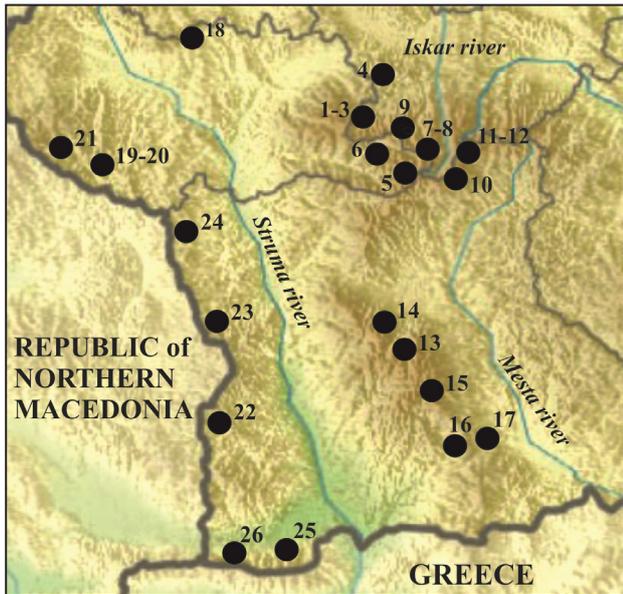


Figure 2. Location of paleoecological sites studied in Southwestern Bulgaria.

Pollen analysis was performed on each core at intervals of 5–10 cm and less often every 2–2.5 cm dependent on the composition of the sediments, the time for their deposition, and the purpose of the respective study. The standard acetolysis procedure of the samples was applied (Faegri, Iversen, 1989) and siliceous particles were also removed (Birks, Birks, 1980). The counting of the pollen grains was performed with microscopes *Amplival* and *Leitz* at magnification 400–800x. The determination of fossil pollen grains and spores was done to the lowest possible taxonomical level with the help of the reference collection at the Laboratory of Palynology at Sofia University, the pollen keys and microphotographs in Beug (1961, 2004), Moore, Webb (1978), Moore et al., (1991), Faegri, Iversen (1989), Punt et al., eds. (1974–2003) and other literature sources. The pollen sum of c. 500 grains used for percentage calculations includes tree and herb pollen, excluding spores of mosses, pteridophytes, pollen of Cyperaceae and aquatics. Percentage pollen diagrams including the most common/important pollen taxa present with values >0.5% and depth/age models are constructed with the software program *Tilia* ver. 2.0.41 (Grimm, 1991–2015). The subdivision of the pollen diagrams into local pollen assemblage zones (LPAZ) which reflect successive changes in

vegetation development was facilitated by the application of CONISS (Grimm, 1987). The definition of a local pollen zone includes a letter code, a brief description of the fossil composition, transitions to neighbouring zones, and if possible, its chronostratigraphic boundaries (Faegri, Iversen, 1989). For several cores pollen accumulation rates (PAR; pollen grains $\text{cm}^{-2}\text{yr}^{-1}$) for the main tree/shrub and herb pollen taxa are also calculated by addition of *Lycopodium* tablets per sample of constant volume (1 or 2 cm^3) before preparation (Stockmarr, 1971). The PAR value of a given taxon is directly dependent on its abundance in the surroundings of the study site and independent of values of other taxa (Davis et al., 1973; Giesecke, Fontana, 2008; Seppa et al., 2009, etc.).

Fossil stomata from needles of conifers were identified and counted together with pollen grains in the sediments of Lake Ribno, Lake Manastirsko-2, Peat bog Vodniza and Peat bog Vapsko-1. Their presence is indicated in absolute numbers or by symbols on the relevant pollen diagrams. For conifers the stomata found on pollen slides are derived from needles and thus provide a valuable proxy for local presence (Ammann et al., 2014). The taxonomical identification was done following MacDonald (2001), Sweeney (2004), Magyari et al. (2012), Finsinger, Tinner (2020) and reference slides, particularly in attempt to distinguish between *Pinus mugo/sylvestris* and *Pinus peuce*.

In sediments of Quaternary age the plant macroremains preserved (fruits, seeds, leaves, wood, fragments of vegetative and reproductive organs, etc.) provide important information for the reconstruction of the local vegetation in a given area, as they are often identified at species level and supplement the information from pollen analysis (Wasylikova, 1986; Birks, Birks, 1980, 2000). Plant macrofossils were determined from Lake Panichishte Core 2, Lake Ostrezko-2, Lake Ostrezko-3, Lake Suho Ezero Core 2, Peat bog Mozgovitsa and Peat bog Popovi Livadi. Additionally, for the purposes of radiocarbon dating, plant macroremains from Lake Sedmo Rilsko, Lake Ribno Banderishko and Peat bog Begbunar were identified. The samples for macrofossil analysis were separated at every 10, 15, 20 or 25 cm

depending on the amount of material available. The plant macrofossils were analyzed with a stereomicroscope at a magnification of 10-80x and the wood sections were examined with a light microscope. The identification was performed with the use of atlases, identification keys, literature sources and reference material (Beijerinck, 1947; Katz et al., 1977; Schoch et al., 1988; Schweingruber, 1990; Tobolski, 2000, etc.). Cuticular analysis was also applied in attempt to distinguish the needles originating from *Pinus mugo* and *Pinus sylvestris* (Struzkova, 2002). The results are presented graphically in the form of macrofossil diagrams constructed with the software program *Tilia* ver. 2.0.41 (Grimm, 1991-2015). The absolute number of the plant macrofossils from a given taxon in each sample is indicated. The presence of fragments of wood and remnants of vegetative parts (stems, leaves, etc.) is shown by appropriate symbol. The macrofossil diagrams are divided into local macrofossil assemblage zones (LMAZ) defined by a letter code, a brief description of the fossil composition, analogous to the LPAZ.

Radiocarbon dating is an essential element of any modern paleobotanical and paleoecological study, as it provides the basis for accurate chronological control over the tracking of changes in flora and vegetation, climate, hydrological regime, etc., archived in the sediments of lakes, peat bogs, mires, paleosoils, paleoethnobotanical materials (Walker, 2005).

For the purposes of this large-scale investigation radiocarbon dating of 129 samples was performed by conventional and AMS methods in 12 laboratories in Europe in the frame of the international cooperation as follows:

63 samples in the Radiocarbon Laboratory (Ua) at the University of Uppsala, Sweden

22 samples in the Radiocarbon Laboratory (Lu) at the University of Lund, Sweden

10 samples in the Radiocarbon Laboratory (Hela) at the University of Helsinki, Finland

9 samples in the Isotoptech Zrt. (DeA) in Debrecen, Hungary

8 samples in the ^{14}C and ^3H Laboratory (Hv) in Niedersächsisches Landesamt für Bodenforschung, Hannover, Germany

4 samples in the Radiocarbon Laboratory (B) at the University of Bern, Switzerland

4 samples in the Radiocarbon Laboratory at the Royal Institute of Cultural Heritage, Brussels, Belgium

3 samples in the Robert van der Graaff Laboratory (UtC) at the University of Utrecht, The Netherlands

3 samples in the ^{14}C CHRONO Centre (UBA) at Queen's University of Belfast, Northern Ireland

1 sample in the Radiocarbon Laboratory (KL) of the Institut für Rheine und Angewandte Kerphysik der Universität Kiel, Germany

1 sample in the Radiocarbon Laboratory (P) of Max-Planck-Institut für Biogeochemie in Jena, Germany

1 sample in the Radiocarbon Laboratory at the INRNE in Sofia, Bulgaria

The results are presented in tables and on the pollen/plant macrofossil diagrams in ^{14}C yrs. BP (0 yrs. BP = year 1950). All radiocarbon dates have been calibrated to calendar years ($\pm 2\sigma$ range) with the computer program OxCal 4.3 (Bronk Ramsey, 2009) using the relevant atmospheric data (Reimer et al., 2013). The mid-point calibration value is also indicated. In this case the calibrated dates (cal. yrs. BP or cal. BC/AD) can also be considered as calendar years. It is recommended to use calibrated years in the scientific literature (Walker, 2005) which is applied in the text. For sites with sufficient radiocarbon dates by interpolation each pollen sample is assigned to the corresponding radiocarbon age. It is also possible to determine and correlate chronologically the boundaries of the local pollen assemblage zones.

The nomenclature for vascular plants follows Flora of Republic of Bulgaria (Jordanov et al., 1963-2012) and Guide to Higher Plants in Bulgaria (Kozhuharov ed., 1992).

* * *

I am grateful to all my colleagues and friends from the country and abroad who were involved in the course of several decades in the expeditions to collect materials, their processing, analyses and discussions in the frame of research projects and scientific programs. I extend my sincere grati-

tude to my co-authors Prof. E. Bozilova, Prof. G. Possnert, Assoc. Prof. E. Marinova, Assoc. Prof. J. Atanassova, Dr. H. Panovska, Assoc. Prof. M. Lazarova, Prof. A. Velchev, Prof. D. Pavlova, Prof. J. Snowball, Prof. H. Jüngner, Dr. A. Feurdean, Dr. G. Skog, Assoc. Prof. E. Chakalova, Prof. D. Koleva, Dr. I. Vajsov, Assoc. Prof. G. Popov, Assoc. Prof. I. Velichkov, Assoc. Prof. G. Hinkov, Prof. Tz. Zlatanov, with whom high quality papers were published.

Special thanks go to Prof. G. Possnert, Prof. H. Jüngner, Prof. M. Geyh and other colleagues who generously provided a considerable number of radiocarbon dates. I am indebted to Prof. H.-J. Beug who gave me the first lessons in the field how to collect cores with hand-coring equipment during his numerous visits to Bulgaria and for the advices and fruitful discussions. The late Prof. H. E. Wright and Prof. B. Ammann ensured funding and guided the expedition to collect materials from glacial lakes in the Rila and Pirin mountains. In the field I always felt the invaluable help from my colleagues and friends Prof. H.-J. Beug, Prof. D. Dimitrov, Assoc. Prof. G. Angelov, Prof. A. Velchev, Assoc. Prof. E. Marinova, Assoc. Prof. D. Uzunov, Prof. L. Penev, Dr. G. Wolff, friends from the Rila Nature Reserve Rilomanastirska Gora, foresters, and many others.

From my first steps in modern paleoecological science since the early 80^{-ties} of the past century I was encouraged and supported by Prof. B. Berglund who was the leader of IGCP Project 158B and introduced me to the international paleocommunity. I am grateful to the late Prof. E. Grimm who kindly provided for free the software package *Tilia* ver. 2.0.41. I thank Assoc. Prof. E. Marinova for her constructive comments and suggestions to improve the chapter on the anthropogenic impact. Assoc. Prof. D. Kozuharov, Prof. D. Pavlova, Assoc. Prof. A. Tosheva and Dr. P. Ivanov provided photos of several sites studied. The technical assistant N. Mihailova has prepared most of the samples for pollen analysis.

2. RILA MOUNTAIN

Physico-geographical characteristics and modern vegetation

Rila Mountain which is the highest massif on the Balkans (peak Musala, 2925 m) is located between 41°52'30"-42°21'40"N and 23°01'22"-24°01'E in Southwestern Bulgaria. It has a roughly triangular shape (70 x 60 x 40 km) with an area of 2396 km². The mountain is bordered on the south and southeast by the Pirin (2914 m) and the Western Rhodopes (2191 m) mountains, and on the west and north by the valleys of several rivers. Inner 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) (Stoichev, Petrov, 1980) (Fig. 1).

Rila massif 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. Some authors consider that Rila Mountain was glaciated twice in the Pleistocene during the Riss and the Würm glacial stages (Ivanov, 1954; Glovnya, 1958, 1962, 1969, etc.) following the Alpine geochronological scheme of the Quaternary glaciations, and others (Velchev, 1995, 1999, 2014; Tonkov et al., 2008) claim to have found evidence also from an earlier glaciation (Mindel). A monograph which presents an extensive review on the Pleistocene glaciations and the formation of the present-day alpine and subalpine landscapes in Bulgaria was recently published (Velchev, 2020). All authors stick to the opinion that the existing visible glacial landforms (cirques, numerous lakes, different types of moraines and trough valleys) were shaped during the last glaciation.

In the last years, with the application of cosmogenic nuclide dating (¹⁰Be) on terminal moraine samples, the extent of the last glaciation in the Rila Mountain was mapped. Most probably, the maximum extent has occurred in two phases, the first one around the beginning (24-23 ky BP), and

the second one around the end of the Last Glacial Maximum (18–16 ky BP), separated by a retreat phase (Kuhlemann et al., 2008, 2013).

The typical montane climate above 1000 m is characterized by the decrease of the annual air temperature by 0.5°C with each 100-m increase in altitude. At 1800–1900 m where the present upper timber-line runs, the mean January temperature is -6°C and the mean August temperature is 11.4°C. As a result of the predominant directions of the moisture transport, the northwestern and northern slopes at altitudes 1000–1700 m receive 1000–1050 mm/year, while the high peaks above 2500 m about 900 mm/year, most of it snow (Velev, 2002).

In Rila Mountain from 600 to 1800 m brown mountain-forest soils (Cambisols) are widespread, and above them up to 2200 m are found dark-colored mountain-forest soils (Humic Cambisols). The latter acquire a mosaic character at the transition between the subalpine and alpine belts due to their combination with mountain-meadow soils (Umbrisols) (Ninov, 1997).

According to the last geobotanical zoning, Rila Mountain is included as a separate region within the Illyrian (Balkan) Province of the European Deciduous Forest Area (Bondev, 2002). The vegetation is closest to that in the central European mountains, for which the dominance of silicate terrains and its high altitude are important. The present vegetation of the Rila Mountain has six vegetation altitudinal belts (Velchev, Tonkov, 1986; Bondev, 1991; Velchev, 2002).

The xerothermic oak belt (up to 600 (700 m)) is clearly expressed on the western, northeastern and southwestern slopes of the mountain. The dominant species are *Quercus cerris* and *Quercus frainetto*, together with *Carpinus orientalis*, *Quercus pubescens*, *Fraxinus ornus*, *Juniperus oxycedrus*, *Paliurus spina-christi*, *Coronilla emerus* and *Colutea arborescens*. Herb communities dominated by *Festuca valesiaca*, *Poa bulbosa* and *Dichanthium ischaemum* are found on treeless terrains.

The xeromesophilous oak and hornbeam belt (700–1000 m) occurs on the western and eastern slopes of the mountain, and is characterized by a tree vegetation composed of *Quercus dalechampii* and *Carpinus betulus* with an admixture of *Ul-*

mus glabra, *Acer platanoides*, *Acer pseudoplatanus*. Fragments of this vegetation type occur up to 1700 m. Stands of *Pinus nigra* and *Ostrya carpinifolia* are also found.

The beech belt (1000–1600 m) is fragmented and occupies areas in the northern and western parts of the mountain. The dominant tree is *Fagus sylvatica*, which also forms mixed woodstands with *Pinus nigra*, *Abies alba* and *Picea abies* at high altitudes. Secondary communities of *Betula pendula*, *Populus tremula*, *Agrostis tenuis*, *Festuca nigrescens*, etc. are also found.

The coniferous belt (1600–(2000) 2200 m) is the most compact and well developed vegetation belt, and is composed mainly of forests of *Pinus sylvestris* and *Picea abies*. The Balkan endemic *Pinus peuce* forms a sub-belt and shapes the timber-line in the western and southern parts of the mountain. Within this belt communities of *Abies alba*, *Betula pendula*, *Populus tremula*, *Juniperus sibirica* and *Vaccinium myrtillus* also occur.

The subalpine belt (2200 (2000)–2500 m) on northern slopes, particularly in the central and eastern parts, is dominated by thick impenetrable formation of *Pinus mugo* (dwarf-pine). On areas, free of dwarf-pine, are found *Juniperus sibirica*, *Vaccinium myrtillus*, and herb communities dominated by *Festuca valida*, *Festuca paniculata*, *Festuca picta*, *Sesleria comosa*, and *Nardus stricta*. *Alnus viridis* is mainly restricted to the mountain brooks along the steep, rocky slopes. The arctic-alpine character of the vegetation is indicated by the presence of dwarf-willows such as *Salix lapponum*, *Salix reticulata* and *Salix waldsteiniana*.

The alpine belt (2500–2925 m) is dominated by the herb communities of *Carex curvula*, *Festuca airoides*, *Festuca riloensis*, *Dryas octopetala*, *Salix herbaceae*, etc. The vegetation of the subalpine and alpine belts is rich in endemics. Most of them are classified as glacial relics that survived the harsh conditions of the glaciations. The present-day vegetation in almost all belts is highly influenced by the anthropogenic activities. In many places the coniferous and deciduous forests have been damaged or destroyed to a large extent and the timber-line has been artificially lowered.

Northwestern Rila Mountain – Study sites

Lake Sedmo Rilsko (site 1)

The northwestern part of the Rila Mountain occupies 24% of its total area and is rich in cirques and glacial lakes. It provides excellent possibilities for exploring important issues related to the Pleistocene glaciations, the character of the glacial bodies, the relictual glacier formations and the postglacial processes. The cirque of the Seven Rila Lakes is the largest one in the mountain, being elongated and extended in a northerly direction. The group of the lakes is located in a tier on the slope between 2535 and 2095 m. The picture of the Pleistocene glaciations is rather complicated and currently two types of glaciation - mountain valley and ice-cap from the last three glacial epochs can be accepted (Fig. 3). Convincing geomorphological evidence related to Mindel glaciation that has covered large areas is

documented by the stadal and terminal moraines on the slopes between the Dzerman river and Skavitsa river, on the water-shed ridge between the basins of the Struma river and Iskar river, and by a number of *roche-moutonnee* on Suhi Rid. During Riss and Würm other types of glacial forms developed. The valley glaciers had deposited accumulative material (frontal, stadal and basal moraines) in the trough part of the Dzerman river and in the cirque itself. After the retreat of the Würm glacier a system of stadal moraines was formed which had blocked the lakes Babreka and Sedmo Rilsko. Most probably, the lakes in the cirque were free of ice already at the termination of the Late Pleniglacial proved by the start of uninterrupted sedimentation and the radiocarbon ages of the lateglacial sediments. During the Younger Dryas stadal rudimentary/embryonic and rock glaciers in the sense of Baltakov (2002) and Hughes et al. (2006) probably developed above 2300-2400 m. The overall picture of the last deglaciation is complicated by

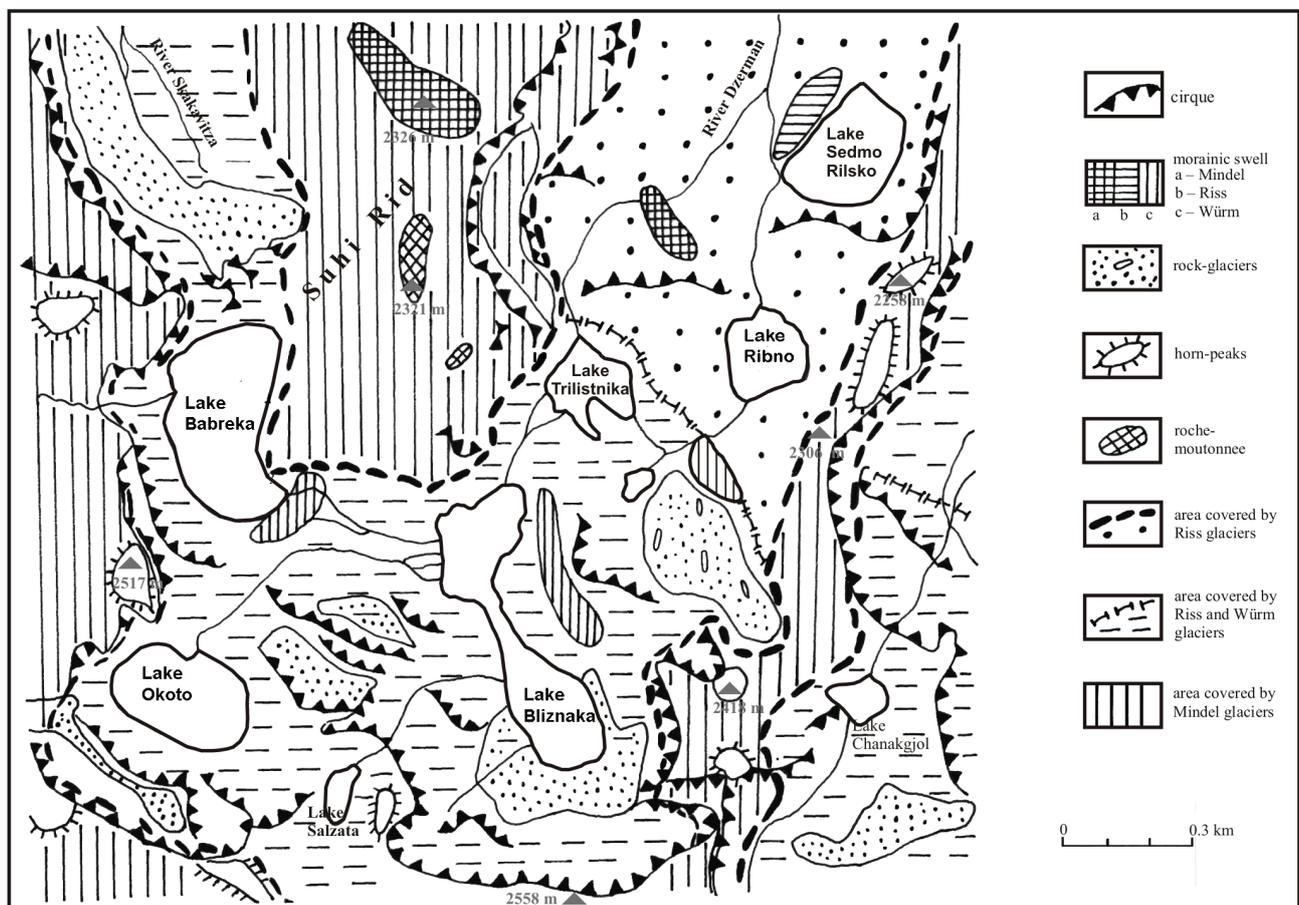


Figure 3. Geomorphological map of the cirque of the Seven Rila Lakes in the Northwestern Rila Mountain (after Tonkov et al., 2008).

the Pleistocene and Holocene cryogenic processes and the formation of the periglacial relief (Tonkov et al., 2008; Velchev et al., 2011).

The lowermost Lake Sedmo Rilsko is situated at 2095 m (42°12'39.64"N, 23°19'36.73"E) in the lower part of the subalpine vegetation belt above the present timber-line. The lake collects water from all upper lakes. The shores are flat and only the southeastern slope is steep and rocky. The lake is about 330 m long and 180 m wide, with a maximum water depth of 11 m (Ivanov, 1964). It is surrounded by groups of *Pinus mugo* and *Juniperus sibirica* within patches of herb vegetation. Not far away, to the north, are found single trees of *Pinus peuce*, *Pinus sylvestris* and *Picea abies* (Bozilova, Tonkov, 2000, 2011) (Figs. 3 and 4).

Coring, lithology and radiocarbon dating

A sediment core 5.2 m long and 5 cm in diameter was obtained from a platform at the central part of the lake at water depth of 8.25 m with square-rod piston sampler. The lithology of the sediments is: 0-415 brown gyttja, 415-435cm grey clay, 435-485

cm olive gyttja, 485-520 grey silt. The radiocarbon age of 8 samples (3 of plant macrofossils and 5 of bulk sediment) was determined and the results are shown on Table 1.

Table 1. Radiocarbon dates from Lake Sedmo Rilsko

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
UtC-6057	225	4006±48	4790-4290 (4540)	<i>Pinus</i> sp. shoot
UtC-6095	355	6480±80	7570-7250 (7410)	<i>Betula</i> fruit and <i>Pinus</i> sp. needle
UtC-6058	410	10170±60	12110-11500 (11805)	plant tissue
LuS-8991	435-437	10840±75	12910-12630 (12770)	gyttja
DeA-24386	442.5	11306±43	13260-13070 (13165)	gyttja
DeA-24388	452.5	12140±46	14160-13820 (13990)	gyttja
LuS-9336	458-460	12640±70	15270-14690 (14980)	gyttja
LuS-9337	470-472	12920±75	15720-15190 (15455)	gyttja



Figure 4. A view of Lake Sedmo Rilsko (Photo D. Pavlova)

Pollen analysis

Pollen analysis was performed at 2.5–5 cm interval and a percentage pollen diagram is constructed (Fig. 5). A separate pollen diagram of the lateglacial section of the core is also presented (Fig. 5a). On the pollen diagram seven local pollen assemblage zones (LPAZ) are recognized (LSR-1 to LSR-7) (Figs. 5 and 6). Brief descriptions are as follows:

LPAZ LSR-1 (520–457 cm, *Artemisia*-*Chenopodiaceae*-*Poaceae*-*Pinus diploxylon*) (17000?–14750 cal. yrs. BP)

The zone is characterized by low values of arboreal pollen c. 15–20%, attributed mainly to *Pinus diploxylon*-type, *Pinus peuce*, and partly *Betula*, *Juniperus* and *Ephedra* (*distachya*-type and *fragilis*-type). The herb pollen taxa dominate, among them *Artemisia* with up to 47%, *Chenopodiaceae* 20%, *Poaceae* 15–20%, and others such as *Achillea*-type, *Galium*-type, *Rumex*, *Brassicaceae*, *Apiaceae*, etc.

LPAZ LSR-2 (457–437 cm, *Pinus diploxylon*-*Artemisia*-*Poaceae*-*Betula*) (14750–12800 cal. yrs. BP)

The total arboreal pollen curve steeply reaches a maximum of 60–70% and then declines to 35%. The most abundant tree taxa are *Pinus diploxylon*-type up to 50%, *Pinus peuce* 10%, *Betula* 10%, *Quercus robur*-type 5%, *Ulmus*, *Tilia*, *Carpinus betulus*, *Corylus*. Among the herb pollen taxa should be mentioned *Artemisia* 20%, *Poaceae* 15%, *Chenopodiaceae* 5%, *Achillea*-type, *Rumex*, *Galium*-type, *Thalictrum*, *Apiaceae*, etc.

LPAZ LSR-3 (437–407 cm, *Artemisia*-*Poaceae*-*Chenopodiaceae*) (12800–11600 cal. yrs. BP)

Pollen of *Artemisia* reaches 35%, *Chenopodiaceae* 15%, *Poaceae* 20%, *Achillea*-type, *Rumex* and *Galium*-type each with 5%. Tree pollen declines to a minimum of 15% and subsequently rises to 50%, attributed to *Betula* 10–20%, *Pinus diploxylon*-type 10%, *Quercus cerris*-type, *Quercus robur*-type and *Corylus* each less than 5%, *Pinus peuce* and *Juniperus* with 2–3%.

LPAZ LSR-4 (407–358 cm, *Betula*-*Quercetum mixtum*-*Pinus*) (11600–8000 cal. yrs. BP)

In this zone the arboreal pollen curve increases to 70–85%, contributed by *Betula* 27%, *Quercus robur*-type 5–35%, *Quercus cerris*-type 3–15%, *Corylus* 5–7%, *Alnus* 2–3%, partly *Ulmus* and *Tilia*,

each with 5%. The participation of *Pinus diploxylon*-type reaches 15% and of *Pinus peuce* 5%. Pollen grains of *Carpinus betulus*, *Acer*, *Fraxinus* and *Fagus* are also recorded. Both pollen types of *Ephedra* disappear. There is a pronounced decline for the participation of *Artemisia* 5%, *Chenopodiaceae* 2%, *Poaceae* 10%, *Achillea*-type, *Rumex*, *Galium*-type, *Ranunculus*-type, and other herb pollen taxa. Spores of *Polypodiaceae* are present with 5%.

LPAZ LSR-5 (358–230 cm, *Pinus*-*Abies*-*Quercetum mixtum*-*Corylus*) (8000–4750 cal. yrs. BP)

In this zone the dominance of deciduous tree pollen represented by *Betula* 10–2%, *Quercus robur*-type 25–5%, *Corylus* 20–5%, *Ulmus* and *Tilia* is replaced by *Pinus diploxylon*-type up to 25–35% and *Pinus peuce* with 28%. Another change is the quick increase of *Abies* pollen up to 20–30%. A continuous pollen curve of *Fagus* appears with 1–2%. Single pollen grains of *Picea*, *Carpinus orientalis*/*Ostrya*, *Hedera* and *Vitis* are also recorded. Significant changes in the participation of the herb pollen taxa are not established.

LPAZ LSR-6 (230–163 cm, *Pinus*-*Abies*-*Fagus*) (4750–3200 cal. yrs. BP)

The pollen curve of *Fagus* displays a rapid increase to 12%, accompanied by the appearance of *Picea* pollen with 2–3%. The pollen curve of *Pinus diploxylon*-type retains its values of 30–35%, *Pinus peuce* with 15–20%, and *Abies* with 20%. Deciduous tree taxa such as *Quercus cerris*-type, *Quercus robur*-type, *Betula*, *Corylus*, *Carpinus*, etc. are present with low pollen frequencies. In this zone begins the pollen curve of *Plantago lanceolata*.

LPAZ LSR-7 (163–0 cm, *Picea*-*Pinus*-*Fagus*) (3200 cal. yrs. BP–till present)

The most characteristic features are the maximum of 15% attained by *Picea*, accompanied by a rise of the pollen curves for *Pinus peuce* and *Pinus diploxylon*-type up to 25% and 35%, respectively. A slight increase for *Juniperus*, *Betula*, *Corylus* and *Quercus robur*-type pollen is observed. Pollen grains of *Juglans* are regularly found. Pollen of *Cereal*-type, *Triticum*-type and *Secale* appears in this zone. Higher values are recorded for *Rumex*, *Plantago lanceolata*, *Scleranthus*, *Poaceae* and *Artemisia* pollen.

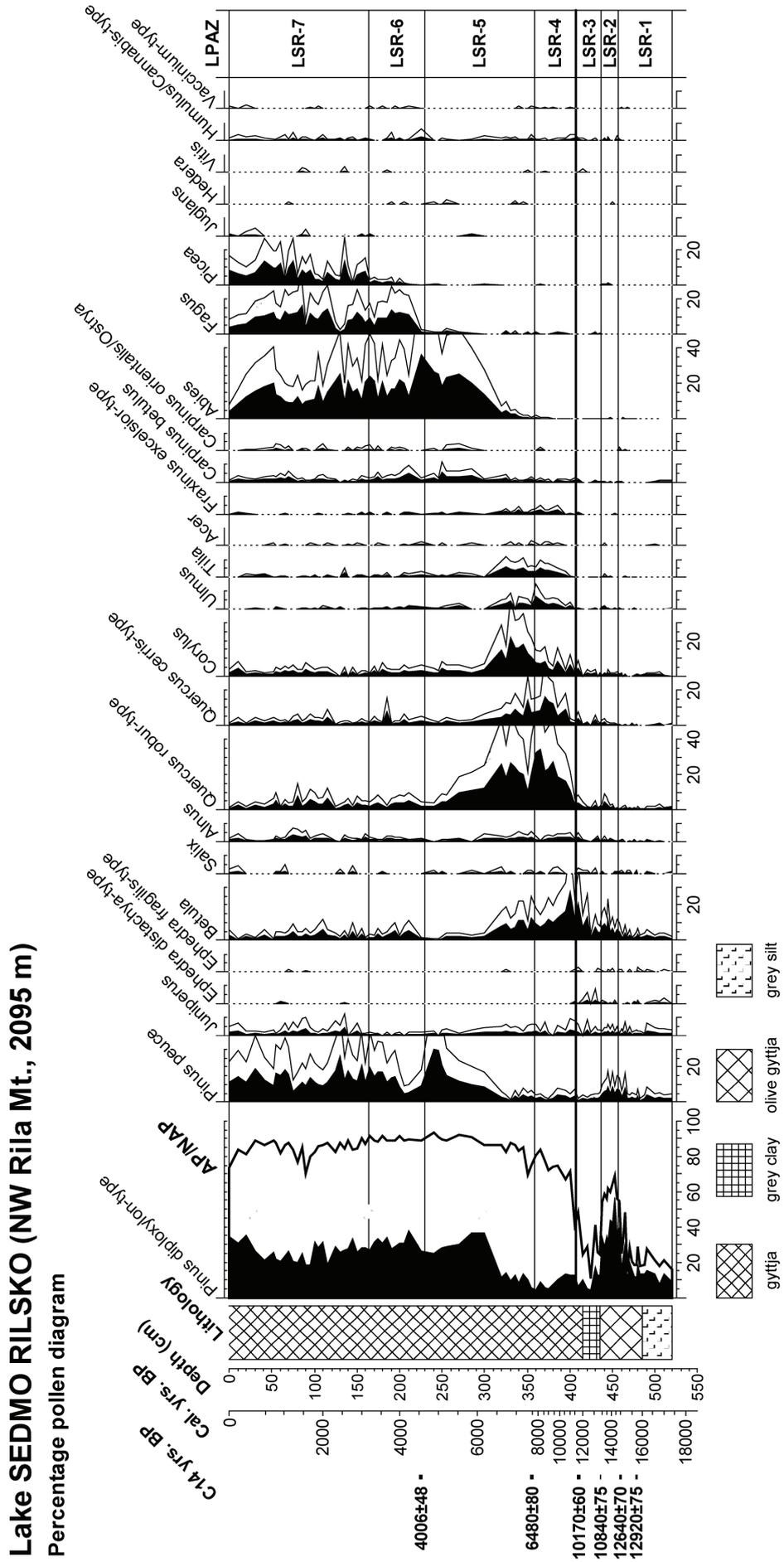
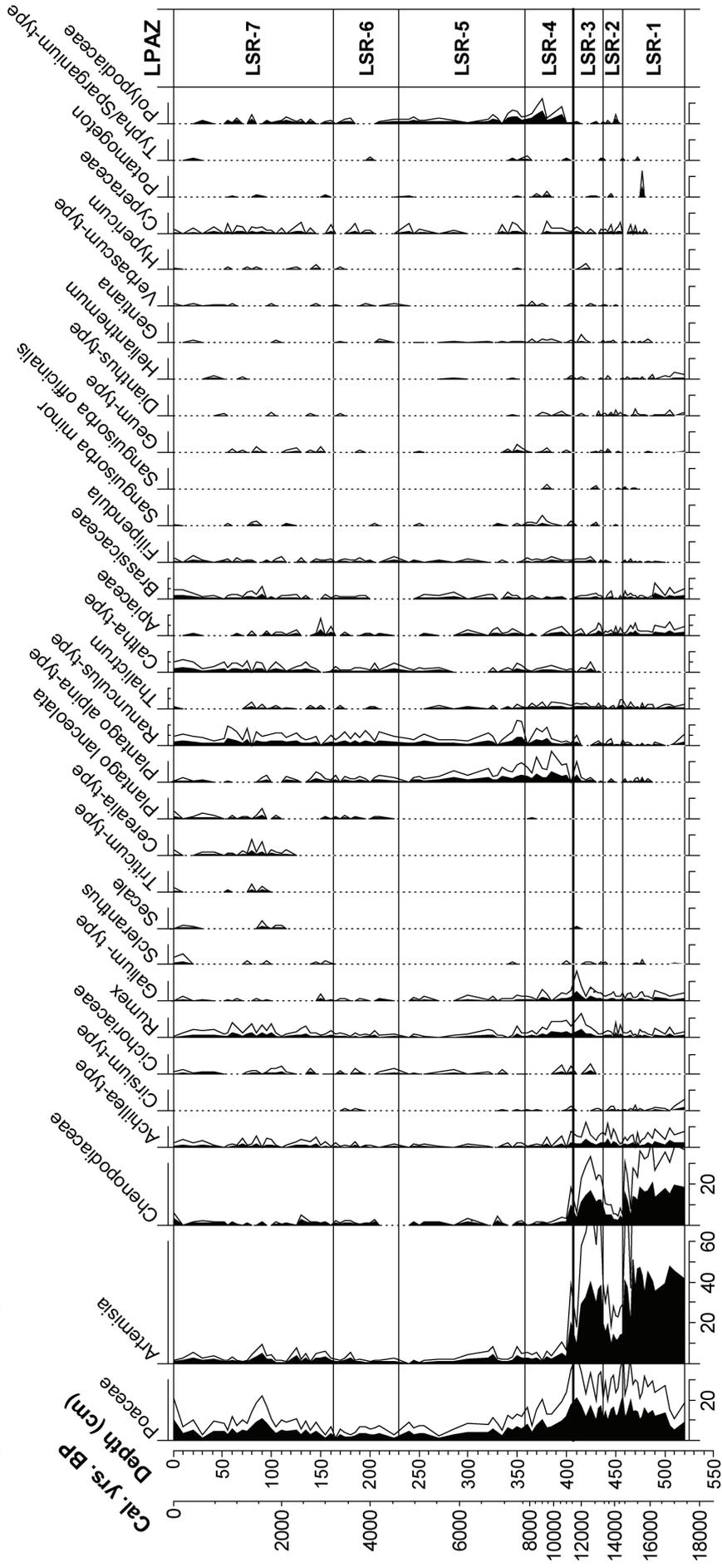


Figure 5. Percentage pollen diagram of Lake Sedmo Rilsko.

Lake SEDMO RILSKO (NW Rila Mt., 2095 m) Percentage pollen diagram (continuation)



Modified after Bozilova, Tonkov (2000, 2011)

Figure 5. Continued.

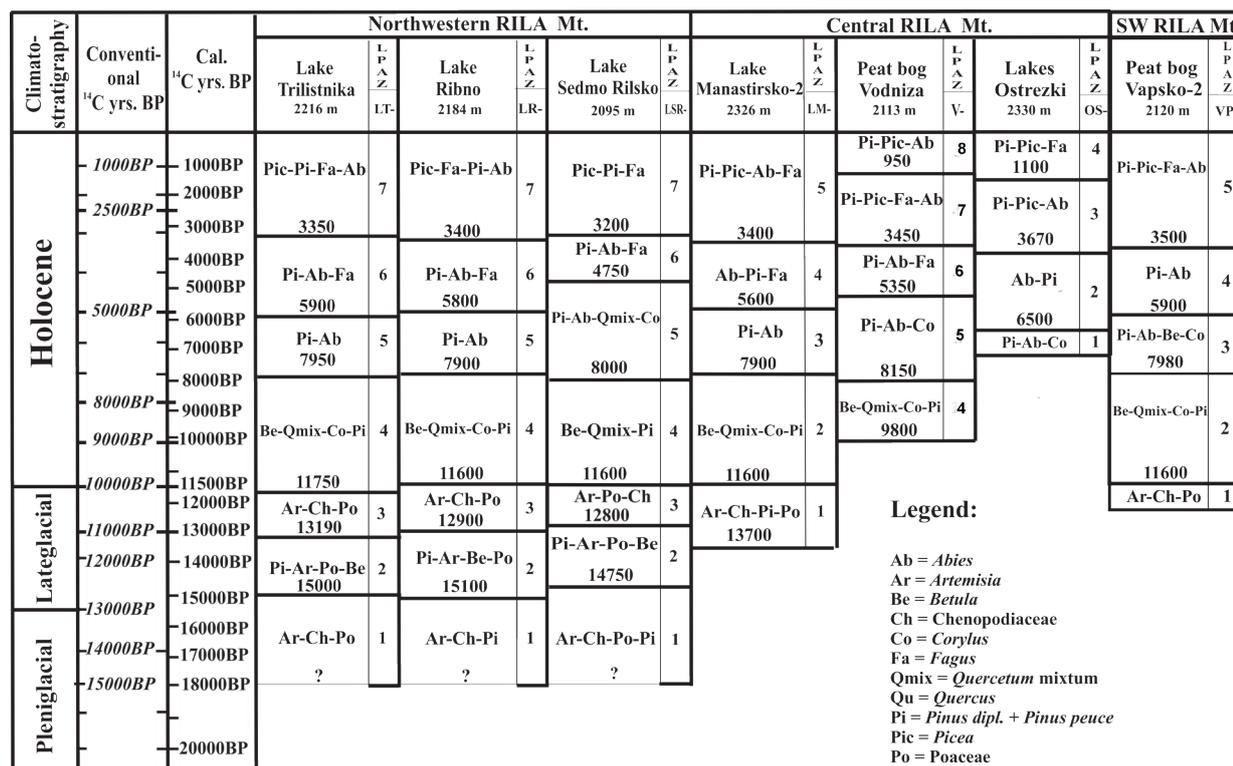


Figure 6. Comparison of the palynostratigraphy and chronology for sites in the Rila Mountain.

Table 2. Radiocarbon dates from Lake Ribno.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Ua-40623	50-51	2106±30	1995-2150 (2070)	gyttja
Ua-40624	99-100	2569±30	2510-2756 (2630)	gyttja
Ua-40625	186-187	4192±31	4621-4840 (4730)	gyttja
Ua-40626	269-270	6359±37	6575-7741 (7160)	gyttja
Ua-40627	354-355	8540±42	9476-9550 (9510)	gyttja
Ua-40628	395-396	9662±47	10780-11210 (11000)	gyttja
Ua-39221	427	10139±52	11400-12050 (11725)	clay/gyttja
Ua-39222	437	10291±56	11800-12400 (12100)	clay/gyttja
Ua-39223	452	10465±53	12100-12700 (12400)	clay/gyttja
Ua-39224	472	11240±59	12990-13260 (13125)	clay/gyttja
Ua-39225	491	12346±67	14000-14750 (14375)	clay/gyttja
Ua-40629	498-500	12692±67	14650-15250 (14950)	clay/gyttja
Ua-39227	532	13483±155	15450-16650 (16050)	silty clay

Lake Ribno (site 2)

The lake is situated at 2184 m (42°12'27.10"N; 23°19'26.31"E) in the subalpine belt and an inlet brings water from the upper Lake Trilistnika, while the outlet runs into Lake Sedmo Rilsko (Fig. 3). The lake is 250 m long with a mean width of 140 m, and a maximum water depth of 2.5 m. The shores of the lake are flat and it is surrounded by sparse groups of *Pinus mugo* and *Juniperus sibirica* among herb vegetation (Ivanov, 1964). A touristic hut is built on the northern shore close to the outlet. (Fig. 7)

Coring, lithology and radiocarbon dating

A sediment core 6.4 m long and 5 cm in diameter was obtained from a platform at the deepest part of the lake with square-rod piston sampler (Fig. 8). The lithology of the sediments is: 0–425 cm gyttja, 425–505 cm clay/gyttja, 505–540 cm silty clay and 540–640 cm grey silt. The radiocarbon age of 13 bulk sediment samples was determined and the results are shown on Table 2. By extrapolation, with some conditionality, the age of the bottom part of the core could be accepted at c. 18000 cal. yrs. BP (Tonkov et al., 2013).



Figure 7. A view of Lake Ribno (Photo A. Tosheva)

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 9). The lowermost 40 cm of the core contain no pollen. A separate pollen diagram of the lateglacial section of the core is presented (Fig. 9a). Pollen accumulation rates (PAR) for the major tree/shrub and herb taxa, complimentary to their percentage values, are also calculated (Fig. 10). Occasionally, a few fossil stomata were found on pollen slides from several sample depths (135, 140, 255, 265 and 375 cm). All of them were identified as *Pinus* sp. and their presence (*) is indicated on the pollen diagram. The stomata can be used to infer local presence of conifers in the catchment area. On the pollen diagram seven local pollen assemblage zones (LPAZ) are recognized (LR-1 to LR-7) (Figs. 9 and 6). Brief descriptions are as follows:

LPAZ LR-1 (600–512 cm, *Artemisia*-*Chenopodiaceae*-*Pinus diploxylon*-*Poaceae*) (18000?–15100 cal. yrs. BP)



Figure 8. Coring at Lake Ribno (Photo S. Tonkov)

Lake RIBNO (NW Rila Mt., 2184 m)

Percentage pollen diagram

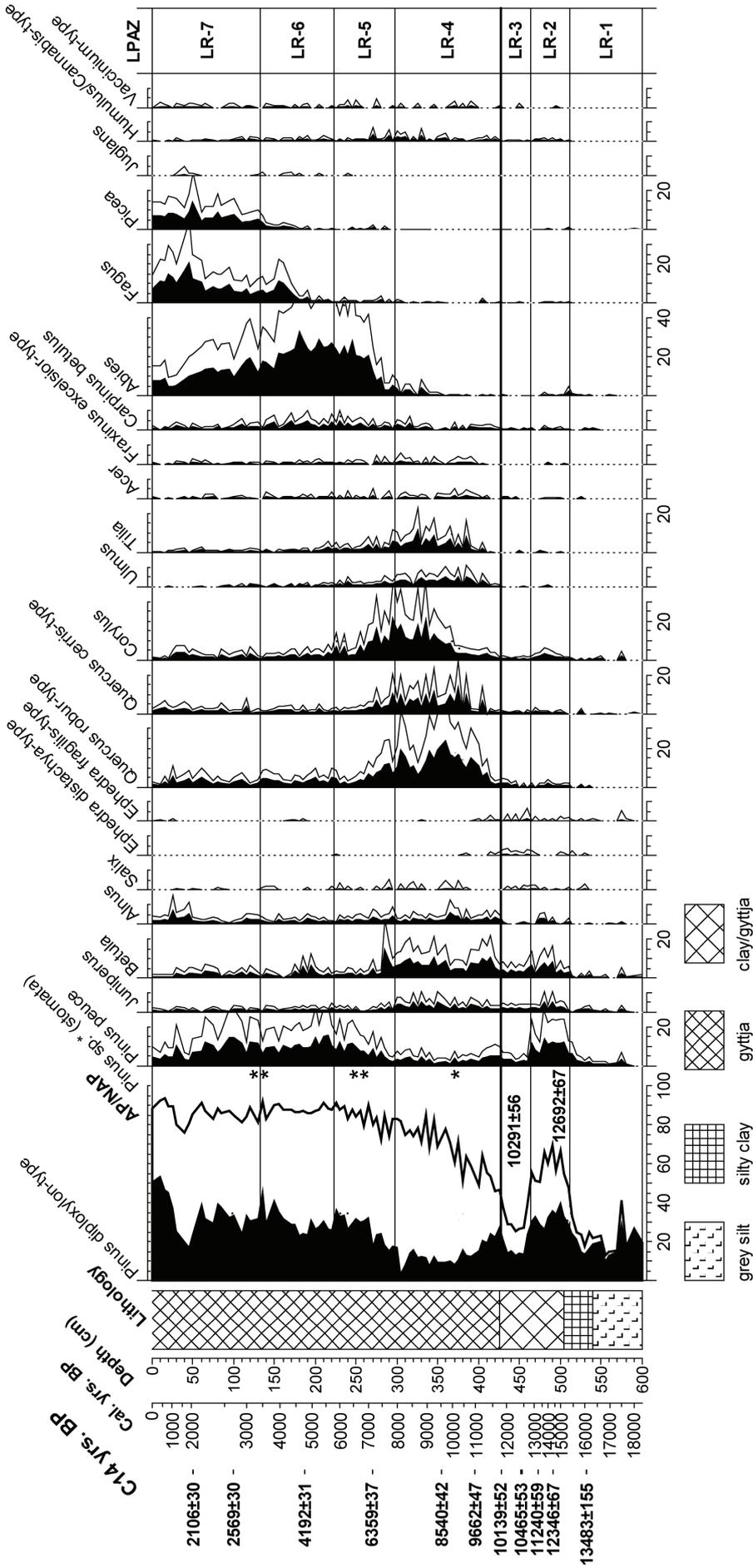
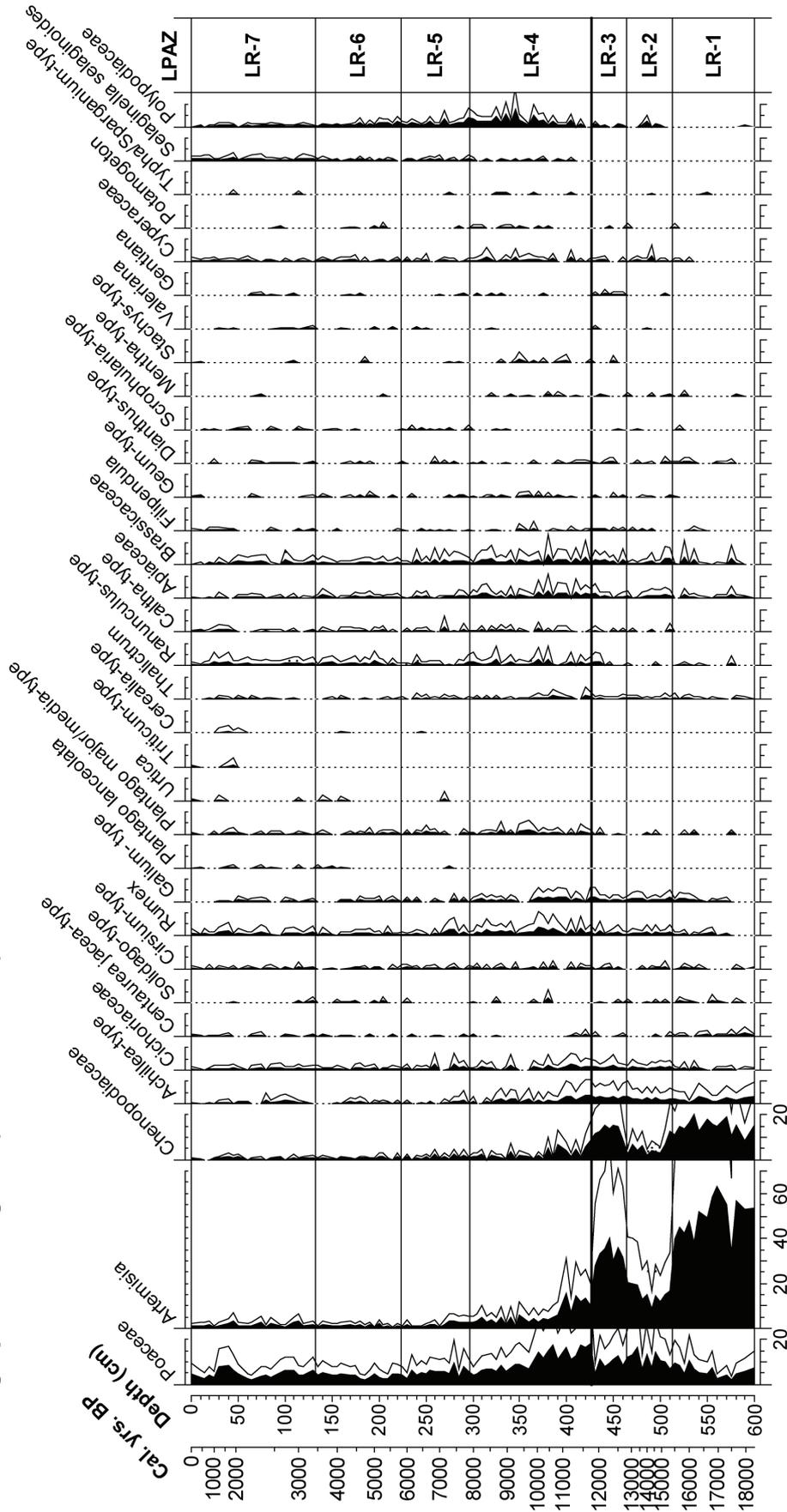


Figure 9. Percentage pollen diagram of Lake Ribno.

Lake RIBNO (NW Rila Mt., 2184 m)
Percentage pollen diagram (continuation)



Modified after Tonkov et al. (2013)

Figure 9. Continued.

Lake RIBNO (NW Rila Mt., 2184 m)
 Percentage pollen diagram - Lateglacial section

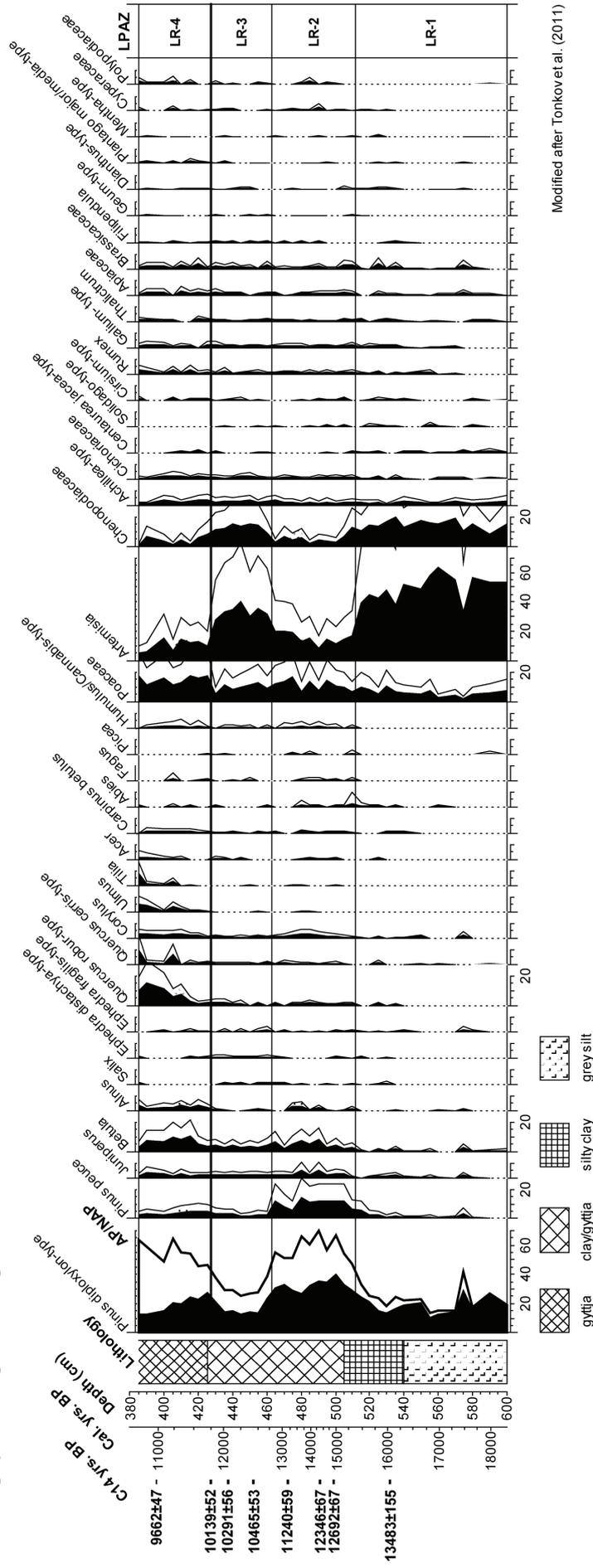


Figure 9a. Percentage pollen diagram of Lake Ribno - Lateglacial section.

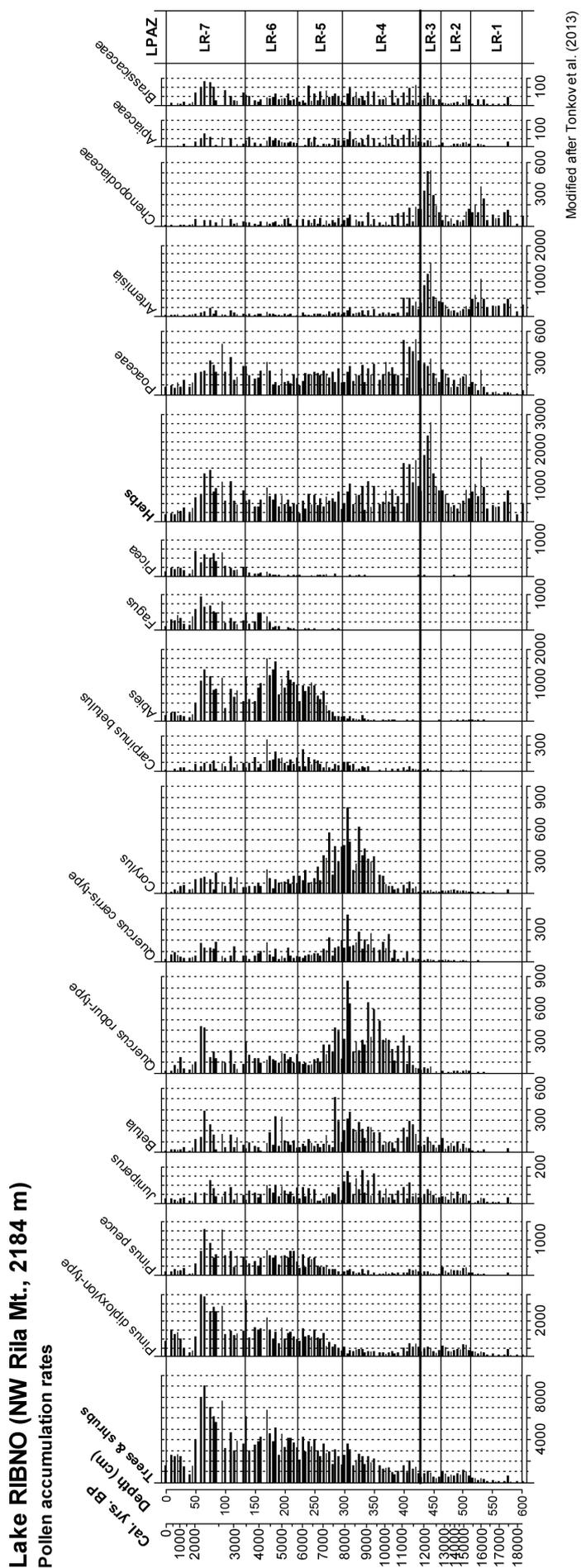


Figure 10. Pollen accumulation rates (PAR; pollen grains $\text{cm}^{-2}\text{yr}^{-1}$) for the main tree/shrub and herb taxa from Lake Ribno plotted against age (cal. yrs. BP).

The quantity of tree pollen averages 20% with a short peak of 43% (level 575 cm). The main component is *Pinus diploxylon*-type with 18-22%, accompanied by some *Pinus peuce*, *Betula*, *Juniperus*, partly *Corylus*, *Alnus* and *Ephedra* (*distachya*-type and *fragilis*-type). The herb pollen taxa are represented by *Artemisia* 40-60%, *Chenopodiaceae* up to 20%, *Poaceae* up to 10%, *Achillea*-type, *Cichoriaceae*, *Centaurea jacea*-type, *Galium*-type, *Rumex*, *Apiaceae*, *Brassicaceae*, *Dianthus*-type, etc. The total PAR of arboreal taxa is c. 500 grains cm⁻² yr⁻¹ contributed by *Pinus diploxylon*-type 200-400, *Juniperus* and *Betula* 50 each. The highest values are established for *Artemisia* up to 1000, *Chenopodiaceae* up to 400 and *Poaceae* 220.

LPAZ LR-2 (512-463 cm, *Pinus-Artemisia-Betula-Poaceae*) (15100-12900 cal. yrs. BP)

The presence of tree pollen reaches 60-68%, attributed mainly to *Pinus diploxylon*-type 30-40%, *Pinus peuce* 10-12%, *Betula* 6%, *Juniperus* and *Corylus* each with 2-3%. Low pollen frequencies are recorded for *Quercus* (*cerris*-type and *robur*-type), *Alnus*, *Carpinus betulus*, *Humulus/Cannabis*-type. Pollen grains of *Abies*, *Fagus*, *Picea* and *Tilia* are also determined. Pollen of *Artemisia* does not exceed 20%, *Chenopodiaceae* 7%, while *Poaceae* reaches 10-15%. New herb pollen taxa such as *Caltha*-type, *Geum*-type and *Gentiana* are recorded. The total PAR of arboreal taxa increases to c. 1000 grains cm⁻² yr⁻¹ represented by *Pinus diploxylon*-type up to 600, *Pinus peuce* 250, *Betula* 100, *Juniperus* 60. The PAR of herb pollen taxa decreases, contributed mainly by *Artemisia* 250, *Poaceae* 200 and *Chenopodiaceae* 50-100.

LPAZ LR-3 (463-427 cm, *Artemisia-Chenopodiaceae-Poaceae*) (12900-11600 cal. yrs. BP)

The tree pollen curve declines to 25-30%, mainly due to *Pinus diploxylon*-type 15%, *Pinus peuce* 3%, partly *Juniperus* 2% and *Betula* less than 5% each. Pollen of *Abies*, *Picea*, *Fagus*, *Tilia* and *Ulmus* becomes sporadic. The presence of *Ephedra* pollen (*distachya*-type and *fragilis*-type) remains constant. The pollen frequencies for *Artemisia* 32-40% and *Chenopodiaceae* 15% increase again, while those for *Poaceae* just slightly decrease. The PAR of trees retains nearly the same values with the exception of *Pinus peuce* with 120 grains cm⁻²

yr⁻¹ and a slight rise of *Quercus robur*-type up to 70. The PAR of herb pollen taxa shows maximal values for *Artemisia* and *Chenopodiaceae* 1500 and up to 600, respectively, and a tendency of increase for *Poaceae*, *Apiaceae* and *Brassicaceae*.

LPAZ LR-4 (427-297 cm, *Betula-Quercetum mixtum-Corylus-Pinus*) (11600-7900 cal. yrs. BP)

The presence of tree pollen reaches 80%, due to *Betula* 10%, *Quercus robur*-type 20%, *Quercus cerris*-type 15%, *Corylus* 10-20%, *Tilia* 10%, *Ulmus* 5%, *Pinus diploxylon*-type 15-20%, *Alnus* and *Juniperus* each less than 5%. Low proportions of *Acer*, *Fraxinus excelsior*-type, *Carpinus betulus*, *Ephedra* (*distachya*-type and *fragilis*-type) pollen are also found. The continuous pollen curve of *Abies* appears reaching 5%. Pollen grains of *Fagus* and *Picea* are regularly determined. The herb pollen taxa are represented by *Poaceae* 15-5%, *Artemisia* up to 15%, *Chenopodiaceae* 5%, *Achillea*-type, *Rumex*, *Cichoriaceae*, *Ranunculus*-type, *Brassicaceae*, *Galium*-type, each below 3-5%, etc. The total PAR of tree taxa increases gradually to 3000 grains cm⁻² yr⁻¹ contributed mainly by *Betula* 300-500, *Quercus robur*-type 600-800, *Quercus cerris* up to 400 and *Corylus* 700-900. Among the herb pollen taxa only *Poaceae* retains values of 250-300, while *Artemisia* and *Chenopodiaceae* sharply decline. The increase for *Apiaceae* and *Brassicaceae* up to 100 each deserves mentioning.

LPAZ LR-5 (297-223 cm, *Pinus-Abies*) (7900-5800 cal. yrs. BP)

The pollen curve of *Abies* reaches 25-30%, *Pinus diploxylon*-type 30-35% and *Pinus peuce* 12%. Pollen of deciduous trees like *Betula*, *Quercus robur*-type, *Quercus cerris*-type, *Corylus*, *Tilia* and *Ulmus* declines, while *Carpinus betulus* is present with 2-4%. Pollen of *Fagus* and *Picea* is continuously found. Significant changes in the participation of the herb pollen taxa are not recorded, except for the appearance of single grains of *Plantago lanceolata*, *Urtica*, *Cerealialia*-type. This zone marks the rise of PAR for the coniferous trees such as *Pinus diploxylon*-type up to 1500 grains cm⁻² yr⁻¹, *Abies* 1000, *Pinus peuce* 500, while the values for the deciduous trees gradually decline.

LPAZ LR-6 (223-133 cm, *Pinus-Abies-Fagus-Picea*) (5800-3400 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type reaches 40–45%, *Abies* is present with 15–30%, *Pinus peuce* with 10%, *Fagus* up to 10%. A continuous pollen curve of *Picea* below 5% appears. A slight increase for *Betula* and *Carpinus betulus* is recorded. Pollen grains of *Juglans* are quite common. The main herb pollen taxa are Poaceae 5%, *Artemisia*, Cichoriaceae, *Rumex*, *Ranunculus*-type, Apiaceae, Brassicaceae, *Plantago major/media*-type, etc. Pollen grains of *Plantago lanceolata*, *Cerealia*-type, *Urtica* are also recorded. The tendency for increase of PAR of trees is visible, attributed to *Pinus diploxylon*-type up to 3000 grains $\text{cm}^{-2} \text{yr}^{-1}$, *Pinus peuce* 750, *Abies* 1500–1750 and *Fagus* 500. Among the herb pollen taxa attention deserves Poaceae with 250–300.

LPAZ LR-7 (133–0 cm, *Picea-Fagus-Pinus-Abies*) (3400 cal. yrs. BP–till present)

The pollen curve of *Picea* rises to 15% together with *Fagus* 20%, while *Abies* declines to 8%. High pollen values are recorded for *Pinus diploxylon*-type 50–55% and *Pinus peuce* 10–15%. The last finds of *Ephedra fragilis*-type pollen are recorded. A slight increase for pollen of *Corylus*, *Quercus* and *Alnus* is established. Important changes

in the frequency and diversity of the herb pollen taxa are not registered. In this zone maximal PAR of the following trees are recorded - *Pinus diploxylon*-type 3500 grains $\text{cm}^{-2} \text{yr}^{-1}$, *Pinus peuce* 1250, *Fagus* 1000 and *Picea* 750.

Lake Trilistnika (site 3)

The uppermost lake investigated is located at 2216 m (42°12'01"N, 23°18'56"E) in the subalpine belt, surrounded by sparse groups of *Juniperus sibirica* and *Pinus mugo* within herb vegetation (Fig. 3). The lake collects water from the upper lakes. The inlet is at its southern part while two outlets are in the northern and eastern parts. The length of the lake is 240 m with a mean width of 200 m and a maximum depth of 6.5 m. The shores are flat, at some places marshy, and only the western shore is steep and rocky (Ivanov, 1964) (Fig. 11).

Coring, lithology and radiocarbon dating

A sediment core 5.9 m long and 5 cm in diameter was recovered with square-rod piston sampler at water depth of 6.3 m. The lithology of the sediments is: 0–430 cm gyttja, 430–500 cm silty clay and 500–590 cm grey silt. The radiocarbon age



Figure 11. A view of Lake Trilistnika (Photo S. Tonkov)

Table 3. Radiocarbon dates from Lake Trilistnika.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Ua-20688	50-52	1645±40	1690-1410 (1550)	gyttja
Ua-20689	105-107	2605±40	2790-2700 (2745)	gyttja
Ua-21598	150-152	3200±40	3550-3340 (3445)	gyttja
Ua-20690	202-204	3925±40	4450-4230 (4340)	gyttja
Ua-20691	240-242	4560±45	5330-5040 (5235)	gyttja
Ua-20692	308-310	6835±50	7760-7580 (7670)	gyttja
Ua-20693	368-370	8040±55	9150-8650 (8900)	gyttja
Ua-20694	396-398	8825±60	10200-9600 (9900)	gyttja
Ua-21599	457-459	11140±100	13450-12850 (13150)	silty clay
Ua-20696	468-470	11365±75	13500-13000 (13250)	silty clay
Ua-21600	481-483	12110±95	15350-13650 (14500)	silty clay
Ua-21601	489-491	12815±130	15950-14350 (15150)	silty clay

of 12 bulk sediment samples was determined and the results are shown on Table 3. It can be suggested that the deposition of grey silt has started before 16000 cal. yrs. BP, similarly with the situation at Lake Ribno (Tonkov et al., 2006, 2008).

Pollen analysis

Pollen analysis was performed at 5-10 cm interval and a percentage pollen diagram is constructed (Fig. 12). A separate pollen diagram of the lateglacial section of the core is also presented (Fig. 12a). The lowermost 40 cm of the core contain no pollen. On the pollen diagram seven local pollen assemblage zones (LPAZ) are recognized (LT-1 to LT-7) (Figs. 12 and 6). Brief descriptions are as follows:

LPAZ LT-1 (590-532 cm, *Artemisia*-*Chenopodiaceae*-*Poaceae*) (18000?-15000? cal. yrs. BP)

Low values of 15-20% are recorded for tree pollen, attributed mainly by *Pinus diploxylon*-type, *Pinus peuce* and *Ephedra* (*distachya*-type and *fragilis*-type). Pollen of *Juniperus*, *Betula*, *Alnus*, *Corylus* and *Carpinus betulus* is also determined. Among the herb pollen taxa dominate *Artemisia*

40-60%, *Chenopodiaceae* 20% and *Poaceae* up to 15%. The presence of *Achillea*-type, *Solidago*-type, *Apiaceae*, *Rumex* pollen is also recorded.

LPAZ LT-2 (532-463 cm, *Pinus*-*Artemisia*-*Poaceae*-*Betula*) (15000?-13190 cal. yrs. BP)

The most characteristic feature is the high proportion of *Pinus diploxylon*-type 50-55%, accompanied by a slight increase of *Pinus peuce*, the appearance of continuous pollen curves for *Betula* and *Alnus*, and a decrease of *Artemisia* and *Chenopodiaceae* to 20% and 5%, respectively. Pollen grains of *Abies*, *Picea*, *Corylus*, *Quercus*, *Ulmus* and *Carpinus* are also recorded. New herb pollen taxa such as *Thalictrum*, *Ranunculus*-type, *Cyperaceae* and spores of *Selaginella selaginoides* and *Polypodiaceae* appear in the fossil record.

LPAZ LT-3 (463-432 cm, *Artemisia*-*Chenopodiaceae*-*Poaceae*) (13190-11750 cal. yrs. BP)

The arboreal pollen curve sharply declines to 20% and *Pinus diploxylon*-type is present with 15-10%. Pollen of *Abies*, *Picea* and *Ulmus* is lacking. The participation of *Artemisia* and *Chenopodiaceae* increases again, reaching 45-55% and 15-20%, respectively, accompanied by pollen of *Achillea*-type, *Dianthus*-type, *Cichoriaceae*, *Galium*-type, *Rumex*, *Apiaceae*, etc.

LPAZ LT-4 (432-322 cm, *Betula*-*Quercetum mixtum*-*Corylus*-*Pinus*) (11750-7950 cal. yrs. BP)

The tree pollen curve reaches 90%, with a maximum of *Betula* 10% and an increase for *Pinus diploxylon*-type 33% and *Pinus peuce* 20-25%. The same tendency is observed for *Quercus cerris*-type 17%, *Corylus* 15-20%, *Tilia* 12%, *Ulmus* and *Alnus*. The first local peak of *Abies* with 15% is recorded. Pollen grains of *Fagus*, *Picea* and *Vitis* are also found. The herb pollen taxa are represented by *Poaceae* 12%, *Artemisia* up to 5%, *Chenopodiaceae* 3%, *Rumex* 5%, *Cichoriaceae*, *Cirsium*-type, *Achillea*-type, each with 1-2%, etc. Spores of *Polypodiaceae* reach a maximum of 10%.

LPAZ LT-5 (322-255 cm, *Pinus*-*Abies*) (7950-5900 cal. yrs. BP)

The pollen curve of *Abies* rises to 30-38% and *Pinus peuce* to 15%. A considerable decrease is registered for *Quercus cerris*-type, *Corylus*, *Tilia*, *Ulmus* and *Betula* pollen, while *Carpinus betulus* is present with 2-4%. Pollen grains of *Fagus* are reg-

LAKE TRILISTNIKA (NW Rila Mt., 2216 m)

Percentage pollen diagram

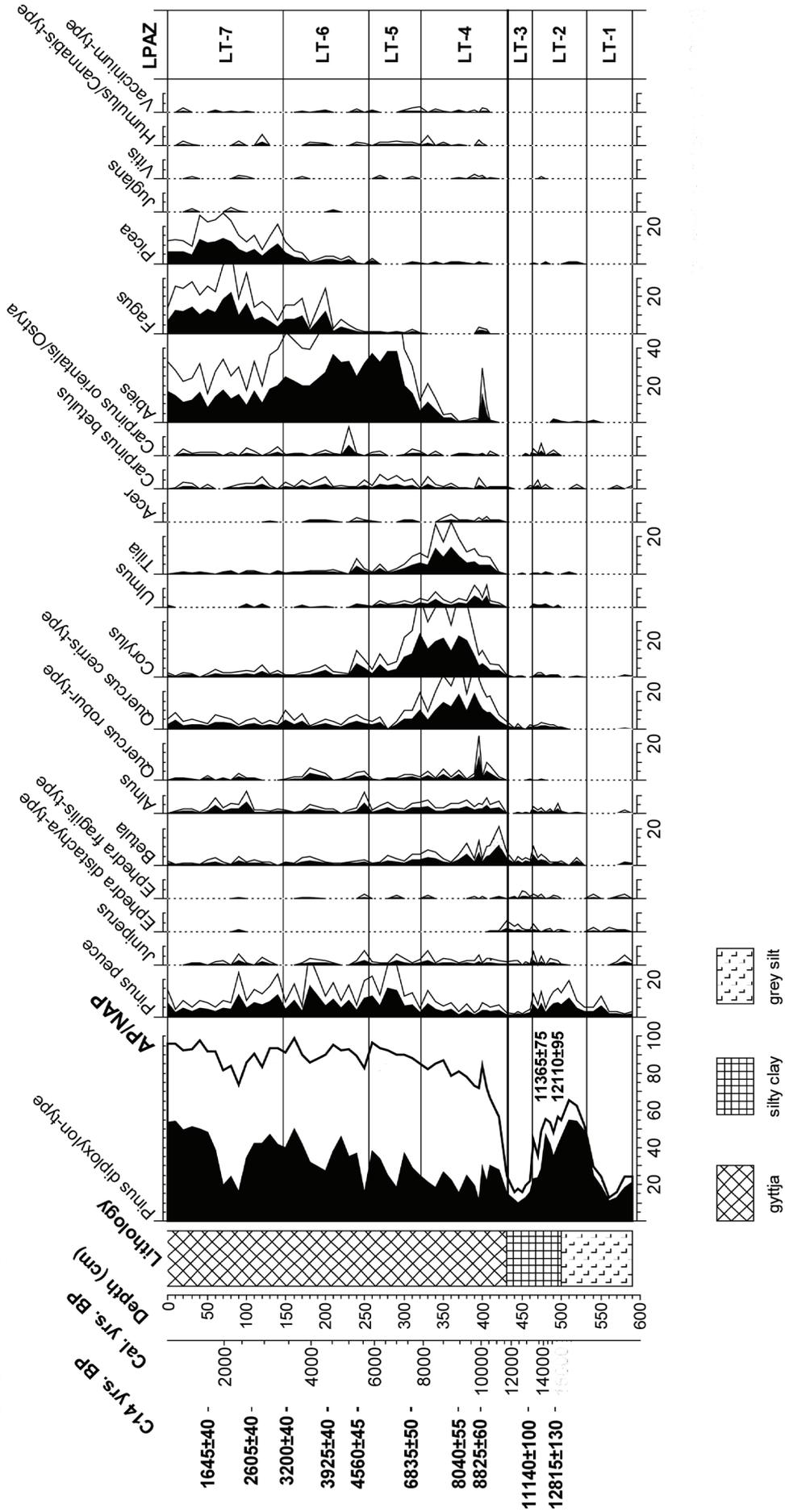
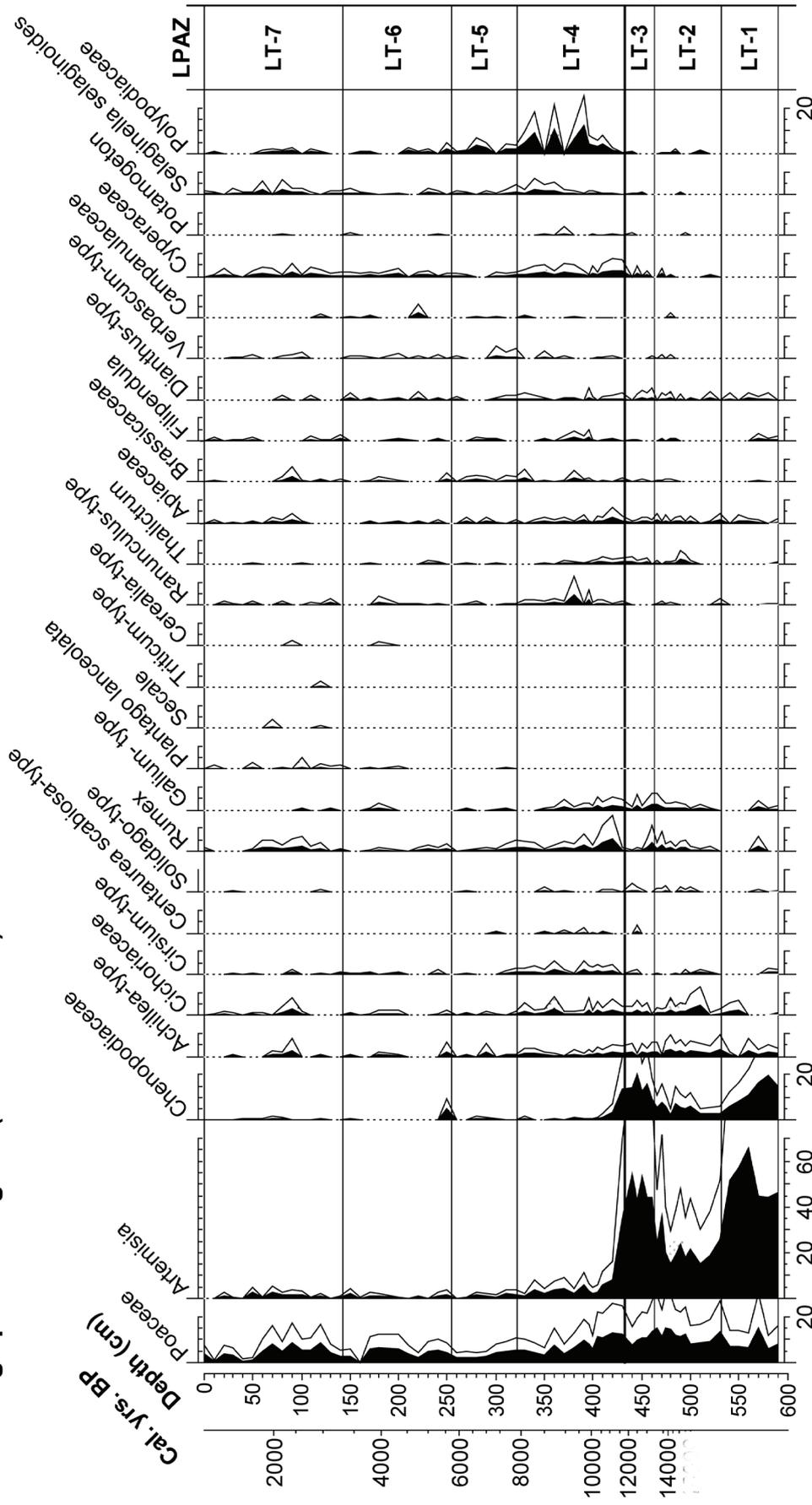


Figure 12. Percentage pollen diagram of Lake Trilistnika.

LAKE TRILISTNIKA (NW Rila Mt., 2216 m)

Percentage pollen diagram (continuation)



Modified after Tonkov et al. (2008)

Figure 12. Continued.

Lake TRILISTNIKA (NW Rila Mt., 2216 m)
Percentage pollen diagram - Lateglacial section

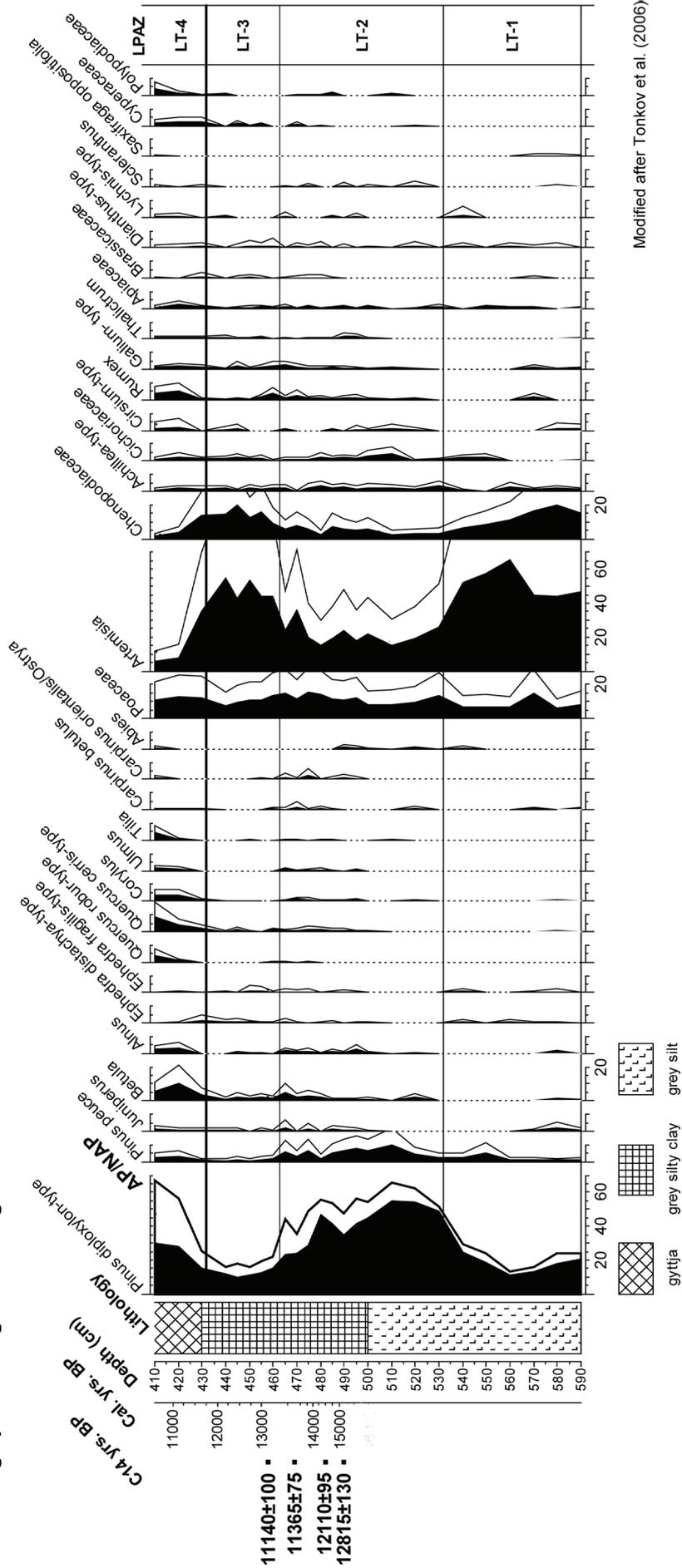


Figure 12a. Percentage pollen diagram of Lake Trilistnika - Lateglacial section.

ularly found. The total quantity of herb pollen taxa varies between 8% and 16%.

LPAZ LT-6 (255-143 cm, *Pinus-Abies-Fagus-Picea*) (5900-3350 cal. yrs. BP)

The pollen curves of *Fagus* and *Picea* rise to 10% and 5%, respectively. High values of 35% are recorded for *Abies* pollen with a subsequent reduction to 18%. The participation of *Pinus diploxylon*-type is up to 45-50% and for *Pinus peuce* up to 15%. Pollen of *Juglans* is recorded for the first time. The main herb pollen taxa are Poaceae 4-6%, *Artemisia* 2%, *Cirsium*-type, *Ranunculus*-type, *Dianthus*-type, etc. The pollen curve of *Plantago lanceolata* appears together with pollen of *Cerealia*-type.

LPAZ LT-7 (143-0 cm, *Picea-Pinus-Fagus-Abies*) (3350 cal. yrs. BP-till present)

The tree pollen curve reaches 95%, contributed mainly by *Pinus diploxylon*-type 50-55%, *Abies* 15%, while *Pinus peuce* decreases below 5%. In this zone pollen of *Fagus* with 20% and *Picea* 12% reach maximal values. Significant changes in the frequency and diversity of the herb pollen taxa are not registered, except for the appearance of pollen of *Secale* and *Triticum*-type.

Lake Panichishte (site 4)

The lake is located at 1370 m (42°15'45.67"N, 23°17'38.97"E) in the lower range of the coniferous belt (Fig. 2). It is one of the few mountain lakes with tectonic origin. The lake has an elliptic shape and occupies an area of 1.2 ha. The maximal water depth is 4 m. The lake is surrounded by a dense forest composed of *Pinus sylvestris* and *Picea abies*, with some *Abies alba*, *Pinus peuce* and *Fagus sylvatica*. The peripheral parts of the lake are overgrown by various hygrophytes and most of the water surface is covered by *Potamogeton natans*. The open areas close to the shores are highly ruderalized (Bozilova et al., 2002; Tonkov et al., 2020) (Fig. 13).

Coring, lithology and radiocarbon dating

Two sediment cores P-2 and P-3, both 5 cm in diameter, were obtained from the central part of the lake with square-rod piston sampler. The Core P-2 with a length of 1.5 m was collected at water depth of 1.7 m and selected for pollen and plant macrofossil analyses. The lithology of the sediments is: 0-50 cm peat with sand and plant remains, 50-



Figure 13. A view of Lake Panichishte (Photo S. Tonkov).

150 cm peaty gyttja. The Core P-3 with a length of 1.15 m was collected at water depth of 2 m and was analysed for pollen content. The lithology of the sediments is: 0-50 cm coarse peat with plant remains, 50-115 cm peaty gyttja. The radiocarbon age of 9 bulk sediment samples was determined and the results are shown on Table 4. The age of both cores spans the last 2000 years.

Pollen analysis

The cores were sampled at 5-10 cm interval and two pollen diagrams are constructed (Figs. 14 and 15). The palynostratigraphical correlation of both cores is feasible due to the similarities in the behaviour of the main pollen curves and the application of the depth/age models constructed by linear interpolation. Three local pollen assemblage zones (LPAZ) are recognized (LP-1 to LP-3). Brief descriptions are as follows:

LPAZ LP-1: Core P-2 (150-73 cm); Core P-3 (115-68 cm) (*Pinus diploxylon-Fagus-Abies*) (1900-1170 cal. yrs. BP)

Table 4. Radiocarbon dates from Lake Panichishte.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Cal. BC/AD (mid-point)	Material dated
Core P-2					
Hel-4375	30-35	870±100	980-650 (815)	970-1300AD (1135AD)	peat with plant remains
Hel-4376	75-80	1340±90	1420-1010 (1215)	530-940AD (735AD)	peaty gyttja
Hel-4377	145-150	1950±90	2140-1630 (1885)	190BC-320AD (65AD)	peaty gyttja
Core P-3					
Ua-61843	10	160±29	290-40 (165)	1660-1910AD (1785)AD	peat with plant remains
Ua-61844	35	388±29	510-320 (415)	1440-1630AD (1535)AD	peat with plant remains
Ua-61845	50	673±30	680-550 (615)	1270-1400AD (1335)AD	peaty gyttja
Ua-61846	70	1349±31	1320-1180 (1250)	630-770AD (700)AD	peaty gyttja
Ua-61847	90	1643±30	1620-1410 (1515)	330-540AD (435)AD	peaty gyttja
Ua-61848	110	1908±31	1930-1740 (1835)	20-210 (115)AD	peaty gyttja

Tree pollen dominates, attributed mainly to *Pinus diploxylon*-type 15-25%, *Fagus* 20-30%, *Abies* 10-20%. Comparatively low pollen frequencies below 5% are registered for *Pinus peuce*, *Picea*, *Juniperus*, *Corylus*, *Quercus cerris*-type, *Quercus robur*-type, *Carpinus betulus*, *Ulmus*, etc. A sharp maximum for *Betula* pollen with 20% is recorded at the transition to the next zone, accompanied by a decline of *Fagus* and a rise of *Pinus diploxylon*-type. The herbs are represented by Poaceae with 5-7% and a variety of taxa, including hydrophytes and hygrophytes such as *Typha/Sparganium*-type, *Typha latifolia*, *Potamogeton*, *Myriophyllum*, and Cyperaceae with 15%.

LPAZ LP-2: Core P-2 (73-22 cm); Core P-3 (68-47 cm) (*Pinus diploxylon-Abies-Fagus*) (1170-570/550 cal. yrs. BP)

The dominant pollen type is *Pinus diploxylon* with 35-40%. Pollen of *Abies*, *Fagus* and *Picea* is present with 5-15%, 10%, 5%, respectively. Pollen of *Juglans* is also found. Pollen of anthropogenic indicators such as *Plantago lanceolata*, *Plantago major/media*-type, *Rumex*, *Polygonum aviculare*-type and of cereals (*Secale*, *Triticum*-type, *Cerealialia*-type) is determined. Significant changes in the pollen frequencies of the local taxa are not established.

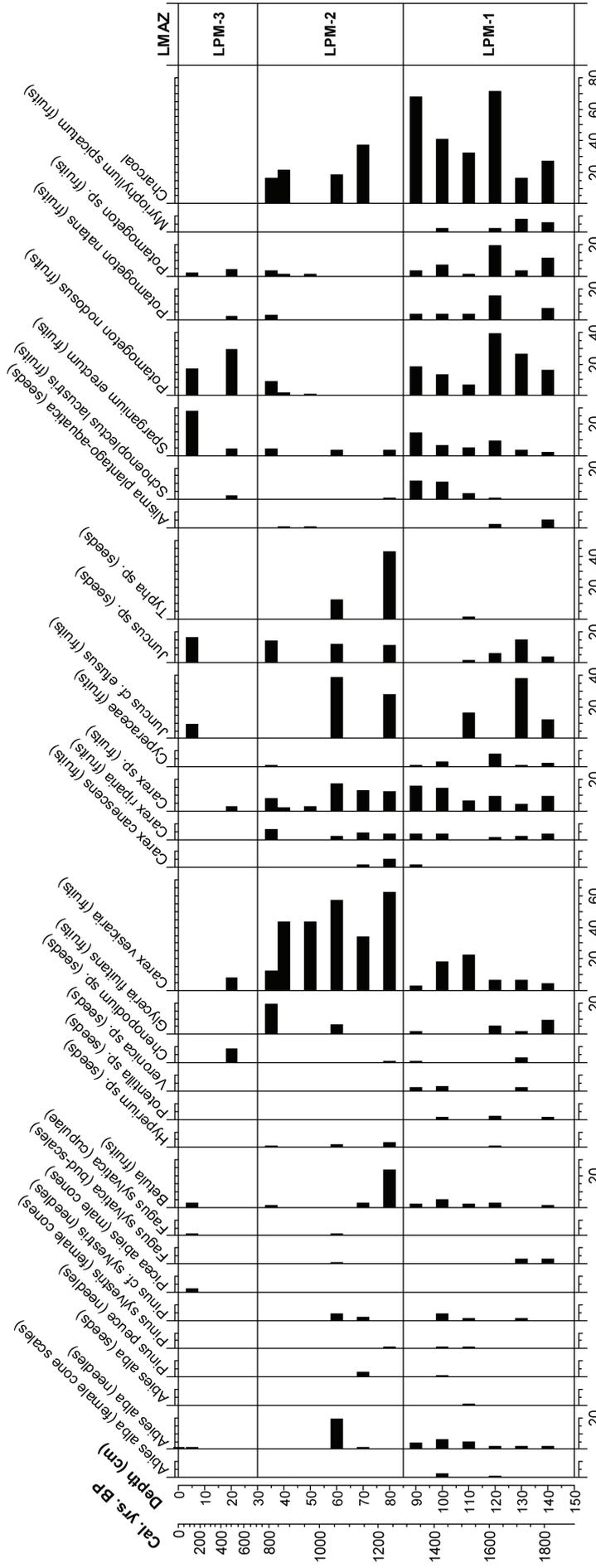
LPAZ LP-3: Core P-2 (22-0 cm); Core P-3 (47-0 cm) (*Picea-Pinus diploxylon-Abies*) (570/550 cal. yrs. BP-till present)

The most characteristic feature is the rise of *Picea* pollen curve up to 15%, accompanied by *Pinus diploxylon*-type with 40-70%, *Abies* 18%, *Fagus* 10%, *Pinus peuce* 5%, *Corylus* up to 10%. The herb pollen taxa are represented by Poaceae 10%, *Achillea*-type, Cichoriaceae, *Plantago lanceolata*, *Rumex*, etc.

Plant macrofossil analysis

The samples for plant macrofossil analysis were taken from Core P-2 at 10 cm interval with a volume of 50 cm³ and analyzed with a binocular at magnification 10-80x. The plant remains found are presented in absolute numbers on a macrofossil diagram (Fig. 16) (Bozilova et al., 2002; Marinova, Tonkov, 2003). The results allow to distinguish three local macrofossil assemblage zones (LMAZ)

Lake PANICHISHTE (NW Rila Mt., 1370 m)
Plant macrofossil diagram (Core P-2)



Modified after Bozilova et al. (2002)

Figure 16. Plant macrofossil diagram of Lake Panichishte (Core P-2).

and their description (LPM-1 to LPM-3) is briefly as follows:

LMAZ LPM-1 (140–85 cm) (1800–1290 cal. yrs. BP)

Plant remains from coniferous and deciduous trees are determined in almost all samples. Needles/fragments of needles and cone scales of *Abies alba* and *Pinus sylvestris* prevail. Fruits of *Betula* and cupules of *Fagus sylvatica* are also found. In the upper part of the zone appear needles of *Pinus peuce*. The macrofossil record is rich in seeds of telmatic, submerged and floating plants such as *Veronica* sp., *Potentilla* sp., *Glyceria fluitans*, *Carex vesicaria*, *Carex riparia*, *Juncus atrata*-type, *Schonoeplectus lacustris*, *Potamogeton nodosus*, *Potamogeton natans*, *Sparganium erectum*, *Myriophyllum spicatum*. Charcoal fragments are also established.

LMAZ LPM-2 (85–30 cm) (1290–750 cal. yrs. BP)

Abundant needles of *Abies alba* and fruits of *Betula* are recorded in several samples. The quantity of *Carex vesicaria* fruits increases. A characteristic feature is the nearly complete absence of seeds and fruits from hydrophytes such as *Potamogeton natans*, *Potamogeton nodosus* and *Myriophyllum spicatum*. Plant macroremains from trees are lacking in the upper part of the zone. Charcoal particles are also found.

LMAZ LPM-3 (30–0 cm) (750 cal. yrs. BP–till present)

Male cones of *Picea abies*, few needles of *Abies alba* and fruits of *Betula* and *Fagus sylvatica* are determined in the uppermost sample. The quantity of seeds and fruits from *Sparganium erectum*, *Juncus* sp. and *Potamogeton natans* increases.

Vegetation history in the Northwestern Rila Mountain

Lateglacial

The age of the sediment cores of the three glacial lakes studied is assumed to be older than 15000–16000 cal. yrs. BP (Fig. 6). The exact time when the lakes became free of ice and grey silt has started to accumulate could not be defined as attempts to obtain radiocarbon dates from the bottom parts of

the cores were not successful. However, it could be suggested that the local cirque glacier has retreated above 2300–2400 m after the end of the Last Glacial Maximum c. 19000 cal. yrs. BP (Tonkov et al., 2008).

The length of the lateglacial sections studied is 113 cm for Lake Sedmo Rilsko (Fig. 5a), 173 cm for Lake Ribno (Fig. 9a) and 158 cm for Lake Trilistnitsa (Fig. 12a). Before the termination of the Late Pleniglacial c. 15000 cal. yrs. BP the biostratigraphy of pollen zones LSR-1, LR-1 and LT-1 indicates typical glacial conditions at high-mid altitudes where open herb vegetation of “mountain-steppe” character dominated by *Artemisia*, *Chenopodiaceae*, *Poaceae* and various cold-resistant and heliophilous species from *Achillea*, *Centaurea*, *Rumex*, *Thalictrum*, *Galium*, *Dianthus*, *Plantago*, *Brassicaceae*, etc. was widely distributed. This vegetation pattern comprised also isolated stands of pines (*Pinus mugo*, *Pinus sylvestris* and *Pinus peuce*) and shrubland of *Juniperus-Ephedra*. Interest attaches to the find of *Ephedra fragilis* pollen complementary to *Ephedra distachya*. Both species were important constituents of the lateglacial flora and inhabited open sandy places. Today *Ephedra fragilis* ssp. *campylopoda* occurs in only one place in Bulgaria, along the Struma river valley, and has not been reported for the Rila Mountain. The identification of pollen grains of trees other than *Pinus* (*Quercus*, *Corylus*, *Carpinus betulus*, *Alnus*, *Abies*, *Fagus*, *Picea*), though in minimal quantities, suggests their probable survival at lower altitudes in sheltered habitats with sufficient moisture and favorable temperature for growth. Therefore, in the absence of a dense forest cover, the find of deciduous tree pollen in the lateglacial lake sediments is not unusual, and the possible re-bedding in the hard grey silt is most unlikely. Differently, other authors accept possible re-deposition of deciduous tree pollen in the lateglacial sediments from unknown deposits as in the case of Lake Kremensko-5 (2124 m) in the Northern Pirin Mountain (Atanassova, Stefanova, 2003).

Based on the increase of arboreal pollen and the decline for *Artemisia* and *Chenopodiaceae*, it can be concluded, that the tendency to warmer climate has started after 16000 cal. yrs. BP. This

trend appears in good conformity with the isotopic signal from ice-cores, the Netherlands and the Alps at the end of Greenland Stadial 2, preceding the Bölling/Alleröd interstadial complex (de Klerk, 2004) (Fig. 17)

The pollen assemblages point unequivocally to an initial stage of afforestation in the approaches to the lakes with pines (*Pinus mugo*, *Pinus sylvestris* and *Pinus peuce*) and *Betula* which has begun c. 15000 cal. yrs. BP. The pine-birch stands restricted the distribution of the mountain herb vegetation and at lower altitudes deciduous trees (*Quercus*, *Carpinus betulus*, *Corylus*) spread from their local refugia as the climate became warmer. The radiocarbon dates of 12640 ± 70 ^{14}C yrs. BP and 12692 ± 67 ^{14}C yrs. BP (Tables 1 and 2) mark the establishment of interstadial vegetation with a maximal spread of trees c. 14000 cal. yrs. BP. The deposition of clay/gyttja richer in organic content serves also as an indication for a change in the trophic conditions

of the lakes and for a higher bioproductivity of the surrounding vegetation.

The time interval identified with pollen zones LSR-2, LR-2 and LT-2 can be successfully correlated with the Bölling/Alleröd interstadial complex from Western Europe. Oxygen isotope studies from Switzerland (Lotter et al., 1992; Ammann et al., 1994) and The Netherlands (Hoek, 1997; Hoek, Bohncke, 2001) indicated a major temperature rise around 12600/12450 ^{14}C yrs. BP with a simultaneous expansion of (shrub) forests according to the paleobotanical data.

It is reasonable to compare the local vegetation development and radiocarbon chronology with the palaeoclimatic signal from Greenland ice-cores (INTIMATE event stratigraphy) (Fig. 17). Following the age-depth models the distinct rise of *Betula*, *Pinus* (*Pinus peuce*, *Pinus diploxylon*-type) and *Juniperus* after c. 15000 cal. yrs. BP is close to the oxygen-isotope shift with a prominent rise in tem-

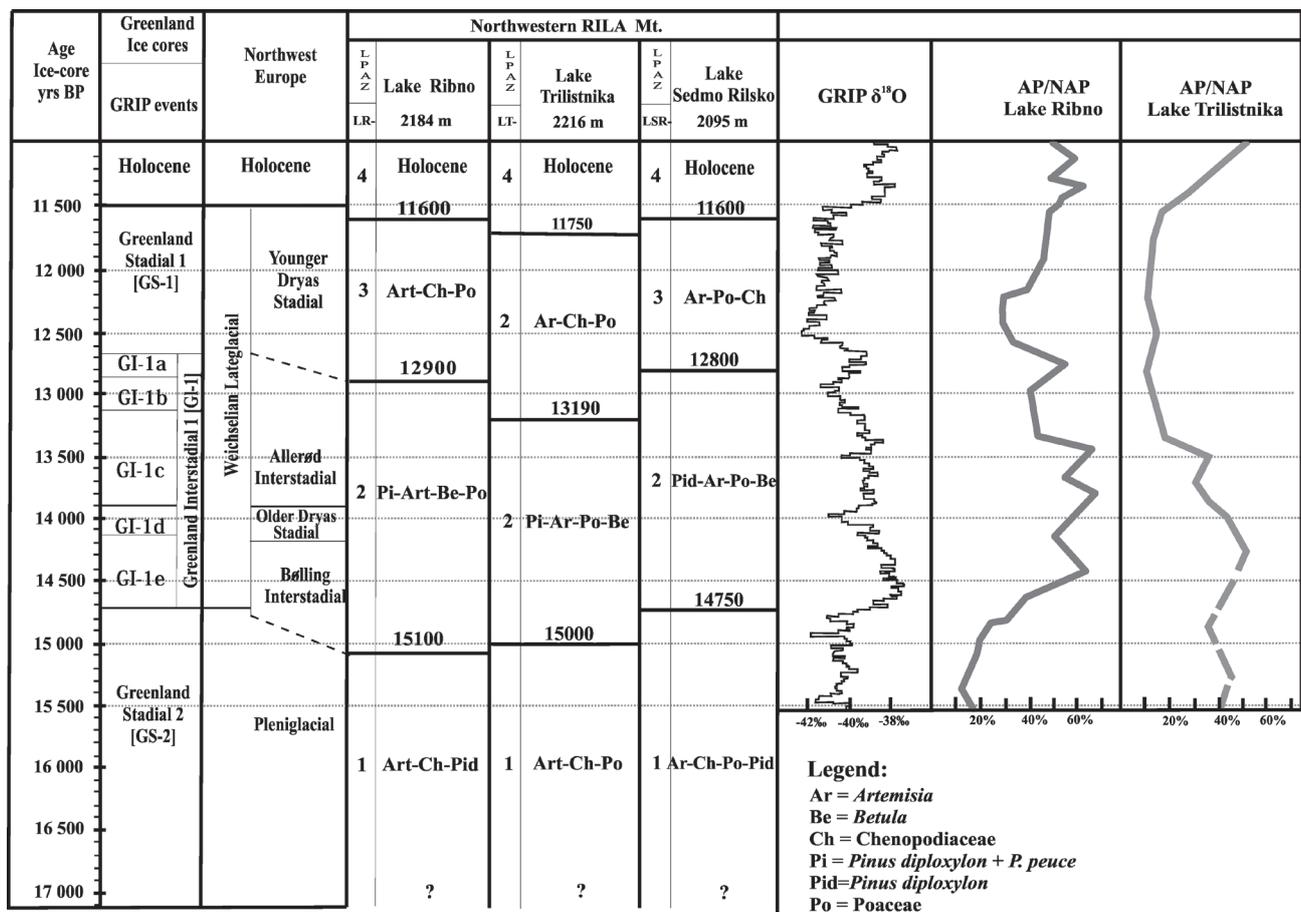


Figure 17. Comparison of the lateglacial palynostratigraphy and chronology of the lakes studied in the Northwestern Rila Mountain with the lateglacial $\delta^{18}\text{O}$ record and event stratigraphy from the GRIP Greenland ice-core (modified after Tonkov et al., 2011).

perature at the start of GI-1e c. 14670 ice-core years before present recorded in the GISP2 core (Stuiver et al., 1995) and at 14700 ice-core years in the GRIP ice-core (Björck et al., 1998). The colder periods GI-1b and GI-1d of the Greenland Interstadial with shorter duration were not identified in the lateglacial pollen diagrams from the Northwestern Rila Mountain probably because the established vegetation cover was not influenced by such short-lived climate fluctuations. However, the decline of total arboreal pollen, mainly for *Pinus* and *Betula*, after c. 13200 cal. yrs. BP indicates a cooling trend at the end of the lateglacial interstadial.

The lateglacial pollen records reveal a reversal towards stadial conditions in the Rila Mountains and this stratigraphic interval, identified with pollen zones LSR-3, LR-3 and LT-3, can be correlated with the last cold phase at the termination of the Lateglacial, the Younger Dryas stadial (Alley, 2000). The drop in temperature and precipitation has favored the re-advance of the mountain herb vegetation and trees have moved downslope. Several radiocarbon dates were obtained for this stadial phase in the Northwestern Rila Mountain, namely from Lake Ribno (Table 2), which aid support in the interpretation of changes in vegetation and climate. The transition from the Bölling/Alleröd interstadial complex to the Younger Dryas stadial has occurred c. 13000/12900 cal. yrs. BP. This result comes in good conformity with the ice-core event GS-1 (Greenland Stadial 1), the Younger Dryas cold event, which has started at 12900 cal. yrs. BP. Indications for a climate warming after 12100 cal. yrs. BP, following the most unfavorable environmental conditions c. 12500 cal. yrs BP, are manifested by the rise of the arboreal pollen curve and the decline for *Artemisia* and *Chenopodiaceae* (Fig. 9a). The transition to Holocene at c. 11700/11600 cal. yrs. BP is clearly marked by the steep rise of the arboreal pollen, attributed mainly to *Pinus*, *Betula*, *Quercus*, *Corylus*, *Carpinus betulus*, and a sharp decline for *Artemisia* and *Chenopodiaceae*.

Holocene

The Holocene vegetation succession in the study area has followed several stages determined by the migration and expansion rates of the main decid-

uous and coniferous trees, and influenced by the climatical, ecological and anthropogenic factors. The time span of these stages and their approximate age ranges are based on the local radiocarbon chronology established (Fig. 6).

The onset of the Holocene was characterized by a quick decline of the “mountain steppe” herb vegetation, the initiation of the re-forestation processes and a change of the type of sediments deposited in the lakes from clay to gyttja (Lotter, Hofmann, 2003). The first Holocene vegetation stage lasted between 11700/11600 and 8000/7900 cal. yrs. BP (pollen zones LSR-4, LR-4 and LT-4) and within it two phases could be distinguished. The duration of the first phase is estimated at 1500-1600 years when pioneer forests of *Betula* have occupied the mountain slopes at mid-higher altitudes on barren soil replacing in many areas the remnants of the lateglacial herb vegetation. A pronounced decline of the “mountain-steppe” elements from *Artemisia*, *Chenopodiaceae*, *Poaceae*, *Achillea*, *Aster* and other herb taxa is observed but they still occupied a great share of the area around the lakes. In the close vicinity to the cirque the birch forests were sparser, accompanied by stands of pines (*Pinus mugo*, *Pinus sylvestris* and *Pinus peuce*), *Alnus* (most probably *Alnus viridis*) and *Juniperus* shrubland. The presence of *Pinus* sp. was confirmed by the find of fossil stomata in the sediments of Lake Ribno c. 10000 cal. yrs. BP (Fig. 9). The pollen data reflect also the beginning of widespread of mixed *Quercus* forests with abundant *Tilia*, *Ulmus*, *Fraxinus excelsior* and *Acer* below the birch zone. The deciduous forests reached their maximal distribution c. 10000-9800 cal. yrs. BP, which marked the commencement of the second phase, when *Corylus* has started to expand in the study area. The absence of a dense forest cover above the deciduous tree zone has facilitated the pollen transport upslope to the subalpine area. By that time, *Abies* has finally established in the vegetation cover of the Northwestern Rila Mountain after 8300-8200 cal. yrs. BP. Even more, the short-term peak for *Abies* pollen curve, registered just before 9900 cal. yrs. BP, (Fig. 12) and the abundance of *Polypodiaceae* spores, can be viewed as a response to more humid climate.

The second stage in the vegetation development, which broadly coincided with the Holocene climatic optimum, was characterized by important changes in the forest composition and its altitudinal zonation after 8000/7900 cal. yrs. BP. In the course of c. 2000 years the ecological conditions have favored the vertical migration of the conifers, (pollen zones LSR-5, LR-5 and LT-5; Fig. 6), particularly for *Abies* from lower altitudes and for *Pinus peuce*. The pioneer forests of *Betula*, and partly those of the mesophilous deciduous trees (*Quercetum mixtum*) and *Corylus*, gave way to *Pinus sylvestris*, *Pinus peuce* and *Abies*. Stomata of *Pinus* sp. found in the fossil record of Lake Ribno indicate local presence of pines at this altitude, most probably *Pinus mugo*. *Carpinus betulus* also slightly increased in the transitional zone between the deciduous and coniferous forests, together with the continuous, though still restricted appearance of *Fagus* stands. In the coniferous belt, or above it on rocky places, stands of birch were preserved as proved by the find of *Betula* fruits in Lake Sedmo Rilsko, radiocarbon dated at 7400 cal. yrs. BP (Table 1). The formation of a coniferous belt presumes a climate shift towards cooler summers and warmer winters with increase in air and soil humidity in the Northern Mediterranean during the second half of the Atlantic period (Cheddadi et al., 1997), in contrast to a warming trend in Northern Europe (Davis et al., 2003). The appearance of *Hedera* pollen in the fossil record confirms this assumption.

The dynamic changes in the vegetation cover manifested after 5800 cal. yrs. BP (pollen zones LSR-6, LR-6 and LT-6; Fig. 6) lasted for 2400 years. Some increase for *Pinus peuce*, *Pinus sylvestris* and *Pinus mugo* was recorded as well as the commencement of the gradual decline for *Abies* after its maximal spread at 4730 cal. yrs. BP. This transformation coincided with the regular, though still restricted occurrence of *Picea abies* in the study area. This time interval has marked the final establishment and the first signs of a wider distribution for *Fagus* in the Northwestern Rila Mountain. The spread of beech has begun rather late, after 4500 cal. yrs. BP, although its immigration from lower altitudes had started earlier c. 7800 cal. yrs.

BP. Beech has formed pure or mixed woodstands either with *Abies alba* or with *Carpinus betulus*, predominantly on northern slopes. Several alternatives alone, i.e. anthropogenic impact, climate change, deterioration of soil conditions or their complex interaction could be proposed to explain the establishment and subsequent expansion of *Fagus* in the mountains of the Balkans, Bulgaria included (Huntley et al., 1989; Bennet, Willis, 1995; Bradshaw, Sykes, 2014). The climate change has been according to Huntley et al. (1989) the primary factor controlling Holocene migrations and abundance changes of *Fagus* in Europe and North America. At least in the lower mountain ranges of Southwestern Bulgaria the spread of *Fagus* on the place of the coniferous *Pinus-Abies* communities was favored by the anthropogenic activities (Tonkov, 2007; Marinova et al., 2012).

The first indications of human interference are visible in the pollen diagrams c. 3700 cal. yrs. BP when pollen grains of *Cerealia*-type, together with the continuous presence of anthropogenic indicators such as *Plantago lanceolata* and *Rumex*, appeared accompanied by a decline for *Abies*. The archaeological information points to a rise in the number of the Late Bronze Age settlements (3400–3200 cal. yrs. BP) in the foothills of the mountains surrounding the Struma valley, and an intensification of the human activity, including deforestation (Marinova et al., 2012).

After 3400 cal. yrs. BP *Picea abies* started to invade areas in the coniferous belt, reaching its first expansion maximum c. 2700 cal. yrs. BP (pollen zones LSR-7, LR-7 and LT-7). This change in the vegetation cover was mainly climatically driven as a shift to lower average temperatures and an increase in precipitation that has occurred in the Northern Hemisphere. Concurrently, in the fossil record of Lake Sedmo Rilsko, the rise of *Picea abies* and the tendency for a decline of *Abies* coincided with the appearance of pollen of anthropogenic indicators.

The vegetation history in the study area since 2700 cal. yrs. BP years was characterized by an intensification of the human interference in all vegetation belts. At many places the upper tree-line was artificially lowered in order to extend pasture

land. Even at high altitudes the find of pollen of cereals from *Triticum*-type and *Cerealia*-type, and of *Juglans*, points to well-developed agriculture and cultivation of walnut in the foothills of the mountain, whereas pollen of *Rumex*, *Plantago lanceolata*, *Scleranthus* is indicative of livestock-grazing in the mountain meadows.

The final enlargement in the distribution of *Picea abies* and *Fagus* was reached in medieval times after 1600 cal. yrs. BP. Subsequently, both trees partly declined, whilst larger areas were occupied by pines, mostly *Pinus mugo* in the subalpine belt and *Pinus sylvestris*.

A more detailed picture of the vegetation history and human impact at lower altitudes (1300-1400 m) in the Northwestern Rila Mountain for the last 2000 years is obtained from the sediment archive of Lake Panichishte. The results complement the paleoenvironmental reconstruction for the study area in historical time.

The pollen and plant macrofossils records revealed that for the period 1900-1200 cal. yrs. BP or 50-750 AD (Figs. 14, 15 and 16) coniferous forests dominated by *Pinus sylvestris* and *Abies alba*, with some *Pinus peuce* and few *Picea abies*, were distributed around the lake. Monodominant plant communities of beech, or mixed in some places with fir and pines, also existed in the vicinity of the lake, as proved by the find of female cones and needles from *Abies alba*, needles and seeds from *Pinus sylvestris* and leaf bud-scales from *Fagus sylvatica*. The deciduous forests were composed of various oak species with *Carpinus betulus*, *Carpinus orientalis*, *Tilia* and *Corylus* on more open areas. The herb communities consisted of Poaceae, *Artemisia*, Chenopodiaceae, Cichoriaceae, *Achillea*, *Ranunculus*, Brassicaceae species. The regular presence of anthropogenic pollen indicators such as *Plantago lanceolata*, *Polygonum aviculare*, *Rumex*, *Cerealia*-type, *Secale*, *Triticum*-type, though in low quantities, testifies for livestock-grazing in the meadows and cereal cultivation in the foothills of the mountain.

After 1200 cal. yrs. BP or 750 AD some changes are recorded in the composition of the forests around the lake. Part of them were probably destroyed c. 1100 AD and, subsequently, open

areas were colonized by *Betula* and various herbs. In the entire Core P-2 (Fig. 16) quite common are fruits from *Betula pendula* with a pronounced maximum shortly before 700 AD. The high quantities of charcoal fragments found presumes the occurrence of natural or human induced forest fires. Also, *Picea abies* and partly *Pinus peuce* started gradually to expand.

In the course of several centuries (1400-1700 AD) the share of *Abies alba* and *Fagus sylvatica* in the forests considerably declined, caused mainly by an increase of the human impact and the invasion of *Picea abies*. Spruce has benefited from the optimal ecological conditions for growth in the forest zone between 1600 and 1300 m, concurrent with the duration of the Little Ice Age (1550-1850 AD) (Grove, 1988), and obviously being climatically influenced. Such a late peak of *Picea* pollen curve was not detected in the pollen diagrams from the subalpine glacial lakes. The herb communities composed of various Poaceae, *Artemisia*, *Achillea*, Cichoriaceae, *Ranunculus*, Brassicaceae species, as well as *Rumex*, *Plantago aviculare* and *Juniperus*, occupied vast areas thus pointing to intense seasonal livestock-grazing. The abundance of anthropogenic pollen confirms the cultivation of cereals (*Triticum*-type, *Secale*) at lower elevations.

The last three centuries in the vegetation development witnessed the establishment of the present-day appearance of the forest cover around Lake Panichishte, dominated by *Pinus sylvestris* and *Picea abies*, with an admixture of *Abies alba*. The communities of beech were reduced in their distribution which could be explained by competition with the conifers, the insufficient air humidity and the soil structure. The pollen records reflect also a decline of the deciduous oak forests, quite probably as a result of their heavy exploitation for various purposes by the local population.

Central Rila Mountain – Study sites

Lake Manastirsko-2 (site 5)

The lake is situated at 2326 m (42°07'46.78"N; 23°24'42.16"E) in the subalpine belt. The lake is

Table 5. Radiocarbon dates from Lake Manastirsko-2.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, $\pm 2\sigma$ (mid-point)	Material dated
Ua-47271	26-28	1245 \pm 75	980-1300 (1140)	peat
Ua-49249	36-38	1517 \pm 31	1330-1530 (1430)	peat
Ua-47272	80-82	1915 \pm 38	1730-1950 (1840)	peat
Ua-48421	130-132	2703 \pm 41	2750-2880 (2815)	peaty gyttja
Ua-47273	180-182	3380 \pm 42	3480-3730 (3605)	peaty gyttj0a
Ua-48422	240-242	5858 \pm 47	6540-6790 (6665)	peaty gyttja
Ua-47274	280-282	7680 \pm 93	8310-8660 (8485)	peaty gyttja
Ua-47275	320-322	8972 \pm 106	9650-10400 (10025)	peaty gyttja
Ua-47423	360-362	9732 \pm 75	11060-11270 (11165)	peaty gyttja
Ua-49250	388-390	10380 \pm 85	11950-12550 (12250)	gyttja
Ua-47276	405-407	11209 \pm 168	12700-13400 (13050)	gyttja
Ua-49251	413-415	11796 \pm 174	13250-14050 (13650)	gyttja

75 m long, 50 m wide, with a surface area of 0.2 ha and a maximum water depth of 2 m. The shores of the lake are flat and marshy, surrounded by sparse groups of *Pinus mugo* and *Juniperus sibirica* among herb vegetation. The inlet brings water from a small upper lake and the outlet drains into Vodniza river (Ivanov, 1964) (Figs. 2 and 18).

Coring, lithology and radiocarbon dating

A sediment core 4.15 m long was obtained from the peaty southeastern shore of the lake with Dachnowsky hand-coring equipment. The lithology of the sediments is: 0-120 cm peat with sand, 120-385 cm peaty gyttja, 385-415 cm light-green gyttja. The radiocarbon age of 12 bulk sediment samples was determined and the results are shown on Table 5. The age of the sediment core is estimated at c. 13700 cal. yrs. BP (Tonkov et al., 2016).

Pollen analysis

Pollen analysis was conducted at 5 cm (2.5 cm for the lateglacial section) interval and a percentage pollen diagram is constructed (Fig. 19). Pollen accumulation rates for the major tree/shrub and herb taxa are also calculated (Fig. 20). Fossil

**Figure 18.** A view of Lake Manastirsko-2 (Photo S. Tonkov).

Lake MANASTIRSKO-2 (Central Rila Mt., 2326 m)

Percentage pollen diagram

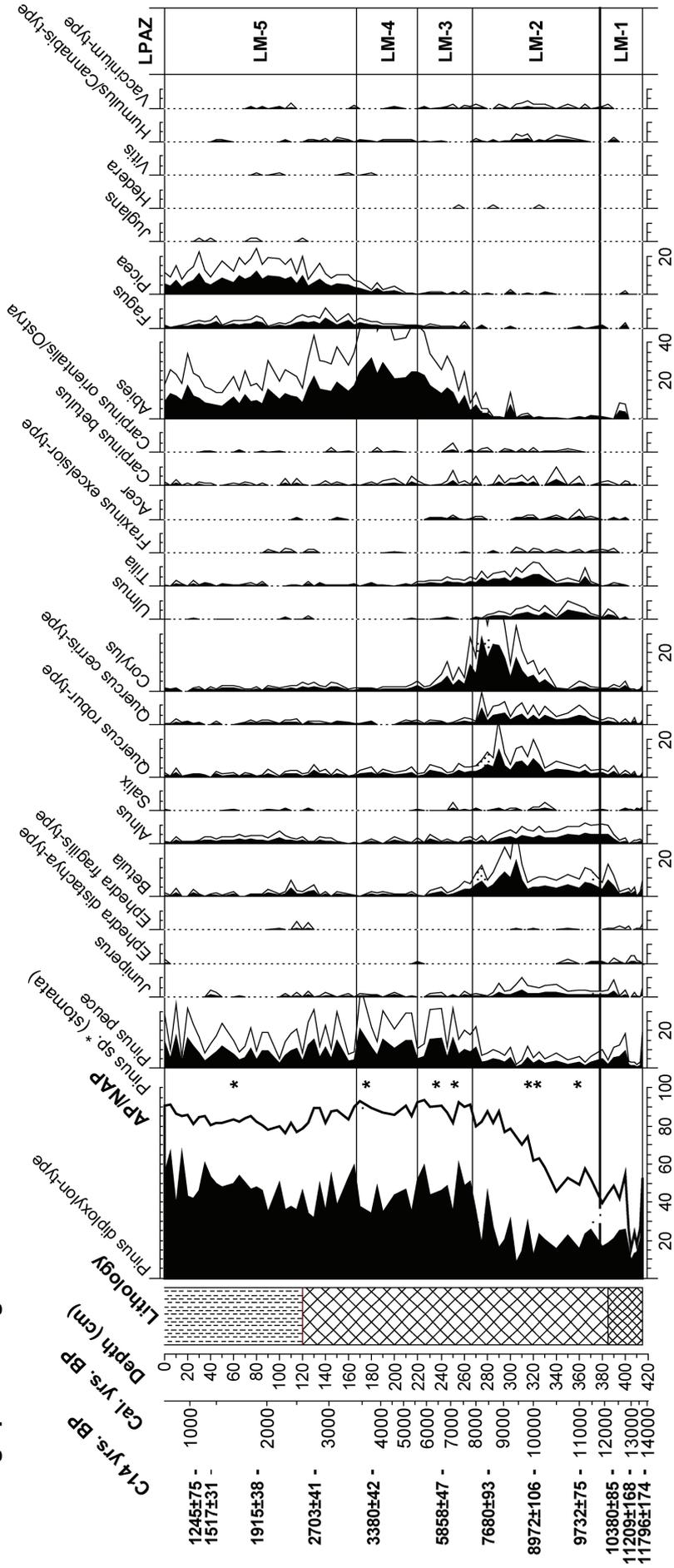
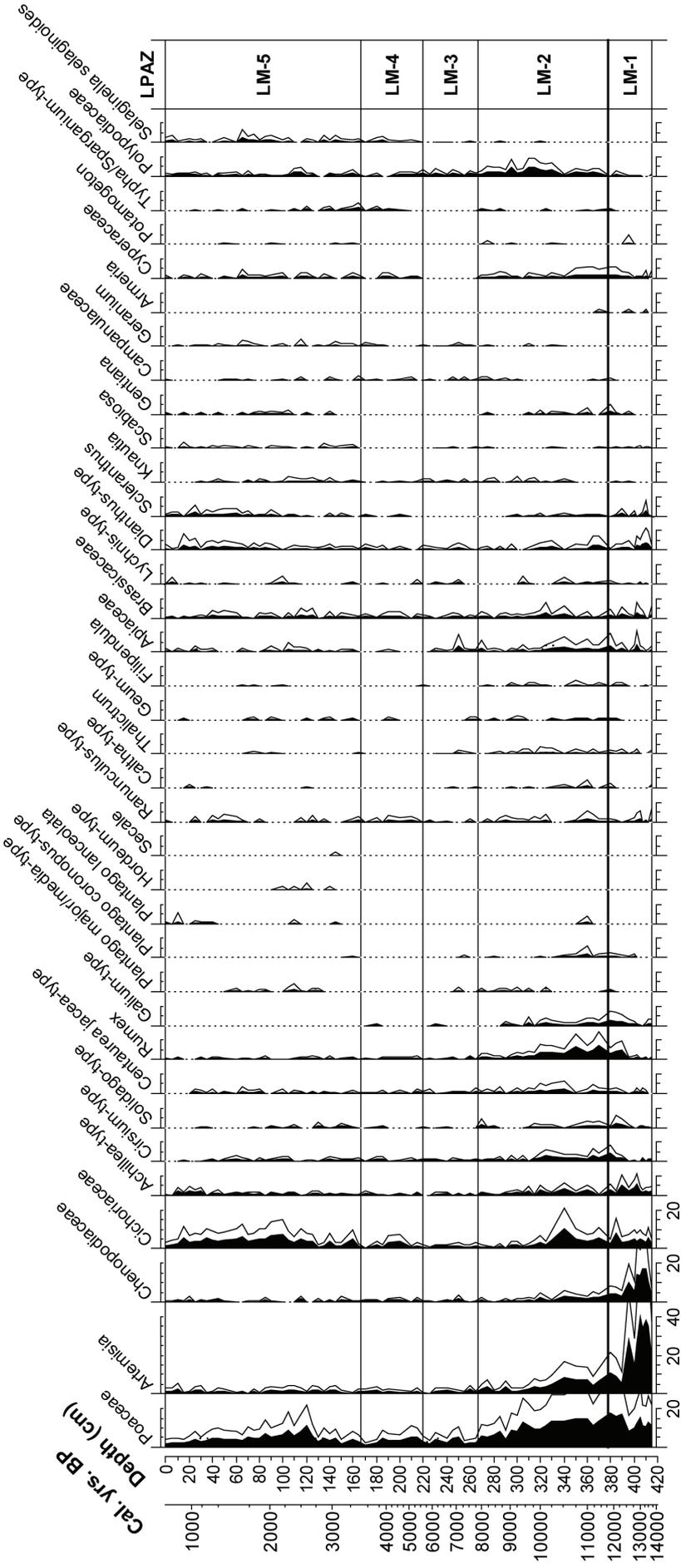


Figure 19. Percentage pollen diagram of Lake Manastirsko-2.

Lake MANASTIRSKO-2 (Central Rila Mt., 2326 m)

Percentage pollen diagram (continuation)

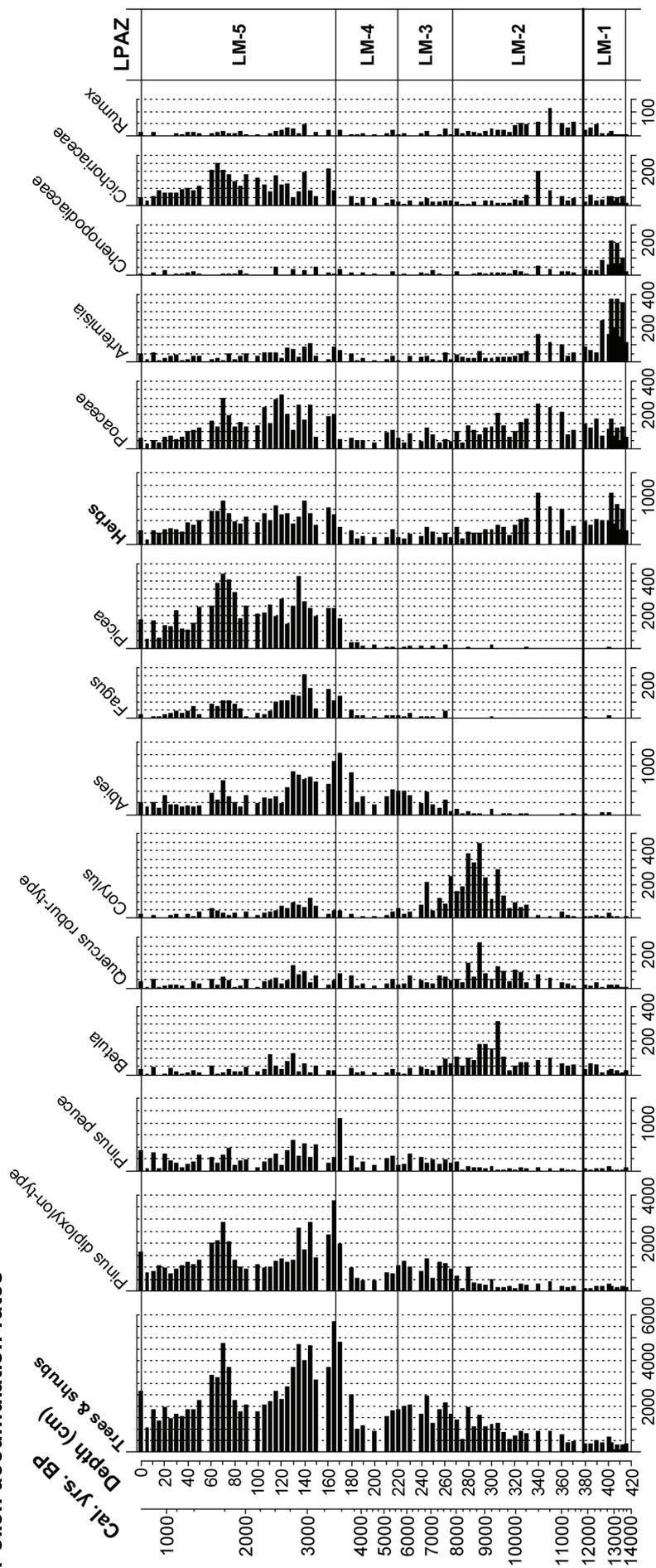


Modified after Tonkov et al. (2016)

Figure 19. Continued.

Lake MANASTIRSKO-2 (Central Rila Mt., 2326 m)

Pollen accumulation rates



Modified after Tonkov et al. (2016)

Figure 20. Pollen accumulation rates (PAR; pollen grains $\text{cm}^{-2}\text{yr}^{-1}$) for the main tree/shrub and herb taxa from Lake Manastirsko-2 plotted against age (cal. yrs. BP).

stomata were occasionally found on pollen slides from several sample depths and their presence (*) is indicated on the pollen diagram. All stomata were identified as *Pinus* sp. On the pollen diagram five local pollen assemblage zones (LPAZ) are recognized (LM-1 to LM-5) (Figs. 19 and 6). Brief descriptions are as follows:

LPAZ LM-1 (415-378 cm, *Artemisia*-*Chenopodiaceae*-*Pinus*-*Poaceae*) (13700-11600 cal. yrs. BP).

Tree pollen varies between 20% and 45% with two short peaks of 55% at levels 415 cm and 405 cm. The main constituent is *Pinus diploxylon*-type 10-30%, accompanied by *Pinus peuce* up to 10%, *Betula* 5-10%, *Juniperus*, *Quercus*, *Tilia*, *Ulmus*, *Corylus* and *Alnus*, each up to 5%, and some *Ephedra* (*distachya*-type and *fragilis*-type). A short-term rise of *Abies* pollen of 5% is also recorded. Herb pollen is represented by *Artemisia* 15-40%, *Chenopodiaceae* up to 18%, *Poaceae* up to 15%, *Achillea*-type up to 5%, *Cichoriaceae* 5-8%, *Galium*-type, *Rumex*, *Cirsium*-type, *Apiaceae*, *Brassicaceae*, *Dianthus*-type, etc. The PAR of trees (shrubs) and herbs is rather low, c. 500 grains cm⁻² yr⁻¹ for each of both groups. The arboreal pollen influxes are contributed mainly by *Pinus diploxylon*-type with 150-250 grains.

LPAZ LM-2 (378-267 cm, *Betula*-*Quercetum mixtum*-*Corylus*-*Pinus*) (11600-7900 cal. yrs. BP)

Tree pollen increases from 40% to 75%, due to *Pinus diploxylon*-type 20%, *Pinus peuce* 5%, *Corylus* up to 10%, *Betula* 5-8%, *Quercus robur*-type up to 10%, *Tilia* 5-7%, *Quercus cerris*-type 5%, *Alnus*, *Ulmus* and *Tilia*. Subsequently, *Corylus* starts to dominate with 15-25%, together with *Betula* up to 20%, *Quercus robur*-type up to 15% and *Quercus cerris*-type 5%. The continuous pollen curve of *Abies* appears reaching 7%. Pollen grains of *Fagus* and *Picea* are regularly determined. The herb pollen taxa are represented by *Poaceae* 8-15%, *Artemisia* 5-8%, *Cichoriaceae* 5-10%, *Chenopodiaceae* 5%, *Rumex* 5-7%, *Ranunculus*-type, *Brassicaceae*, *Apiaceae* and *Galium*-type each with 3-5%. The arboreal PAR increases gradually from c. 500 to nearly 2000 grains cm⁻² yr⁻¹, contributed significantly by *Pinus diploxylon*-type 500-1000, *Betula* up to 300, *Corylus* 400-450 and *Quercus robur*-type up to 200.

LPAZ LM-3 (267-220 cm, *Pinus*-*Abies*) (7900-5600 cal. yrs. BP)

The pollen curves of *Abies*, *Pinus diploxylon*-type and *Pinus peuce* rise reaching 25%, 50-60% and 15%, respectively. Pollen of deciduous trees from *Betula*, *Quercus robur*-type, *Quercus cerris*-type, *Corylus*, *Tilia* and *Ulmus* quickly declines. The continuous presence of *Fagus* and *Picea*, though with low frequencies, is recorded. The PAR for *Pinus diploxylon*-type and particularly for *Pinus peuce* and *Abies* doubled compared to the previous zone. Changes in the presence of the herb pollen taxa are not established, except for a decline of *Poaceae* below 5%.

LPAZ LM-4 (220-167 cm, *Abies*-*Pinus*-*Fagus*) (5600-3400 cal. yrs. BP)

Tree pollen dominates with 80-90%, attributed to *Pinus diploxylon*-type 40-60%, maximal frequencies for *Abies* 25-30%, *Pinus peuce* 10-20%, *Fagus* and *Picea* each with 3-5%. Continuous pollen curves for *Betula*, *Quercus robur*-type and *Alnus* are recorded. The PAR for the main coniferous species starts sharply to increase, reaching maximal values: *Pinus diploxylon*-type 3000 grains cm⁻² yr⁻¹, *Pinus peuce* 1000 and *Abies* 1250. The most frequent herb pollen taxa are *Poaceae* 5%, *Artemisia*, *Cichoriaceae*, *Rumex*, *Cirsium*-type, *Ranunculus*-type, *Brassicaceae*, etc.

LPAZ LM-5 (167-0 cm, *Pinus*-*Picea*-*Abies*-*Fagus*) (3400 cal. yrs. BP-till present)

Pollen of *Picea* continues to increase and reaches 10-15%, while *Abies* declines to 10-15%. High values are established for *Pinus diploxylon*-type 60-65% and *Pinus peuce* 10-15%. A slight increase for *Betula*, *Corylus*, *Alnus* and *Fagus* is recorded. Pollen of *Juglans* is occasionally found. In the uppermost samples the total PAR of trees and shrubs substantially decreases, particularly noticeable for *Pinus diploxylon*-type, *Picea abies*, *Abies* and *Fagus*. A higher diversity of herb pollen taxa is present, in particular the appearance of anthropogenic indicators like *Secale*, *Hordeum*-type and *Plantago lanceolata*, accompanied by an increase for *Poaceae* and *Cichoriaceae* pollen. A secondary rise for the pollen curve of *Cichoriaceae* with 5-8% is established, together with *Poaceae*, *Achillea*-type, *Artemisia*, *Scleranthus*, *Brassicaceae*, etc.

Peat bog Vodniza (site 6)

This peat bog, a former lake, is located near the timber-line at 2113 m (42°07'46.78"N; 23°24'42.16"E) at a distance of c. 200 m in altitude below Lake Manastirsko-2 (Fig. 2). The site has an elongated shape 90 m long and 40 m wide. It is formed in a depression with a steep and stony southwestern slope, surrounded by groups of *Pinus mugo*, *Pinus peuce*, *Picea abies* and *Juniperus sibirica*. A small brook runs through the peat bog and drains into Vodniza river. The bog surface and its peripheral parts are overgrown by spots of *Sphagnum* sp., *Carex nigra*, *Carex rostrata*, *Deschampsia caespitosa*, *Eriophorum angustifolium*, *Eriophorum latifolium*, *Parnassia palustris*, *Geum coccineum*, *Geum bulgaricum*, *Silene roemerii*, *Veratrum lobelianum*, *Bartsia alpina*, *Rumex alpinus*, *Bistorta vivipara*, *Cirsium appendiculatum*, etc. (Tonkov et al., 2018) (Fig. 21).

Coring, lithology and radiocarbon dating

A sediment core 5 m long was obtained from the central part of the peat bog with Dachnowsky hand-coring equipment. The lithology of the sediments is: 0–215 cm sedge peat with plant fragments, 215–500 cm peaty gyttja. The radiocarbon age of 8 bulk sediment samples was determined

and the results are shown on Table 6. The age of the core is estimated at c. 9800 cal. yrs. BP. (Tonkov et al., 2018).

Pollen analysis

Pollen analysis was conducted at 10 cm interval. A percentage pollen diagram is constructed (Fig. 22). Pollen accumulation rates for the major tree/

Table 6. Radiocarbon dates from Peat bog Vodniza.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Ua-54136	71-73	877±26	720-910 (815)	peat
Ua-54137	151-153	1561±27	1390-1530 (1460)	peat
Ua-55775	214-216	2387±31	2340-2680 (2510)	peaty gyttja
Ua-54138	253-255	3168±28	3350-3460 (3405)	peaty gyttja
Ua-54139	333-335	5196±30	5900-6000 (5950)	peaty gyttja
Ua-55011	384-386	6756±35	7570-7670 (7620)	peaty gyttja
Ua-47275	441-443	7572±34	8340-8430 (8385)	peaty gyttja
Ua-54141	487-489	8501±35	9460-9540 (9500)	peaty gyttja

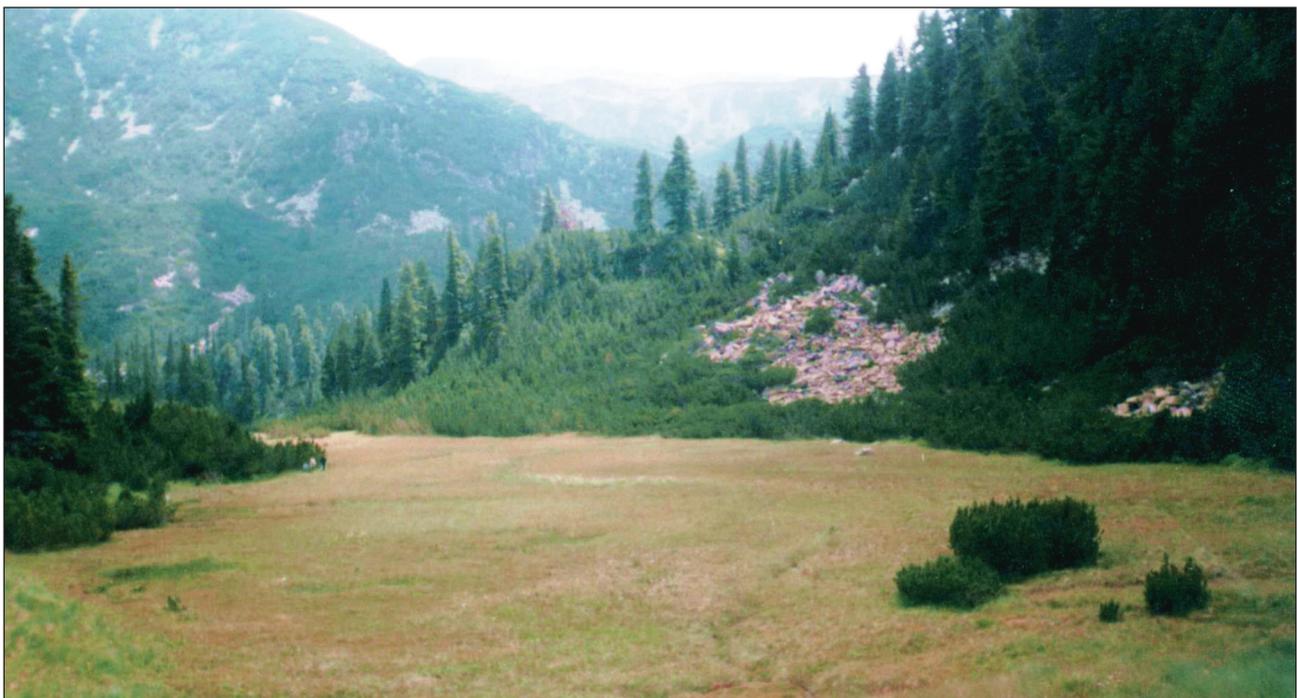


Figure 21. A view of Peat bog Vodniza (Photo S. Tonkov).

Peat bog VODNIZA (Central Rila Mt., 2113 m)

Percentage pollen diagram

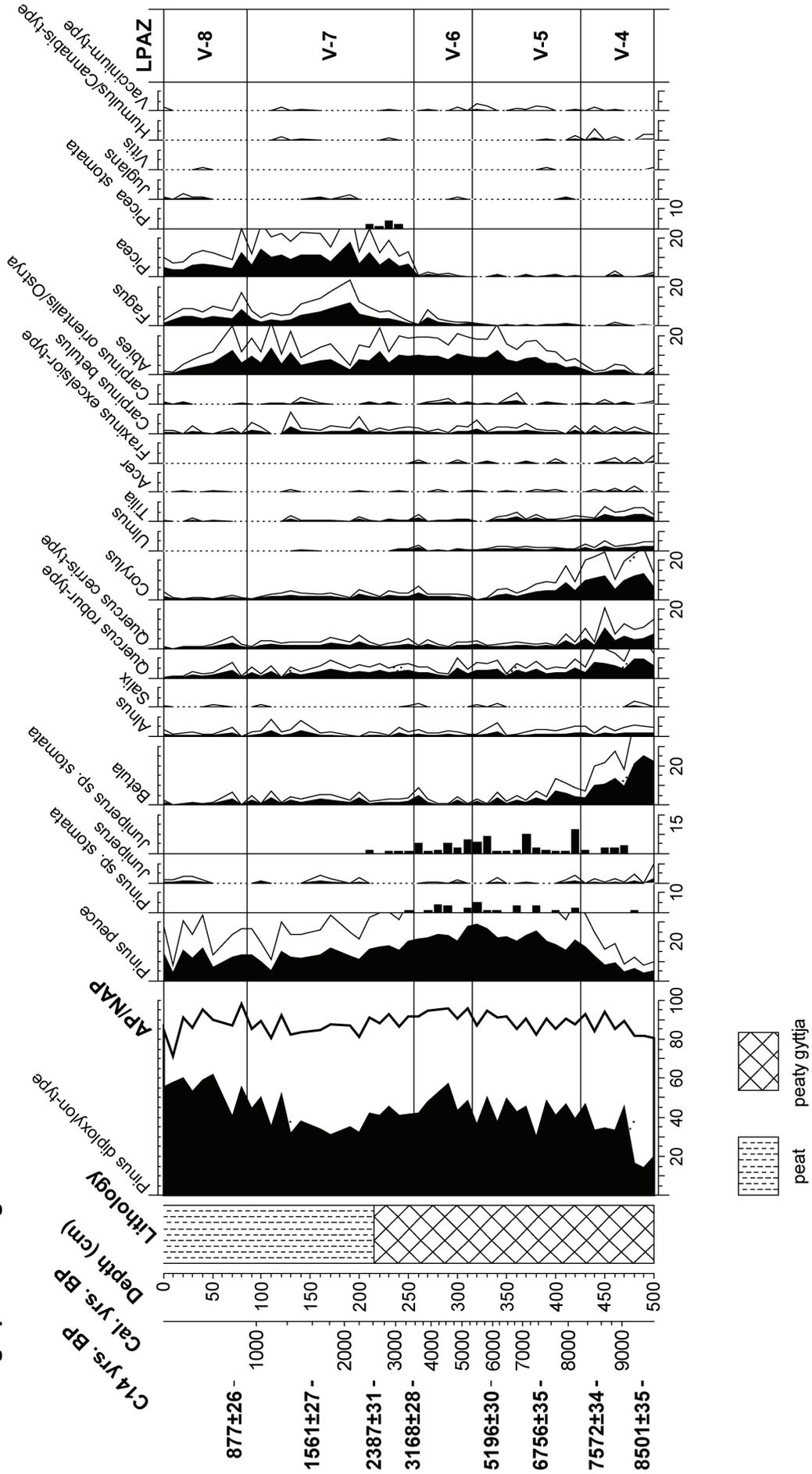
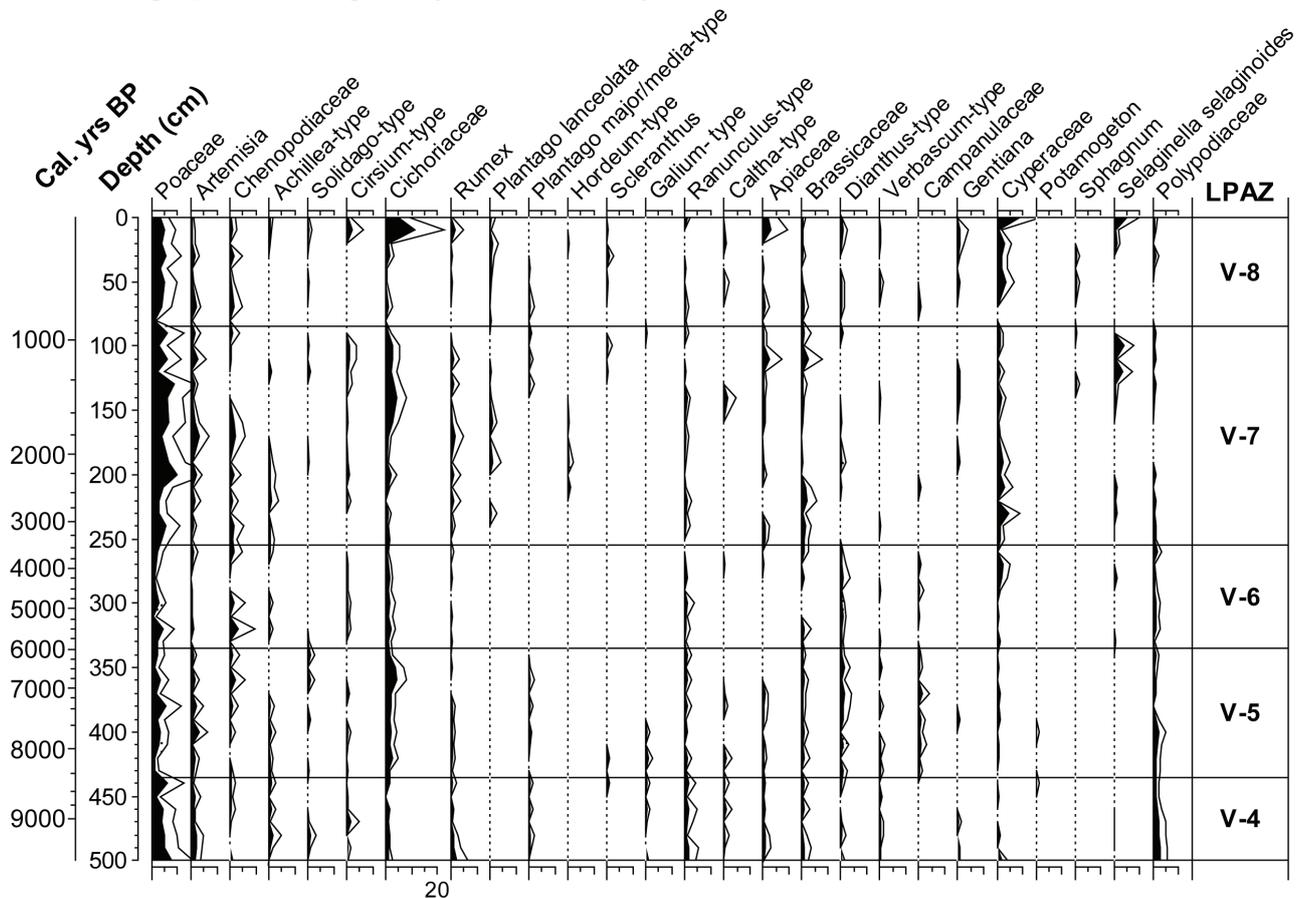


Figure 22. Percentage pollen diagram of Peat bog Vodniza.

Peat bog VODNIZA (Central Rila Mt., 2113 m) Percentage pollen diagram (continuation)



Modified after Tonkov et al. (2018)

Figure 22. Continued.

shrub and herb taxa are also calculated (Fig. 23). On the pollen diagram five local pollen assemblage zones (LPAZ) can be recognized (V-4 to V-8) (Figs. 22 and 6). Brief descriptions are as follows:

LPAZ V-4 (500-425 cm, *Betula-Quercetum* mixtum-*Corylus-Pinus*) (9800-8150 cal. yrs. BP)

Arboreal pollen dominates with 80-95%, due to *Betula* up to 25%, *Pinus diploxylon*-type 20-40%, *Pinus peuce* 5-15%, *Corylus* 5-12%, *Quercus robur*-type 10%, *Quercus cerris*-type 5-10%, *Corylus* 5-12%, *Tilia* 2-4%. Low pollen frequencies are found for *Acer*, *Carpinus betulus*, *Ulmus*, *Alnus*, *Fagus* and *Picea*. The continuous pollen curve of *Abies* starts in this zone. The total arboreal PAR increases from 1500 to 3000 grains $\text{cm}^{-2} \text{yr}^{-1}$, contributed mainly by *Pinus diploxylon*-type 1000, *Betula* 350-500, *Quercus* 200-400, *Corylus* up to 400. Herb pollen is represented by *Poaceae* 5-8%,

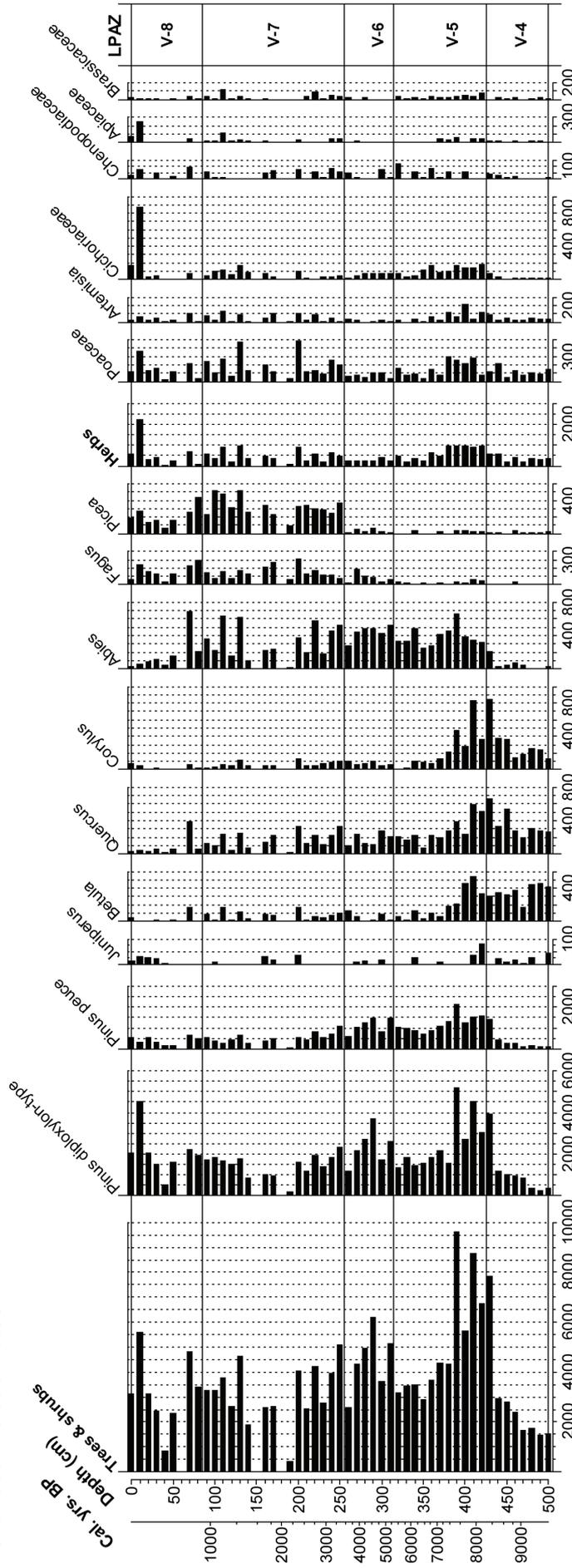
Artemisia 3%, *Cichoriaceae* 2%, *Rumex* 2%, *Ranunculus*-type, *Brassicaceae*, *Apiaceae*, etc. The total PAR of the herbs is c. 500. Spores of *Polypodiaceae* do not exceed 5%.

LPAZ V-5 (425-315 cm, *Pinus-Abies-Corylus*) (8150-5350 cal. yrs. BP)

The pollen curves of *Pinus peuce* and *Abies* rise to 25% and 10%, respectively. The pollen frequency of *Pinus diploxylon*-type is 40-45%. The presence of deciduous tree pollen from *Betula*, *Quercus cerris*-type, *Quercus robur*-type, *Corylus*, *Tilia* and *Ulmus* declines. Pollen of *Fagus* and *Picea*, although with rather low frequencies, is regularly found. Pollen of *Vitis*, *Humulus/Cannabis*-type and *Vaccinium*-type is also recorded. The total PAR of arboreal taxa quickly increases to 7500-9500 grains $\text{cm}^{-2} \text{yr}^{-1}$ (*Pinus diploxylon*-type 4000-4500, *Pinus peuce* 1500-2000, *Corylus* 800) and

Peat bog VODNIZA (Central Rila Mt., 2113 m)

Pollen accumulation rates



Modified after Tonkov et al. (2018)

Figure 23. Pollen accumulation rates (PAR; pollen grains $\text{cm}^{-2}\text{yr}^{-1}$) for the main tree/shrub and herb taxa from Peat bog Vodniza plotted against age (cal. yrs. BP).

than declines to c. 4000. The relevant values for *Abies* reach 400–600. Significant changes in the presence of the herb pollen taxa are not observed, except for a slight rise of Cichoriaceae and a reduction of Polypodiaceae spores.

LPAZ V-6 (315–255 cm, *Pinus-Abies-Fagus*) (5350–3450 cal. yrs. BP)

Tree pollen dominates with 87–95%, attributed to *Pinus diploxylon*-type 40–60%, maximal frequencies for *Pinus peuce* 20–30%, *Abies* 10%, *Quercus robur*-type and *Fagus* each up to 3–5%. Pollen of deciduous trees from *Carpinus betulus*, *Carpinus orientalis/Ostrya*, *Ulmus*, *Tilia* is constantly present with low values. The total PAR of arboreal taxa is between 3500 and 6000 grains $\text{cm}^{-2} \text{yr}^{-1}$, contributed mainly by *Pinus diploxylon*-type 2000–2500, *Pinus peuce* 1000, *Abies* 450, *Fagus* 200. The most frequent herb pollen taxa are Poaceae 5%, Cichoriaceae, Chenopodiaceae, *Ranunculus*-type, *Dianthus*-type, Brassicaceae.

LPAZ V-7 (255–85 cm, *Pinus-Picea-Fagus-Abies*) (3450–950 cal. yrs. BP)

The sharp increase of *Picea* to 10–15% is accompanied by a maximum of *Fagus* 10%. Pollen of *Pinus diploxylon*-type, *Pinus peuce* and partly *Abies* tends to decline. Minor values below 5% are recorded for pollen of *Betula*, *Alnus*, *Corylus*, *Quercus robur*-type, *Quercus cerris*-type and *Carpinus betulus*. Pollen of *Juglans*, *Humulus/Cannabis*-type and *Vaccinium*-type is occasionally found. The total PAR of arboreal taxa is between 2500 and 4500 grains $\text{cm}^{-2} \text{yr}^{-1}$. The values established for *Picea* are 400, for *Fagus* 200–300, and for *Abies* 200–600. The highest presence of Poaceae (up to 10% and PAR of 350), an increase for Cichoriaceae (PAR up to 900), *Artemisia*, Chenopodiaceae, *Rumex*, Brassicaceae is recorded. Pollen of *Plantago lanceolata* and *Hordeum*-type appears. The presence of Cyperaceae pollen and spores of *Selaginella selaginoides* and *Sphagnum* is worth mentioning.

LPAZ V-8 (85–0 cm, *Pinus-Picea-Abies*) (950 cal. yrs. BP–till present)

Arboreal pollen declines to 70%, attributed mainly to *Abies*, *Picea*, *Fagus*, *Pinus peuce*, *Quercus* and *Betula*. Pollen of *Pinus diploxylon*-type reaches a maximum of 60%. The total PAR of arboreal taxa

is similar to the previous zone, with some increase for *Pinus diploxylon*-type to 2000 grains $\text{cm}^{-2} \text{yr}^{-1}$, and a decline for deciduous taxa and *Abies*. The herb pollen is characterized by higher values for Cichoriaceae (PAR up to 900), Apiaceae, Chenopodiaceae, *Plantago lanceolata*.

Stomata analysis

Fossil stomata from needles of conifers were identified and counted together with pollen. Their presence in absolute numbers is indicated on the pollen diagram (Fig. 22). The taxonomical identification was aimed particularly in attempt to distinguish between *Pinus mugo/sylvestris* and *Pinus peuce*. Fossil stomata were regularly found on pollen slides in the interval 480–210 cm (9300–2400 cal. yrs. BP), usually in the form of detached individuals, and rarely in small groups joined by fragmentary epidermal tissue. The number of stomata is below 10 per sample with several exceptions. It is likely that most of the stomata recovered in gyttja sediment cores are released during the disintegration of leaves in shallow peripheral parts and then probably resuspended and distributed in a manner similar to pollen (MacDonald, 2001). The taxonomical resolution usually reaches only the genus level, which is comparable to pollen, but lower than for macrofossils. The taxonomical identification of the fossil stomata revealed that they originated from three genera: *Pinus*, *Juniperus* and *Picea* (Fig. 24). Most numerous are the fossil stomata from *Juniperus* sp., followed by those of *Pinus* (*Pinus mugo/sylvestris*, *Pinus peuce*) and *Picea abies*. Fossil stomata of spruce appear in the sediment record after 3100 cal. yrs. BP, which is in good conformity with the quick rise of *Picea* pollen curve c. 3300 cal. yrs. BP (Fig. 22). The attempts to distinguish between fossil stomata from *Pinus mugo/sylvestris* and *Pinus peuce* (*Diploxylon*-type from *Haploxylon*-type) on the basis of morphological and size differences were not successful, mainly due to their low number and the impossibility to apply measurement statistics. This observation was recently supported by Finsinger, Tinner (2020) in their detailed study of stomata of conifers. They noted that the stomata of European species



Figure 24. Photos of fossil stomata (scale bar = 30 μm). A. *Picea abies*. B. *Pinus* sp. C. *Juniperus* sp. (after Tonkov et al., 2018)

of the Pinaceae family analysed bear genus-specific features which confirmed earlier studies by Trautmann (1953) who claimed for instance that among species of *Pinus* sp. the stomata morphologies were not distinguishable with simple visual observations of stomata features. Therefore, it is accepted that fossil *Pinus* stomata originate from all three *Pinus* species (*Pinus mugo*, *Pinus sylvestris* and *Pinus peuce*) which grow today in the study area.

Lakes Ostrezki (sites 7 and 8)

The group of Lakes Ostrezki comprises several lakes (42°07'12.57"N, 23°29'13.29"E) with permanent water surface and half a dozen smaller ones that dry up during summer. The group is located in the subalpine belt above the present tree-line on the western slope of a large cirque (Fig. 2). Lake Ostrezko-2 (site 7) is located at 2320 m (42°07'14.18"N, 23°29'11.33"E) and has an elliptic shape with peaty shores and an area of about 0.15 ha. The water depth is 1.5 m (Fig. 25). Lake Ostrezko-3 (site 8) is located at 2340 m (42°07'16.24"N, 23°29'13.53"E) and has a circular shape with an area of about 0.1 ha and water depth of 1.7 m. The distance between both lakes is 60 m. The lakes are surrounded by groups of *Pinus mugo* and *Juniperus sibirica* and herb vegetation composed of *Nardus stricta*, *Poa alpina*, *Deschampsia caespitosa*, *Carex nigra*, *Carex echinata*, *Campanula alpina*, *Geum coccineum*, *Geum montanum*, *Ra-*

nunculus montanus, *Potentilla ternata*, *Dianthus microlepis*, *Plantago gentianoides*, *Primula deorum*, *Gentiana pyrenaica*, etc. (Tonkov, Marinova, 2005).

Coring, lithology and radiocarbon dating

The core from Lake Ostrezko-2 was recovered from the northern peaty shore. The core is 2 m long. The lithology of the sediments is: 0-25 cm *Sphagnum* peat, 25-200 cm gyttja. The core from Lake Ostrezko-3 was recovered from the southern periphery at water depth of 0.7 m. The core is 1.8 m long. The sediment is gyttja. The equipment used was Dachnowsky hand-coring. The radiocarbon age of 5 bulk sediment samples was determined and the results are shown on Table 7.

Table 7. Radiocarbon dates from Lakes Ostrezki.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, $\pm 2\sigma$ (mid-point)	Material dated
Ostrezko-2				
B-6101	53-67	1290 \pm 40	1300-1080 (1190)	gyttja
B-6617	95-105	2720 \pm 40	2920-2750 (2835)	gyttja
B-6099	146-154	3510 \pm 40	3890-3640 (3765)	gyttja
B-6098	175-185	4830 \pm 40	5650-5470 (5560)	gyttja
Ostrezko-3				
P-174	150-156	5700 \pm 35	6620-6400 (6510)	gyttja



Figure 25. A view of Lake Ostrezko-2 (Photo S. Tonkov).

Pollen analysis

The cores were sampled at 5-10 cm intervals and two percentage pollen diagrams are constructed (Figs. 26 and 27). The palynostratigraphical correlation of the cores is feasible due to the similarities in the behaviour of the main pollen curves and the application of a depth/age model constructed for Lake Ostrezko-2 (Fig. 26). As a result four local pollen assemblage zones (LPAZ) are recognized (OS-1 to OS-4) as the oldest LPAZ OS-1 is present only in the pollen diagram from Lake Ostrezko-3 (Figs. 27 and 6). Brief descriptions are as follows:

LPAZ OS-1: Lake Ostrezko-3 (180-155 cm, *Pinus-Abies-Corylus*) (~ 6760-6500 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type dominates with 40-50%, accompanied by *Abies* 5-10%, *Pinus peuce* 4% and deciduous tree pollen of *Corylus* 15-25%, *Betula*, *Tilia*, *Ulmus* and *Quercus*. Single pollen grains of *Picea* and *Fagus* are recorded. The herb pollen taxa are represented by Poaceae

5-10%, Cichoriaceae, *Artemisia*, *Centaurea*, *Dianthus*-type, etc.

LPAZ OS-2: Lake Ostrezko-3 (155-117 cm); Lake Ostrezko-2 (200-145 cm) (*Abies-Pinus*) (6500-3670 cal. yrs. BP)

Pollen of *Abies* rises to 30% and *Pinus diploxylon*-type reaches 40-60%. The pollen curve of *Fagus* appears in this zone. Among the herb pollen taxa are determined Poaceae, *Achillea*-type, *Cirsium*-type, Apiaceae, etc.

LPAZ OS-3: Lake Ostrezko-3 (117-27 cm); Lake Ostrezko-2 (145-55 cm) (*Pinus-Picea-Abies*) (3670-1100 cal. yrs. BP)

The dominant pollen type is *Pinus diploxylon* with 50%. The pollen curve of *Picea* appears and increases to 7%. Pollen of *Abies* tends to decline and a slight increase for *Fagus* is established. The presence of *Corylus* pollen is insignificant. Alongside with the great variety of herb pollen taxa, the continuous presence of anthropogenic pollen indicators such as *Plantago lanceolata*, *Plantago*

Lake OSTREZKO-2 (Central Rila Mt., 2320 m)
Percentage pollen diagram

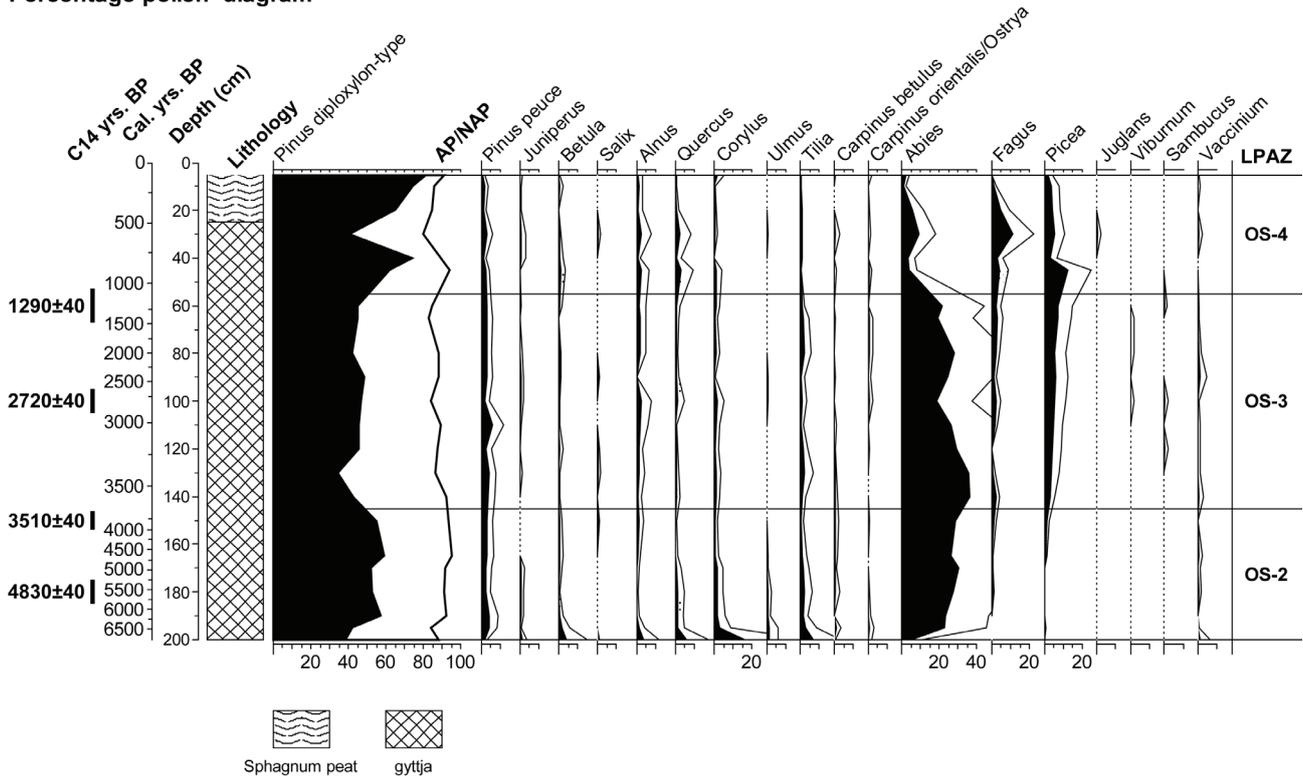
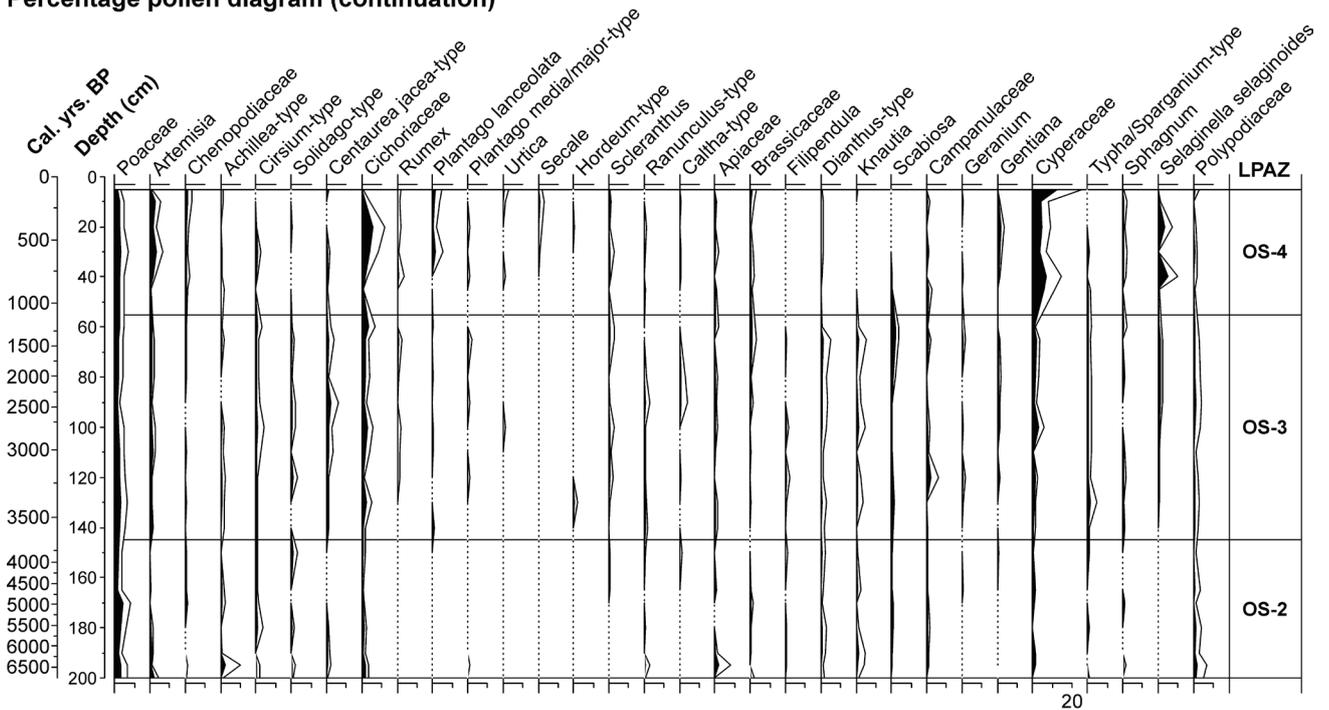


Figure 26. Percentage pollen diagram of Lake Ostrezko-2.

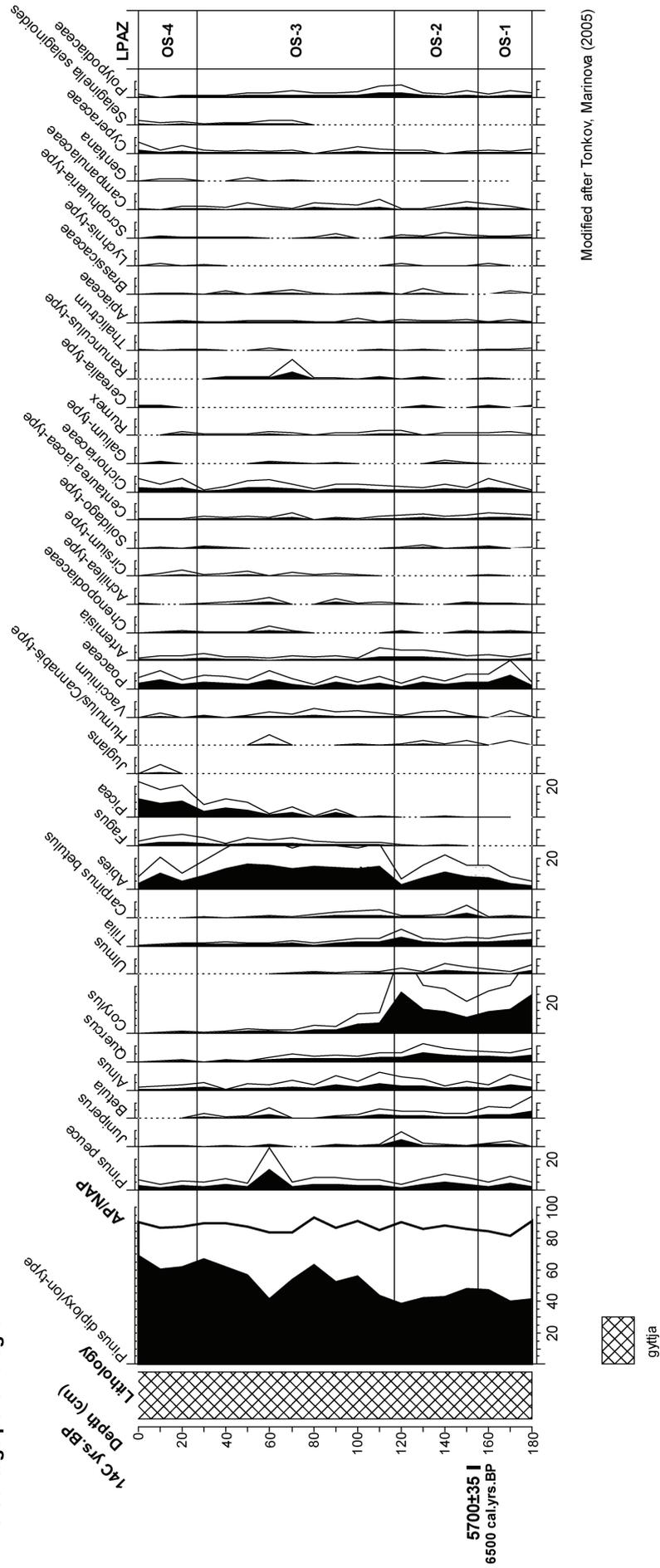
Lake OSTREZKO-2 (Central Rila Mt., 2320 m)
Percentage pollen diagram (continuation)



Modified after Tonkov, Marinova (2005)

Figure 26. Continued.

Lake OSTREZKO-3 (Central Rila Mt., 2340 m)
 Percentage pollen diagram



Modified after Tonkov, Mairnova (2005)

Figure 27. Percentage pollen diagram of Lake Ostrezko-3.

major/media-type, *Scleranthus*, *Urtica* and *Galium*-type begins.

LPAZ OS-4: Lake Ostrezko-3 (27-0 cm); Lake Ostrezko-2 (55-5 cm) (*Pinus-Picea-Fagus*) (1100 cal. yrs. BP-till present)

Pollen of *Pinus diploxylon*-type increases to 60-80%, as well as pollen of *Picea* and *Fagus*, each with 10%. The pollen curve of *Abies* declines to 8%. Pollen of *Juglans* is also found. Numerous herb pollen taxa are also determined, among them the share of the anthropogenic pollen indicators such as *Plantago lanceolata*, *Rumex*, *Artemisia*, *Cichoriaceae*, *Secale*, *Hordeum*-type increases.

Plant macrofossil analysis

The samples for plant macrofossil analysis were taken at every 10-20 cm and studied at magnification 10-40x. Macrofossils such as fruits and seeds are presented in absolute numbers per 20 ml (Lake Ostrezko-2) and per 40 ml (Lake Ostrezko-3). The abundance of wood fragments and remains of vegetative parts (stems, leaves, etc.) is shown on a relative scale by black dots (Figs. 28 and 29). The analysis is focused on core Lake Ostrezko-2 which is bound to a radiocarbon chronology. The results from the macrofossil determination allow to distinguish three local macrofossil assemblage zones (LMAZ) and their description (MOS-1 to MOS-3) is briefly as follows:

LMAZ MOS-1: Lake Ostrezko-2 (200-150 cm); Lake Ostrezko-3 (180-90 cm) (~ 6760-3760 cal. yrs. BP)

The fossil record contains needles, seeds, female cones of *Pinus mugo*, *Pinus peuce*, needles of *Pinus sylvestris* and wood of *Pinus* sp.; fruits of *Alnus viridis*; seeds and fruits of various herbs such as *Dianthus*, *Silene*, *Thymus*, etc. Charcoal particles are also found.

LMAZ MOS-2: Lake Ostrezko-2 (150-50 cm); Lake Ostrezko-3 (90-33 cm) (3760-1000 cal. yrs. BP)

There is abundance of needles of *Pinus mugo*, *Pinus sylvestris* and *Juniperus sibirica*. The first records of needles of *Picea abies* and *Abies alba* are established. Seeds of herbs from *Cardamine*, *Cirsium*, *Doronicum*, etc. are determined, as well as moss remains.

LMAZ MOS-3: Lake Ostrezko-2 (50-5 cm); Lake Ostrezko-3 (33-10 cm) (1100 cal. yrs. BP-till present)

The plant macrofossil record is rather poor, represented by sporadic finds of needles of *Pinus mugo*, *Pinus sylvestris*, *Picea abies*, *Juniperus sibirica*; fruits of sedges and vegetative parts of mosses (*Sphagnum*, *Drepanocladus*).

Lake Suho Ezero-RM (site 9)

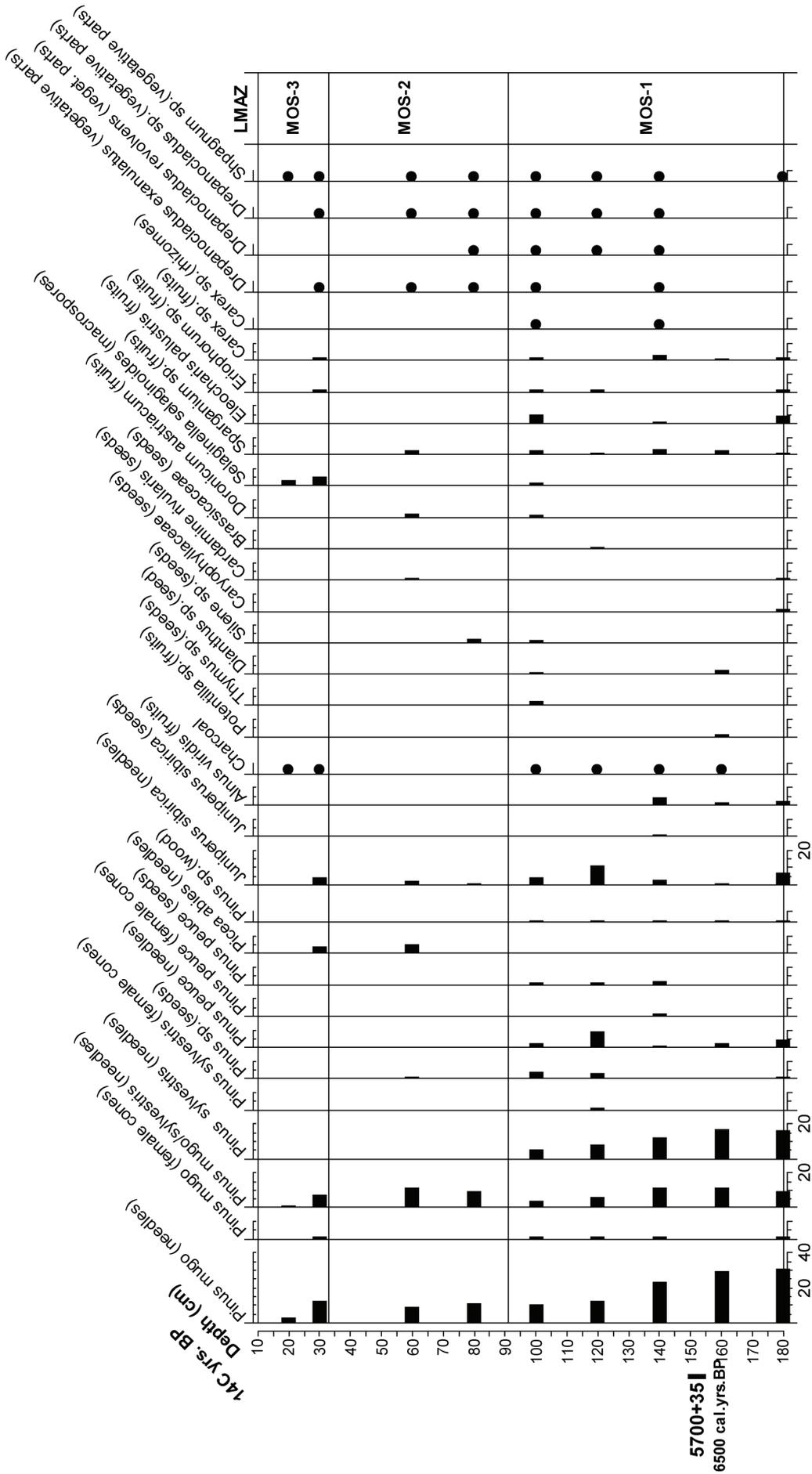
This lake is one of the lowest located lakes in the mountain at 1900 m (42°09'57.61"N, 23°25'07.30"E) northeast of the Rila Monastery (Fig. 2). Its origin is most likely tectonic. The lake has an elongated shape with a length of 380 m and a maximum width of 70 m. The water surface area is 1.95 ha. It receives two tributaries from the north and one from the east. The lake has a visible outlet and often dries up completely at the end of summer (Ivanov, 1964) (Fig. 30). The slope that descends to the northern shore is steep and groups of *Alnus viridis*, single trees of *Pinus sylvestris*, *Betula pendula*, *Populus tremula*, *Pinus peuce* and *Picea abies* grow in the gullies. The coniferous forest around the southern and eastern shores is composed of *Picea abies* with an admixture of *Pinus peuce* and *Pinus sylvestris*. The flat open western shore is occupied by groups of *Pinus mugo* and *Juniperus sibirica*. In the approaches to the lake from the Rilska river valley between 1500 and 1850 m are growing *Abies alba*, *Acer heldreichii*, *Acer pseudoplatanus*, *Sorbus aucuparia*, *Populus tremula* and *Fagus sylvatica*. The herb communities on the open areas around the lake are composed of *Festuca valida*, *Calamagrostis arundinaceae*, *Anthoxanthum odoratum*, *Tripleurospermum caucasicum*, *Geum coccineum*, *Thalictrum aquilegifolium*, *Centaurea nervosa*, *Campanula alpina*, etc. The highly ruderalized places are dominated by *Rumex acetosella*, *Rumex alpinus*, *Cirsium appendiculatum*, *Urtica dioica*, *Veratrum album* (Tonkov et al., 1998).

Coring, lithology and radiocarbon dating

A core 3.2 m long was obtained from the southwestern part with Dachnowsky hand-coring equipment when the lake was completely dried

Lake OSTREZKO-3 (Central Rila Mt., 2340 m)

Plant macrofossil diagram



Modified after Tonkov, Marinova (2005)

Figure 29. Plant macrofossil diagram of Lake Ostrezko-3.



Figure 30. A view of Lake Suho Ezero-RM (source: ranica.bg).

up. The lithological composition of the sediments shows an alternation of gyttja layers mixed with sand and of separate sand layers. The thickness of these layers varies from 2 to 25 cm. There is no regularity in the distribution of the two lithological units. One possible explanation for the formation of these layers might be the irregular drying of the lake and the deposition of coarse inorganic eroded material, which contributes to the absence of a stable hydrological regime. The position of these layers is indicated on the pollen diagram. The radiocarbon age of 2 bulk sediment samples was determined and the results are shown on Table 8. The exact time when the sedimentation of the analyzed core has started is difficult to determine. It is obvious that the uppermost 140 cm were deposited during the last 1400 years and the palynostratigraphy of the core indicates most probably a Subatlantic age.

Pollen analysis

The core was sampled at 5 cm or at longer/shorter intervals to avoid the sand layers. On the pol-

len diagram (Fig. 31) four local pollen assemblage zones (LPAZ) could be distinguished (RM-1 to RM-4). Brief descriptions are as follows:

LPAZ RM-1 (320-218 cm, *Pinus-Picea-Fagus*)

The participation of *Pinus diploxylon*-type is 30-55%, *Pinus peuce* 5-13%, *Picea* up to 18%, *Fagus* 5-7%, *Betula* and *Alnus* each with 5-7%, *Abies* 5%, and minimal values for *Juniperus*, *Quercus*, *Tilia*, *Corylus* and *Carpinus betulus*. Pollen of *Juglans* is regularly found. The herb pollen taxa are rather diverse and present with low frequencies (except for Poaceae 5-15%) such as Cichoriaceae, *Achillea*-type, *Artemisia*, Chenopodiaceae, *Scleranthus*, *Rumex*, *Dianthus*-type, etc.

Table 8. Radiocarbon dates from Lake Suho Ezero-RM.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Cal. AD (mid-point)	Material dated
LuA-4315	52-64	1290±100	1360-980 (1170)	590-970 (780)	gyttja with sand
LuA-4316	130-140	1470±110	1615-1170 (1400)	335-780 (550)	gyttja

Lake SUHO EZERO-RM (Central Rila Mt., 1900 m)

Percentage pollen diagram

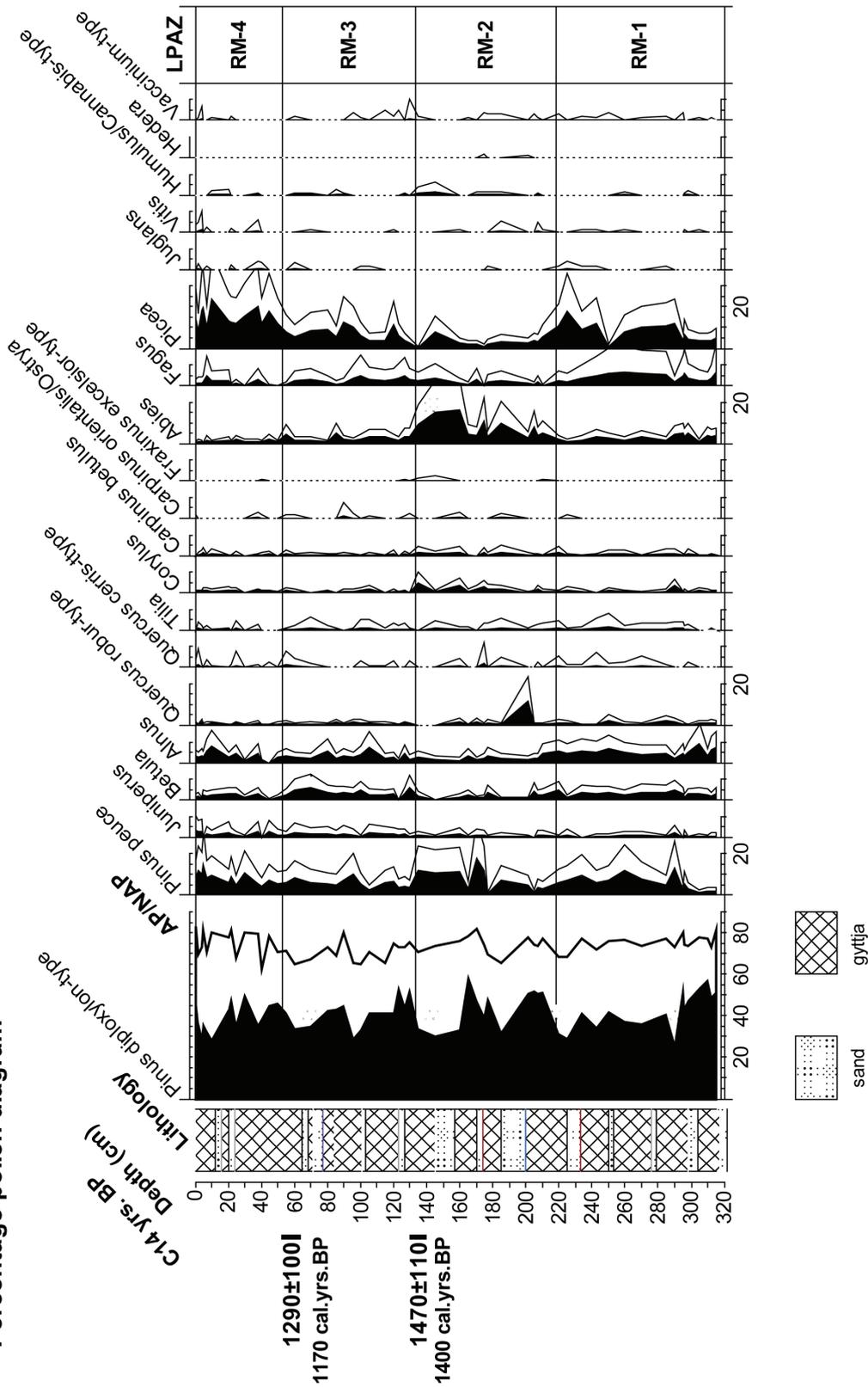


Figure 31. Percentage pollen diagram of Lake Suho Ezero-RM.

LPAZ RM-2 (218-133 cm, *Pinus-Abies*)

Pollen of *Pinus diploxylon*-type with 60% dominates together with *Pinus peuce* 18%. A maximal value of 16% is registered for *Abies* pollen. A slight increase to 12% is established for *Quercus robur*-type and *Corylus* 4%, while *Fagus*, *Alnus*

and *Betula* decrease. Among the herb pollen taxa should be mentioned Cichoriaceae, *Plantago lanceolata*, *Scleranthus*, Ranunculaceae, *Thalictrum*, *Gentiana*, *Cerealia*-type, *Triticum*-type, etc.

LPAZ RM-3 (133-53 cm, *Pinus-Picea-Fagus*) (1400-1170 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type retains its dominant role with 35-55%. *Picea* and partly *Fagus*, *Betula*, *Alnus*, *Juniperus* increase again. Pollen of *Abies* decreases to 2-3%. The herb pollen taxa are rather diverse, represented by Poaceae 18%, *Achillea*-type, *Plantago lanceolata*, *Rumex*, *Scleranthus*, *Secale*, *Ranunculus*-type, Apiaceae, Brassicaceae, *Caltha*-type, etc.

LPAZ RM-4 (53-0 cm, *Picea*-*Pinus*) (1170 cal. yrs. BP-till present)

The pollen curve of *Picea* reaches maximal values of 20-23%, together with *Pinus peuce* 8-12%. Pollen of *Pinus diploxylon*-type declines to 30%. The herb pollen taxa are almost the same like in the previous zone, with a more pronounced presence of *Rumex*, *Cerealia*-type, *Secale* and *Triticum*-type.

Vegetation history in the Central Rila Mountain

Lateglacial

The oldest pollen record from the study area, bound to a consistent radiocarbon chronology, originates from the core retrieved from the subalpine Lake Manastirsko-2. It reveals the paleo-environmental changes and vegetation dynamics for the last c. 14000 years. The lateglacial interval spans the lowermost 37 cm of the sequence (pollen zone LM-1, Fig. 19) but due to the low time resolution a clear distinction between the upper part of the Bölling/Alleröd interstadial complex and the Younger Dryas stadial is hardly possible. In general, the pollen stratigraphy indicates typical glacial conditions with vast distribution of open herb vegetation of "mountain-steppe" character dominated by *Artemisia*, Chenopodiaceae, Poaceae and other cold resistant species from *Achillea*, *Thalictrum*, *Centaurea*, *Rumex*, *Galium*, Apiaceae, etc. Stands of *Pinus*, *Betula* and shrubland of *Juniperus-Ephedra* were also found. The minor quantities of deciduous tree pollen from *Alnus*, *Quercus*, *Corylus*, *Ulmus*, the short-term rise of *Abies*, and the peak of the total arboreal pollen curve c. 12700 cal. yrs. BP, could be interpreted as a response to a signal of climate improvement which correlates

with the GRIP $\delta^{18}\text{O}$ curve indicating a warmer interval (GI-1a) (Dansgaard et al., 1993). At lower altitudes deciduous trees started gradually to spread from local microrefugia where humidity and soil moisture were sufficient for their growth.

The low PAR of trees c. 500 grains $\text{cm}^{-2} \text{yr}^{-1}$ throughout the lateglacial interval, contributed mainly by *Pinus diploxylon*-type, confirms the scarce, most likely isolated presence of pines (*Pinus mugo/sylvestris*). The abundance of *Pinus peuce* and *Betula* can be considered as disparagingly low. Regarding the PAR of the main herbs, a steep decline in the values for both *Artemisia* and Chenopodiaceae is observed at 12700 cal. yrs. BP, and a gradual increase for the pollen influxes of Poaceae at the transition to the Holocene (Fig. 20).

Holocene

Comprehensive information on the Holocene vegetation dynamics is obtained from Lake Manastirsko-2 and Peat bog Vodnza, while the paleoecological record from Lakes Ostrezki spans the last 6700 years and from Lake Suho Ezero-RM the last c. 2500-2000 years.

The amelioration of the climate at the onset of the Holocene has resulted in quick afforestation and diminishing of the areas occupied by the "mountain steppe" herb vegetation dominated by *Artemisia*, Chenopodiaceae and other cold-resistant herbs. Initially, during the time interval 11600-9800 cal. yrs. BP (the lower part of pollen zone LM-2, Fig. 19) forests of *Betula* with groups of pines (*Pinus mugo*, *Pinus sylvestris*, *Pinus peuce*) and some *Juniperus* began to colonize areas at mid-higher altitudes on barren soils. The presence of pines in the near vicinity of Lake Manastirsko-2 is justified by the first finds of fossil stomata between 11000 and 10000 cal. yrs. BP. More likely, they derived from *Pinus mugo* which grows today around the lake. The participation of *Juniperus* in the Early Holocene vegetation cover was confirmed by the continuous finds of fossil stomata since 9300 cal. yrs. BP in the sediments of Peat bog Vodniza (Fig. 22).

Meanwhile, the birch forests continued to expand, particularly between 9800 and 7900 cal. yrs BP, and the participation of *Pinus* has gradually in-

creased (pollen zone LM-2, Fig. 19). The composition of the fossil pollen assemblages indicates the beginning of widespread of *Quercus* forests with *Tilia*, *Ulmus*, *Fraxinus* and *Acer* below the birch zone. This deciduous forest belt has reached its maximal distribution c. 10000 cal. yrs. BP at the time when *Corylus* started to expand in the study area. The gradual increase of the arboreal PAR for the time window 11600–8150/7900 cal. yrs. BP confirms the afforestation process which was enlarged after 9700 cal. yrs. BP. Moreover, the short-term steep decline of the arboreal PAR at 8230 cal. yrs. BP, particularly manifested by *Pinus diploxylon*-type and less by *Betula* (level 275 cm, Fig. 20), can be considered as a vegetation response to the 8.2 ky climatic event (Alley, Ágústsdóttir, 2005) at higher altitudes. For the first time evidence of this abrupt cooling was identified in a pollen diagram from the Rila Mountain.

Gradually, *Abies* has steadily established in the vegetation cover while the occurrences of *Fagus* and *Picea* have remained still rare. A foregoing short-term peak of *Abies* pollen, registered at 9300 cal. yrs. BP (Fig. 19), coincides with a similar one recorded from the northwestern part of the mountain (Tonkov et al., 2008, 2013).

The forest composition and the altitudinal vegetation zonation started to change after 8150/7900 cal. yrs. BP. The conifers *Abies*, *Pinus* and *Pinus peuce* enlarged their areas replacing at many places the birch forests and pushing the mixed oak forests and hazel downslope. Stands of *Betula* continued to be found within the coniferous belt or above the timber-line. The dynamic transformation lasted for c. 2000 years (pollen zones LM-3 and V-5, Figs. 19 and 22) and has resulted in the formation of a compact coniferous belt dominated by pines and fir. This change is also supported by the presence of *Pinus* sp. stomata, most probably originating from *Pinus mugo* at the elevation of Lake Manastirsko-2, and together with *Juniperus* stomata in the sediments of Peat bog Vodniza. The high PAR of *Pinus diploxylon*-type, *Pinus peuce* and *Abies* testifies for a substantial increase in the population density of the coniferous woods, while the deciduous trees *Betula*, *Quercus* and *Corylus* began quickly to decline after 7400 cal. yrs. BP. The

presence of *Carpinus betulus*, *Fagus* and *Picea abies* has remained still restricted.

The paleoecological information from the area of the Seven Rila Lakes presents a synchronous pattern of vegetation changes, characterized by the expansion of *Pinus* and *Abies* and a decline for *Betula*. Fossil stomata of *Pinus* sp. were determined in the sediments of Lake Ribno (Tonkov et al., 2013) as well as fossil fruits of *Betula* in the sediments of Lake Sedmo Rilsko. In conformity with the above studies in the Northwestern Rila Mountain, the onset of this important change in the composition of the vegetation cover, confined to c. 8200–8000 cal. yrs. BP, was obviously triggered by a climate shift as shown by the summer and winter reconstructions of temperature and precipitation values across Europe. In summer, relatively cooler and somewhat wetter conditions established in many parts of Southern Europe, while in winter time cooler drier conditions prevailed (Davis et al., 2003; Mauri et al., 2013). The 8.2 ky climatic event has also probably influenced this change as the various aspects of this shift may have spread over a period of up to 600 years (Rohling, Palike, 2005). The short-term steep decline of the PAR of trees at 8230 cal. yrs. BP was established only from Lake Manastirsko-2 unlike the situation at Peat bog Vodniza. Quite probably, the reason was the lower ecological sensitivity and response of the arboreal vegetation to this climatic oscillation at lower altitudes.

The subsequent stage in the vegetation development between 5600/5350 and 3450 cal. yrs. BP has manifested the widest distribution of *Pinus sylvestris*, *Pinus mugo*, *Pinus peuce* and *Abies* in the Central Rila Mountain. The enlargement of the areas occupied by the conifers was facilitated by favorable climatic conditions, and after soils with stable humic horizons had developed (Bennett, Willis, 1995). The regular presence of fossil *Pinus* stomata confirms that pines were growing around the Peat bog Vodniza, and the high PAR for the coniferous species indicates the existence of a dense forest cover (Fig. 23). This vegetation reconstruction is supported also by the PAR of conifers established from the higher located site Lake Manastirsko-2, reaching maximal values at 3400 cal.

yrs. BP and thus, indicating that the timber-line was placed higher than in present times (Fig. 20). A characteristic feature for this time interval is also the slow-rate penetration of *Picea abies* into the coniferous belt and the gradual increase of *Fagus* at lower altitudes after c. 4500 cal. yrs. BP.

The paleoecological evidence from Lakes Ostrezki which extends back to c. 6700 cal. yrs. BP provides valuable information about the distribution of the main tree taxa and the position of the tree-line. The pollen frequencies and the plant macrofossils (needles and seeds) for the time window 6700-3770 cal. yrs. BP point to the existence of stands of *Pinus mugo*, *Juniperus sibirica* and *Alnus viridis* at that altitude among patches of herb vegetation. The high presence of *Abies* pollen (25-35%) confirms its participation in the composition of the coniferous belt, whereas a gradual decline for *Pinus peuce* has started after 4500 cal. yrs. BP. The tree-line shaped by *Pinus sylvestris*, *Pinus peuce* and some *Abies* was running in close proximity to the lakes, proved by the find of fossil needles and seeds (Fig. 29).

After 3400 cal. yrs. BP *Picea abies* spread into the coniferous belt and its maximal distribution was attained between 2250 and 1100 cal. yrs BP in the conditions of a changing climate with lower average temperatures and increase in precipitation (van Geel et al., 1998). Pines and fir partly declined while birch slightly increased. Beech also started to enlarge at lower altitudes along the mountain river valleys. The appearance of fossil stomata of *Picea abies* and the steep increase of its PAR undoubtedly points that spruce has reached the elevation of the Peat bog Vodniza c. 3100 cal. yrs. BP (Figs. 22 and 23). A similar age for the expansion of spruce in the study area is obtained from Lake Manastirsko-2 as the pollen curve of *Picea* starts to rise and the total arboreal PAR substantially increases since 3400 cal. yrs. BP, attributed mainly to *Pinus diploxylon*-type, *Pinus peuce*, *Abies* and *Picea* (Fig. 20). Thus, the higher located site has also archived the changes in the composition of the coniferous belt and the increasing density of the forest cover at lower elevations.

In the diagrams from Lakes Ostrezki the decline of *Abies* pollen c. 3500 cal. yrs. BP is accompanied

by a rise of *Picea* pollen and the appearance of its first macrofossils (needles) at 2800-2700 cal. yrs. BP. In comparison, the palynological records from the area of the Seven Rila Lakes indicate also that the first of several expansion maxima of spruce in the Northwestern Rila Mountains was reached c. 2800-2600 cal. yrs. BP.

Indications of human presence are clearly visible in the pollen diagrams of Lake Manastirsko-2 and Peat bog Vodniza after c. 3400 cal. yrs. BP when pollen grains of *Hordeum*-type and *Secale* are determined, pointing to agricultural activities in the foothills of the mountain (Figs. 19 and 22). The increase of both pollen and influx values for Cichoriaceae and Poaceae, the appearance of *Plantago lanceolata*, *Scleranthus*, and the rise for *Rumex* suggest an enlargement of the open area used for seasonal pastures.

In the pollen and plant macrofossil diagrams from Lakes Ostrezki the continuous pollen curves of *Plantago lanceolata*, *Rumex*, *Scleranthus*, *Urtica*, considered as indicators of human disturbance in mountainous areas, appear at 3770 cal. yrs. BP. Part of Poaceae, *Artemisia* and Cichoriaceae pollen could be also included in this group. The abundance of charcoal fragments just before 3770 cal. yrs. BP and c. 2800 cal. yrs. BP presumes that some of the forest fires were caused by the local people to extend the areas for high mountain-pasture land. The decrease of macrofossils from *Pinus sylvestris* and *Pinus peuce*, alongside with the finds from heliophilous herbs like *Potentilla* sp., *Dianthus* sp., *Silene* sp., *Doronicum austriacum*, indicates openings in the vegetation cover and lowering of the tree-line.

The evidence for the first signs of anthropogenic impact, derived from the area of the Seven Rila Lakes, is comparable with the presence of anthropogenic indicators such as *Plantago lanceolata* and *Rumex* in the fossil records of Lakes Ostrezki after 3400-3200 cal. yr BP, coinciding with the starting point of increase for *Fagus* and *Picea abies*.

In the vicinity of Lake Suho Ezero-RM forests of *Pinus sylvestris*, *Pinus peuce* and stands of *Pinus mugo* were distributed c. 2500-2000 years ago. The presence of *Picea* pollen with 10-18% shows that spruce has already gained a consid-

erable participation in the composition of the coniferous forests, while *Fagus* has enlarged mainly below 1300 m along the valley of the Rilska river. The rise of *Abies* pollen curve could be explained with a thinner forest filter and easier pollen transport upslope, rather than by an increase of fir in the coniferous forests. The herb vegetation on open places was rather diverse in species composition and the presence of anthropophytes as *Rumex*, *Scleranthus* and some *Chenopodiaceae* species is connected with reclamation of new areas for high-mountain pastures (Fig. 31). The general increase of the anthropophytes, accompanied by higher percentage values for *Cereal*-type, and the appearance of *Triticum*-type pollen c. 1400 cal. yrs. BP unequivocally testify to an intensive agricultural activity.

The vegetation development in historical time was characterized by an intensification of the anthropogenic impact, proved by the increase of pollen for *Cichoriaceae*, *Plantago lanceolata* and *Scleranthus*, indicative of livestock-grazing in the mountain meadows. The find of *Juglans* pollen points to its cultivation. After c. 1000 cal. yrs. BP at many places the tree-line was artificially lowered in order to extend mountain pasture land.

The last enlargement of *Picea abies*, and partly of *Fagus*, as recorded from Lake Manastirsko-2 was reached c. 1700 cal. yrs. BP and afterwards both trees started to decline. The vegetation development around Peat bog Vodniza, particularly after 900 cal. yrs. BP, featured an intensification of the anthropogenic impact, proved by the increase of pollen for *Cichoriaceae*, *Plantago lanceolata*, *Plantago major/media*, *Rumex*, *Scleranthus*, indicative of grazing in the mountain meadows. Larger areas were occupied by *Pinus*, mostly *Pinus mugo* in the subalpine belt. A tendency for a decline of the PAR for *Abies*, *Pinus peuce*, *Betula*, *Quercus*, and partly for *Picea*, is observed after 1500 cal. yrs. BP in the diagrams of Lake Manastirsko-2 and Peat bog Vodniza (Figs. 20 and 23).

The macrofossil record in the sediments of Lakes Ostrezki after 1240 cal. yr BP is rather poor, comprising only scarce needles of *Pinus mugo*, *Juniperus sibirica* and other occasional finds, which reflect the characteristics of the present-day veg-

etation in the subalpine belt as highly influenced by humans.

Southwestern Rila Mountain – Study sites

Lake Sucho Ezero (site 10)

This peat bog, a former lake, is situated 6 km westwards from the mountain resort Trestenik at 1900 m (42°03'52.46"N; 23°34'03.32"E) in a glacial valley in the lower of the two troughs. The upper one still contains a lake with open water while the investigated site is filled in with sediments, except for a small streamlet meandering through it (Fig. 2). The peat bog is located close to the timber-line in the coniferous belt. The main tree species are *Pinus sylvestris*, *Picea abies* and *Pinus peuce*. More rarely are found *Abies alba*, *Betula pendula*, *Populus tremula*. At some places are growing stands of *Pinus mugo* and *Juniperus sibirica*, while the bog vegetation is represented by *Vaccinium myrtillus*, *Bruckenthalia spiculifolia*, *Eriophorum vaginatum*, *Carex canescens*, *Carex nigra*, *Carex echinata*, *Heleocharis palustris*, *Cardamine amara*, *Cardamine rivularis*, *Ranunculus montanus*, *Rumex alpinus*, *Deschampsia caespitosa*, etc. (Bozilova, Smit, 1979; Bozilova et al., 1990) (Fig. 32)

Coring, lithology and radiocarbon dating

The coring of the lake was performed in the central part with motor Streif sampler in plastic tubes each 1 m long and 5 cm in diameter. The Core-2 is 12 m long. The lithology of the sediments is: 10–630 cm peat, 630–780 cm peaty gyttja, 780–900 cm gyttja, 900–1100 cm grey clay and 1100–1200 cm grey silt. The radiocarbon age of 2 bulk sediment samples was determined and the results are shown on Table 9. For the interpretation of the results and the delimitation of the local pollen assemblage zones are used also the 3 radiocarbon dates obtained for the first core (Bozilova, Smit, 1979).

Pollen analysis

Pollen analysis was performed at 2, 4 or 10 cm interval and a percentage pollen diagram is constructed (Fig. 33). The interval 900–1200 cm ap-



Figure 32. A view of Lake Suho Ezero (Photo S. Tonkov).

peared rather poor in pollen content. On the pollen diagram seven local pollen assemblage zones (LPAZ) are recognized (SE-1 to SE-7). Brief descriptions are as follows:

LPAZ SE-1 (1200-913 cm, *Artemisia*-*Chenopodiaceae*-*Poaceae*)

Pollen of *Pinus diploxylon*-type is 20-40% and of *Pinus peuce* 5-8%. Single pollen grains or small

quantities of pollen are determined from *Betula*, *Ephedra distachya*-type, *Quercus*. The herb pollen taxa dominate represented by *Artemisia* 35-40%, *Chenopodiaceae* 30%, *Poaceae* 5-10%, *Achillea*-type, *Cichoriaceae*, *Centaurea*, *Rumex*, *Ranunculaceae* and *Caryophyllaceae*.

LPAZ SE-2 (913-865 cm, *Pinus*-*Betula*-*Poaceae*-*Artemisia*)

The quantity of arboreal pollen reaches 45-50%, contributed by *Pinus diploxylon*-type 30-35%, *Betula* 13%, *Pinus peuce* 3-5%, *Quercus* 2%, *Alnus*, *Salix*, etc. The presence of herb pollen taxa declines but their variety increases represented by *Artemisia* 12%, *Chenopodiaceae* 5-10%, *Poaceae* up to 20%, *Achillea*-type 5-7%, *Apiaceae* 7%, *Rumex*, *Caryophyllaceae*, *Galium*-type, *Plantago major/media*-type, etc.

LPAZ SE-3 (865-825 cm, *Artemisia*-*Poaceae*-*Chenopodiaceae*)

The quantity of arboreal pollen sharply decreases to 20% and low frequencies are registered for *Pinus diploxylon*-type 10%, *Pinus peuce* 1-2%, *Betula* 3%, *Quercus* 2%. The rest of tree taxa are

Table 9. Radiocarbon dates from Lake Suho Ezero.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Core-1				
Gr	50-55	1620±60	1700-1350 (1525)	peat
Gr	170-180	2185±35	2320-2110 (2205)	peat
Gr	280-300	2880±30	3150-2880 (3015)	peat
Core-2				
Hv	540-560	5680±75	6640-6310 (6475)	peat
Hv	850-853	10575±220	12960-11750 (12355)	gyttja

Lake SUHO EZERO (SW Rila Mt., 1900 m)

Percentage pollen diagram (Core 2)

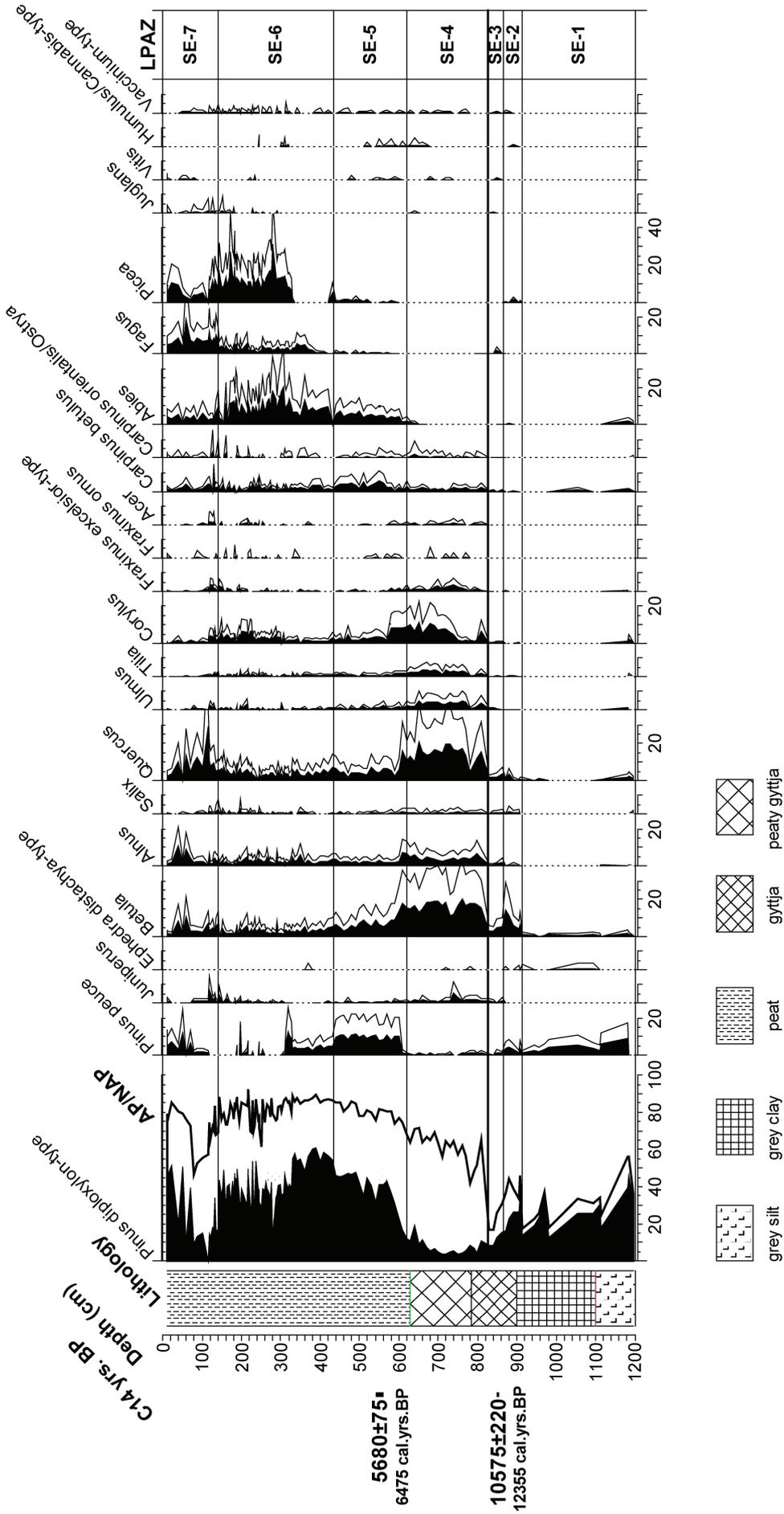
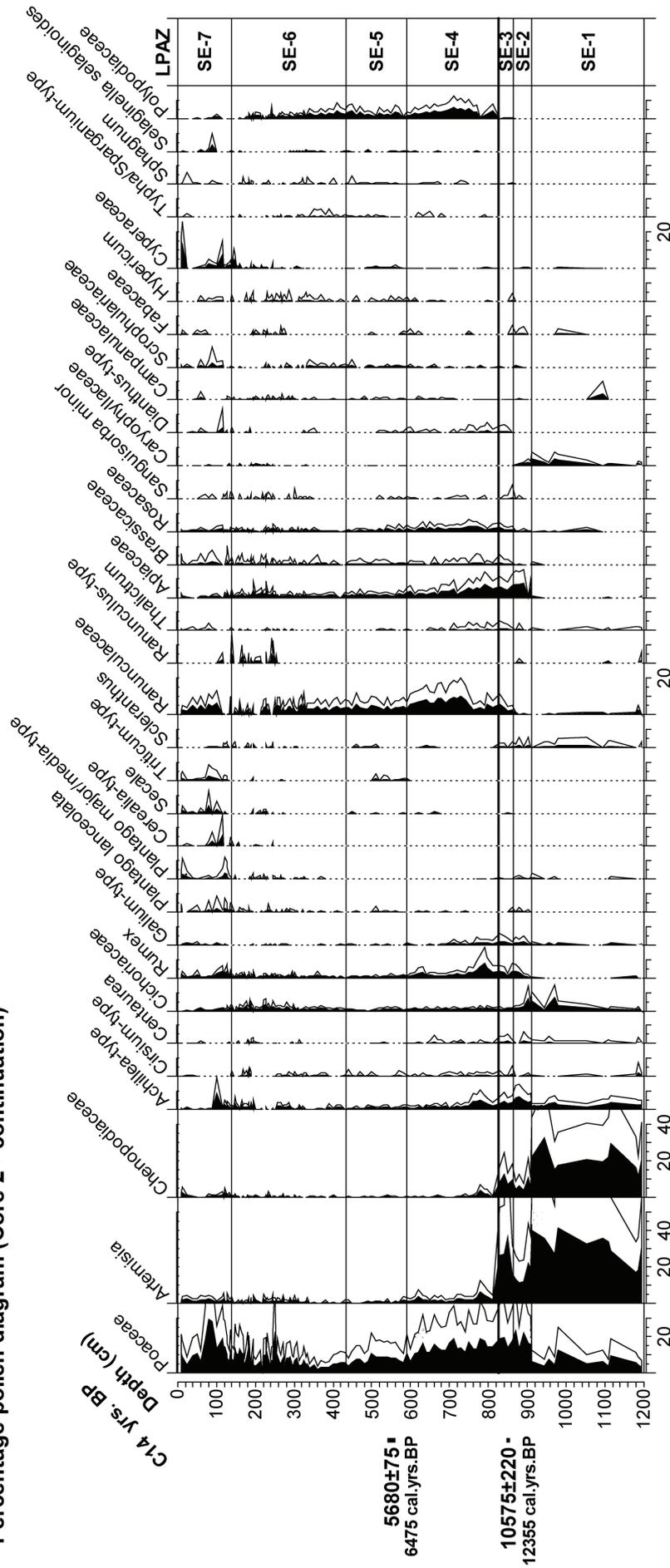


Figure 33. Percentage pollen diagram of Lake Suho Ezero (Core 2).

Lake SUHO EZERO (SW Rila Mt., 1900 m)
 Percentage pollen diagram (Core 2 - continuation)



Modified after Bozlova et al. (1990)

Figure 33. Continued.

absent or represented by single pollen grains. The main herb pollen taxa such as *Artemisia* up to 25-35%, *Chenopodiaceae* 12%, *Poaceae* 15-20% increase again.

LPAZ SE-4 (825-620 cm, *Betula-Quercetum mixtum-Pinus*)

Tree pollen rises quickly to 65-70%, due to *Betula* 15-20%, *Quercus* 15%, *Ulmus*, *Tilia* and *Corylus* each with 3-5%, *Juniperus* 2%. The pollen curves of *Carpinus betulus*, *Carpinus orientalis/Ostrya* and *Acer* appear. The lowest values for *Pinus diploxylon*-type 5-8% are registered. Subsequently, a maximum of 10-12% for *Corylus* is established as well as for *Ulmus*, *Tilia* and *Fraxinus excelsior*-type. The herb pollen taxa are represented by *Poaceae* 15-18%, *Ranunculaceae* 5%, *Rumex* 8%, *Apiaceae* 5%, *Artemisia* up to 5%, *Chenopodiaceae* 3%, *Rosaceae*, *Dianthus*-type, etc.

LPAZ SE-5 (620-433 cm, *Pinus-Abies*)

The presence of *Pinus diploxylon*-type increases to 43%, *Pinus peuce* up to 12% and *Abies* 5-7%. The pollen frequencies of *Betula*, *Quercus*, *Corylus* and *Alnus* decline to 8%, 5-7%, 3% and 2%, respectively. Low quantities of *Fagus* and *Picea* pollen are recorded in almost all samples. The total herb pollen decreases to 18% without any important changes in the variety of the pollen types. New pollen taxa are *Triticum*-type, *Viola*, *Filipendula*.

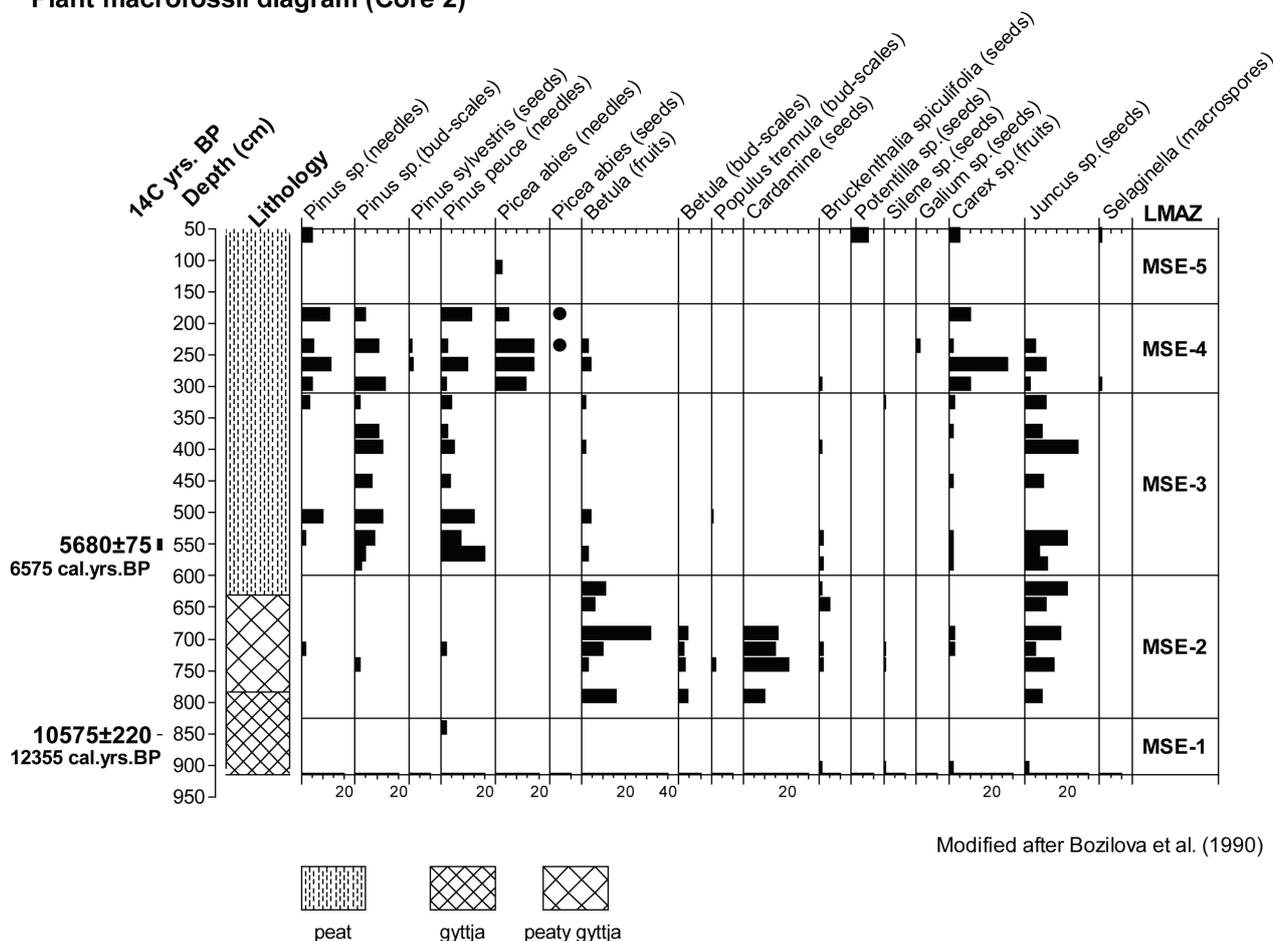
LPAZ SE-6 (433-140 cm, *Pinus-Abies-Fagus-Picea*)

The pollen values of *Pinus diploxylon*-type reach 60-65% and of *Abies* 15-20%. In this zone appears the pollen curve of *Fagus* up to 5%. The presence of *Picea* increases sharply to 15-18%. The herb pollen taxa are represented by *Poaceae*, *Artemisia*, *Cichoriaceae*, and the presence of *Plantago lanceolata*, *Ranunculus*-type, *Sanguisorba minor* pollen is regular.

LPAZ SE-7 (140-0 cm, *Picea-Pinus-Fagus*)

Lake SUHO EZERO (SW Rila Mt., 1900 m)

Plant macrofossil diagram (Core 2)



Modified after Bozilova et al. (1990)

Figure 34. Plant macrofossil diagram of Lake Suho Ezero (Core 2).

The pollen curve of *Pinus diploxylon*-type fluctuates around 40–50%, accompanied by *Picea* 10%, *Pinus peuce* 5–12%, *Abies* 10%, *Fagus* 7–8%, *Quercus* 10%, *Corylus* 5%, *Juniperus*, *Salix*. Pollen grains of *Juglans* are regularly found. The pollen curve of Poaceae reaches maximal values of 15–30% and the presence of *Achillea*-type, *Rumex*, *Ranunculaceae*, *Plantago major/media*-type, *Plantago lanceolata*, *Cerealia*-type, *Secale*, *Triticum*-type pollen is worth mentioning.

Plant macrofossil analysis

The core was sampled also at 15–25 cm interval. Plant macrofossils were not established in the intervals 915–1120 cm and 0–50 cm. The frequency of the macrofossils found is shown in absolute numbers on a diagram (Fig. 34) and five local macrofossil assemblage zones (LMAZ) are distinguished (MSE-1 to MSE-5). Brief descriptions are as follows:

LMAZ MSE-1 (915–825 cm)

Several seeds from *Silene* sp., *Juncus* sp., *Bruckenthalia spiculifolia*, fruits of *Carex* sp. and a needle of *Pinus peuce* are determined.

LMAZ MSE-2 (825–600 cm)

A characteristic feature is the abundance of fruits and bud-scales of *Betula*. Needles and bud-scales of *Pinus* sp. (*Pinus sylvestris*, *Pinus mugo* and *Pinus peuce*), seeds of *Juncus* sp., *Cardamine* sp., *Bruckenthalia spiculifolia*, *Silene* sp. and fruits of *Carex* sp. are present.

LMAZ MSE-3 (600–310 cm)

Needles of *Pinus peuce* and *Pinus* sp., bud-scales of *Pinus* sp. are determined. The number of *Betula* fruits is lower compared to the previous zone. Seeds of *Juncus* sp., *Bruckenthalia spiculifolia*, *Silene* sp. and fruits of *Carex* sp. are found.

LMAZ MSE-4 (310–170 cm)

Needles and seeds of *Picea abies* appear in this zone. The number of needles and bud-scales of *Pinus* sp. increases. There are well preserved needles of *Pinus peuce*, fruits of *Betula* and *Carex* sp., seeds of *Juncus* sp. and *Potentilla* sp.

LMAZ MSE-5 (170–50 cm)

The number of plant macrofossils is rather low, including sporadic finds of needles of *Pinus* sp. and *Picea abies*, seeds of *Potentilla* sp. and fruits of *Carex* sp.

Peat bog Vapsko-1 (site 11)

The peat bog is situated in a depression in the lower part of the subalpine belt at 2143 m (42°04'34.04"N, 23°31'25.84"E) just above the present tree-line (Fig. 2). The peat bog has a nearly rectangular shape and is about 50 m long and 10–15 m wide. It is surrounded by groups of *Pinus mugo* and *Juniperus sibirica* within patches of herb vegetation. Single trees of *Pinus peuce*, *Pinus sylvestris* and *Picea abies* are found to the east and west of the coring site. Stands of *Betula pendula* and *Sorbus aucuparia* grow close to the tree-line. The bog surface is overgrown by hummocks of *Sphagnum* sp., *Carex nigra*, *Carex rostrata*, *Nardus stricta*, *Agrostis capillaris*, *Eriophorum latifolium*, *Veratrum lobelianum*, etc. (Fig. 35). The coniferous forest belt in this part of the mountain is dominated by *Pinus peuce*, admixed with *Picea abies* and *Pinus sylvestris*. The recent distribution of *Fagus sylvatica* is fragmented and restricted at lower altitudes below 1200–1000 m together with the oak forests (Tonkov et al., 2018).

Coring, lithology and radiocarbon dating

The sediment core is 1.5 m long and was collected with Dachnowsky hand-coring equipment from the central part of the peat bog. The lithology of the sediments is: 0–40 cm slightly decomposed *Sphagnum*–*Cyperaceae* peat, 40–135 cm *Cyperaceae* peat and 135–150 cm clay with fine sand. The radiocarbon age of 4 bulk sediment samples was determined and the results are shown on Table 10. The age of the sediment core is c. 10000 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig.

Table 10. Radiocarbon dates from Peat bog Vapsko-1.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
RICH-23864	23–26	2171±28	2310–2060 (2185)	peat
UBA-21556	47–50	4046±33	4790–4420 (4605)	peat
UBA-21557	97–100	6143±40	7170–6930 (7050)	peat
UBA-21558	147–150	8867±52	10180–9740 (9960)	clay with sand



Figure 35. A view of Peat bog Vapsko-1 (Photo S. Tonkov).

36). Four local pollen assemblage zones (LPAZ) can be delimited (VP-2 to VP-5). Brief descriptions are as follows:

LPAZ VP-2 (150–113 cm, *Betula-Quercetum mixtum-Corylus-Pinus*) (10000–7900 cal. yrs. BP)

Tree pollen dominates with 50–65%, attributed to *Betula* 17%, *Pinus diploxylon*-type 10% with a short-term peak of 30%, *Pinus peuce* and *Juniperus* each below 5%, *Corylus* 10–15%, *Quercus robur*-type 10%, *Quercus cerris*-type 7% and *Tilia* 6%. Low pollen frequencies of *Abies*, *Carpinus betulus*, *Carpinus orientalis/Ostrya*, and traces of *Fagus*, *Picea*, *Vitis* and *Hedera* pollen are found. The herb pollen taxa are represented by Poaceae and Apiaceae, each up to 13–15%, *Cirsium*-type 10–5%, *Artemisia* 5%, *Rumex* 5%, *Ranunculus*-type, Brassicaceae, *Dianthus*-type, etc. High values of *Polyodiaceae* spores 10–17% are recorded.

LPAZ VP-3 (113–77 cm, *Pinus-Abies-Betula-Corylus*) (7900–5900 cal. yrs. BP).

Tree pollen increases to 88%, due mainly to *Pinus diploxylon*-type 40–70%, *Pinus peuce* 5–10%, *Corylus* 10–15%, *Betula* 13%, *Quercus robur*-type and *Quercus cerris*-type each with 5%. Subsequently, pollen of deciduous trees from *Betula*, *Quercus robur*-type, *Quercus cerris*-type, *Corylus*, *Tilia* and *Ulmus* quickly declines. The continuous pollen curve of *Abies* appears with 2–5% and rises to 12%. Sporadic pollen grains of *Picea*, *Carpinus betulus* and *Acer* are found. The total herb pollen is 5–10%, and the main pollen taxa registered are Poaceae, *Cirsium*-type, Brassicaceae, Apiaceae and *Rumex*.

LPAZ VP-4 (77–37 cm, *Pinus-Abies*) (5900–3500 cal. yrs. BP)

Coniferous pollen dominates represented by *Pinus diploxylon*-type 80%, *Pinus peuce* 8–10%, maximal values for *Abies* 12–15%. Pollen of deciduous trees such as *Betula*, *Alnus*, *Quercus*, *Carpinus betulus*, *Carpinus orientalis/Ostrya*, *Tilia*, *Corylus* is constantly present with rather low frequencies.

Pollen of *Fagus* and *Picea* is recorded in all samples with 1-2%. The most common herb pollen taxa are Poaceae up to 8%, *Artemisia*, Apiaceae, *Cirsium*-type, Chenopodiaceae, *Ranunculus*-type, *Dianthus*-type, Brassicaceae, etc.

LPAZ VP-5 (37-0 cm, *Pinus-Picea-Fagus-Abies*) (3500 cal. yrs. BP-till present)

The pollen curves of *Picea* 8% and *Fagus* up to 5% rise, while pollen of *Pinus diploxylon*-type and *Abies* declines to 50% and 3-5%, respectively. The

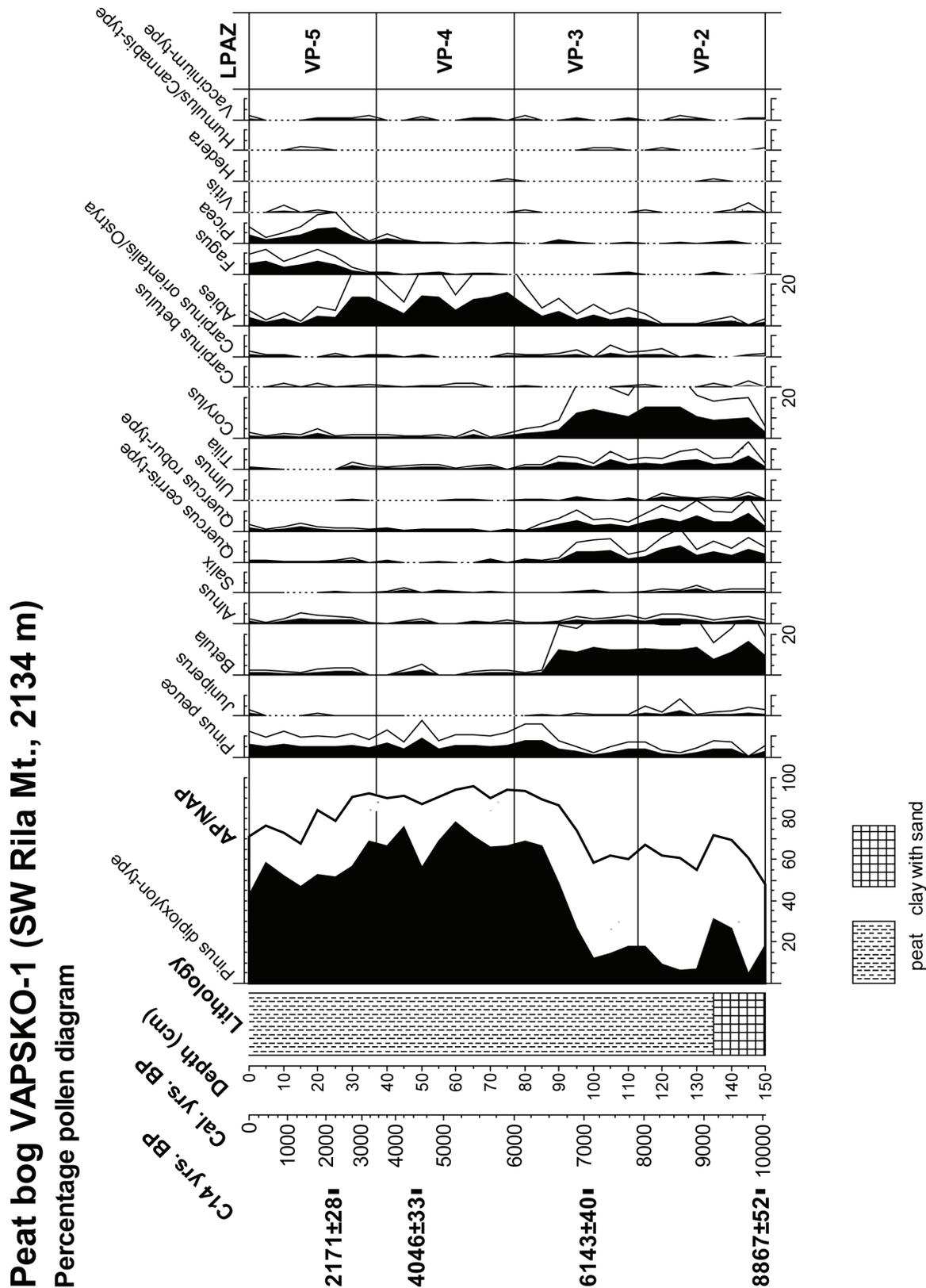


Figure 36. Percentage pollen diagram of Peat bog Vapsko-1.

presence of *Pinus peuce* remains without changes. Minor values below 2-3% are recorded for *Betula*, *Alnus*, *Corylus*, *Quercus robur*-type, *Quercus cerris*-type, *Carpinus betulus* and *Juniperus*. Pollen of *Humulus/Cannabis*-type, *Vitis* and *Vaccinium*-type is occasionally found. The total herb pollen increases to 30%, attributed mainly to Poaceae 15%, *Artemisia* and *Apiaceae* each with 2-3%, *Chenopodiaceae*, *Achillea*-type, *Brassicaceae*, *Campanulaceae*, etc. The continuous presence of *Plantago lanceolata* and *Scleranthus* pollen is recorded in this zone. Pollen of *Secale* is also determined.

Peat bog Vapsko-2 (site 12)

The peat bog is located at 2120 m (42°04'26.85"N, 23°31'27.81"E) in the lower range of the subalpine belt, at the present timberline, c. 220 m southeast from the Peat bog Vapsko-1 (Fig. 2). The peat bog

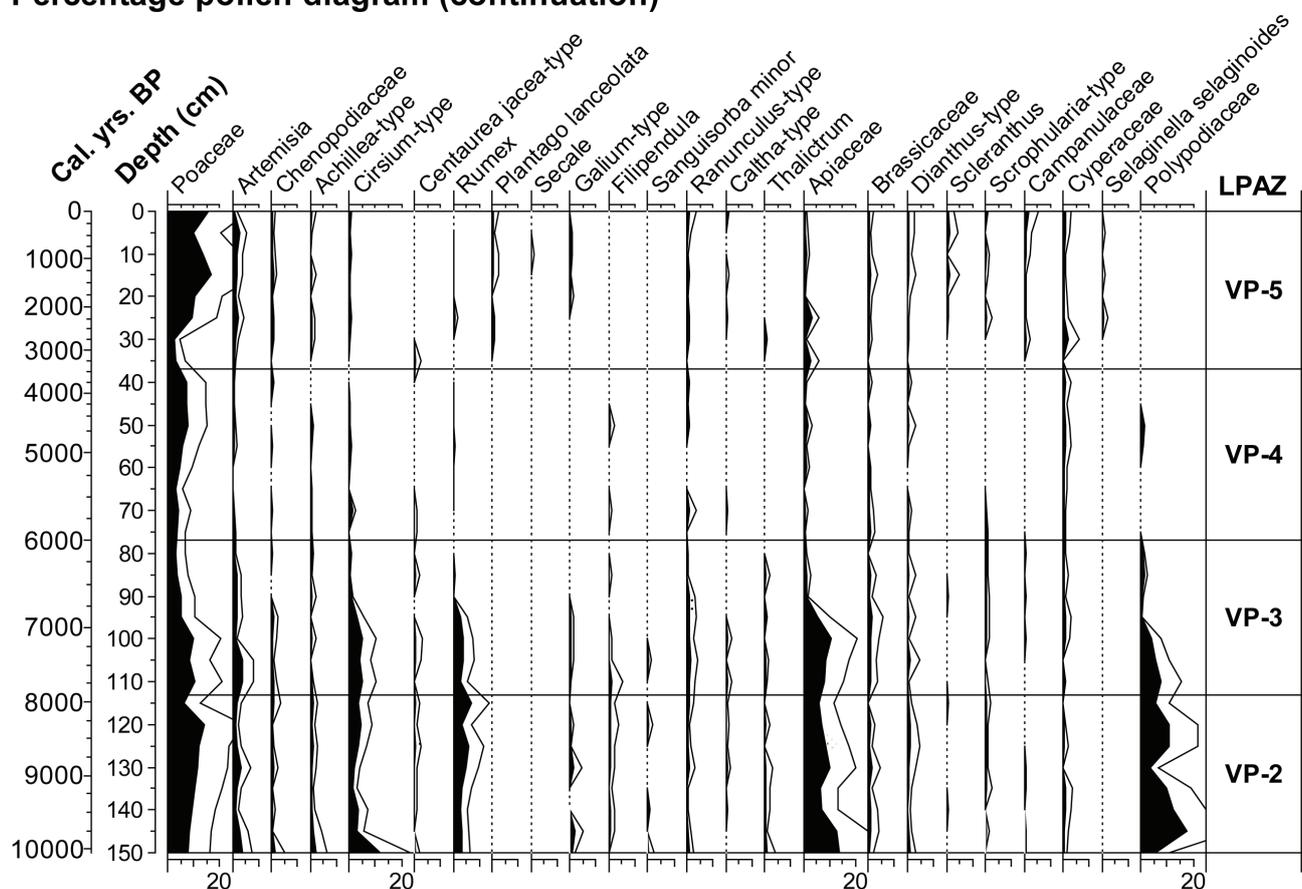
is about 90 m long and 20-35 m wide. It is surrounded by dense stands of *Pinus mugo* with some *Juniperus sibirica*, *Picea abies* and *Pinus peuce* to the north, northwest and southwest. To the east the peat bog borders a steep high slope overgrown by *Pinus mugo* and scattered trees of *Pinus peuce*. The bog surface is covered by hummocks of *Sphagnum* sp., *Carex nigra*, *Carex rostrata*, *Deschampsia caespitosa*, *Nardus stricta*, *Eriophorum latifolium*, *Potentilla palustris*, *Veratrum lobelianum*, *Rumex alpinus*, *Caltha laeta*, *Plantago gentianoides*, *Gentiana nivalis*, etc. (Tonkov et al., 2019)(Fig. 37)

Coring, lithology and radiocarbon dating

The sediment core is 3.05 m long and was collected with Dachnowsky hand-coring equipment from the deepest part of the peat bog. The lithology of the sediments is: 0-195 cm slightly decomposed

Peat bog VAPSKO-1 (SW Rila Mt., 2134 m)

Percentage pollen diagram (continuation)



Modified after Tonkov et al. (2018)

Figure 36. Continued.



Figure 37. A view of Peat bog Vapsko-2 (Photo S. Tonkov).

Table 11. Radiocarbon dates from Peat bog Vapsko-2.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
DeA-10895	24	2121±26	2290-2000 (2095)	peat
DeA-10105	55	3636±30	4080-3860 (3970)	wood
DeA-10896	72	4333±29	4970-4840 (4905)	peat
RICH-21695	102-104	4778±37	5600-5330 (5465)	peat
DeA-10106	142	5165±32	6000-5760 (5880)	seed
RICH-21694	194-196	6417±44	7430-7260 (7345)	peat
DeA-10897	215	7605±48	8540-8340 (8440)	peaty gyttja
DeA-10107	237	8700±58	9890-9540 (9715)	wood
DeA-10898	273	9153±46	10490-10220 (10355)	peaty gyttja
RICH-21693	302-304	10301±51	12390-11830 (12110)	gyttja with fine sand

Cyperaceae peat with plant remains, 195-280 cm peaty gyttja and 280-305 cm gyttja with fine sand. The radiocarbon age of 10 samples (3 of plant macrofossils and 7 of bulk sediment) was determined and the results are shown on Table 11. The age of the core is 12100 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 38). Pollen accumulation rates for the major tree/shrub and herb taxa are also calculated (Fig. 39). Fossil stomata in low number were occasionally found on pollen slides from 13 sample depths and their presence (*) is also shown on the pollen diagram. Five local pollen assemblage zones (LPAZ) can be delimited on the pollen diagram (VP-1 to VP-5) (Figs. 38 and 6). The palynostratigraphical correlation of the cores Vapsko-1 and Vapsko-2 is feasible due to the similarities in the behaviour of the main pollen curves and the application of the

Peat bog VAPSKO-2 (SW Rila Mt., 2120 m)

Percentage pollen diagram

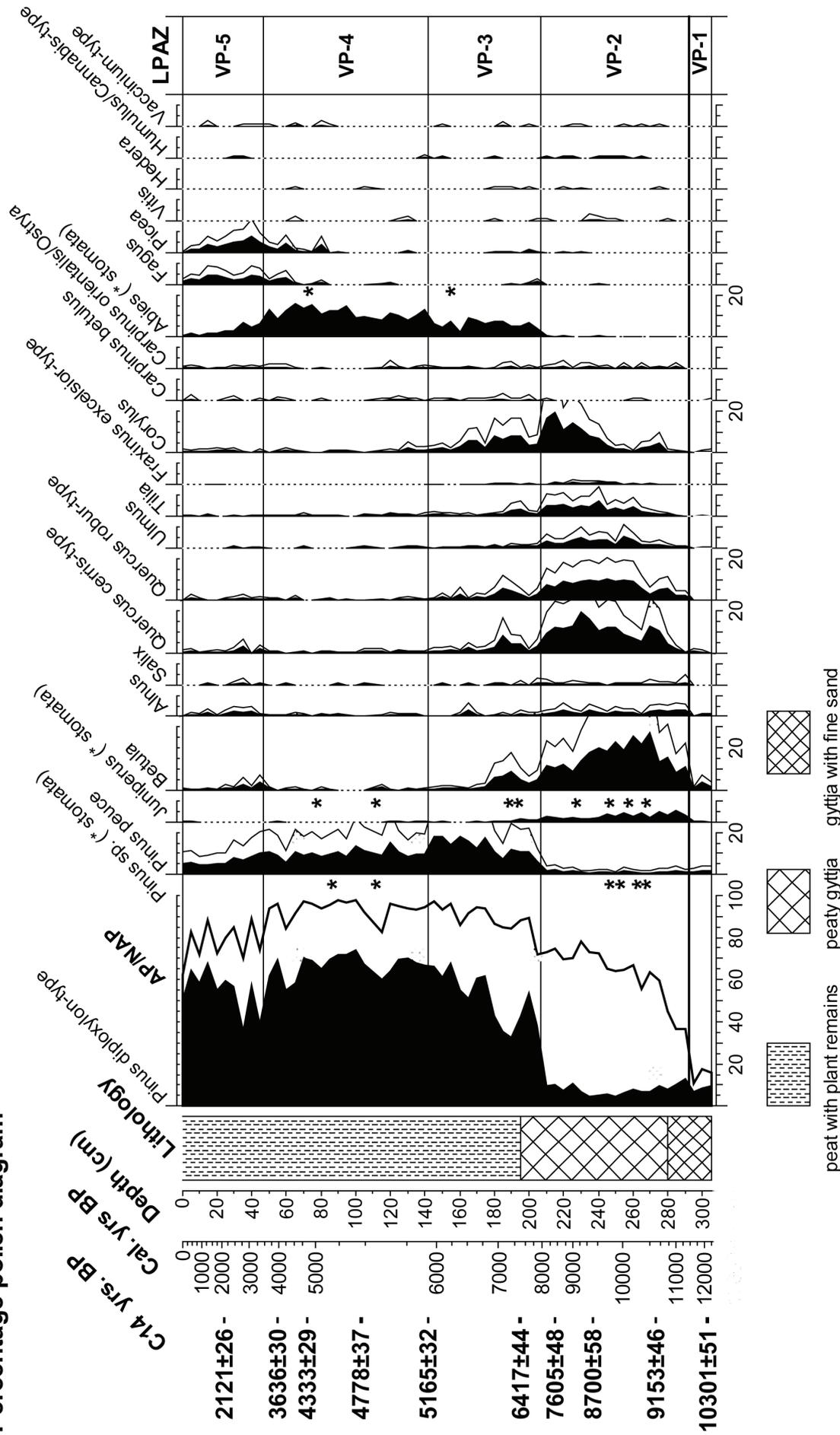
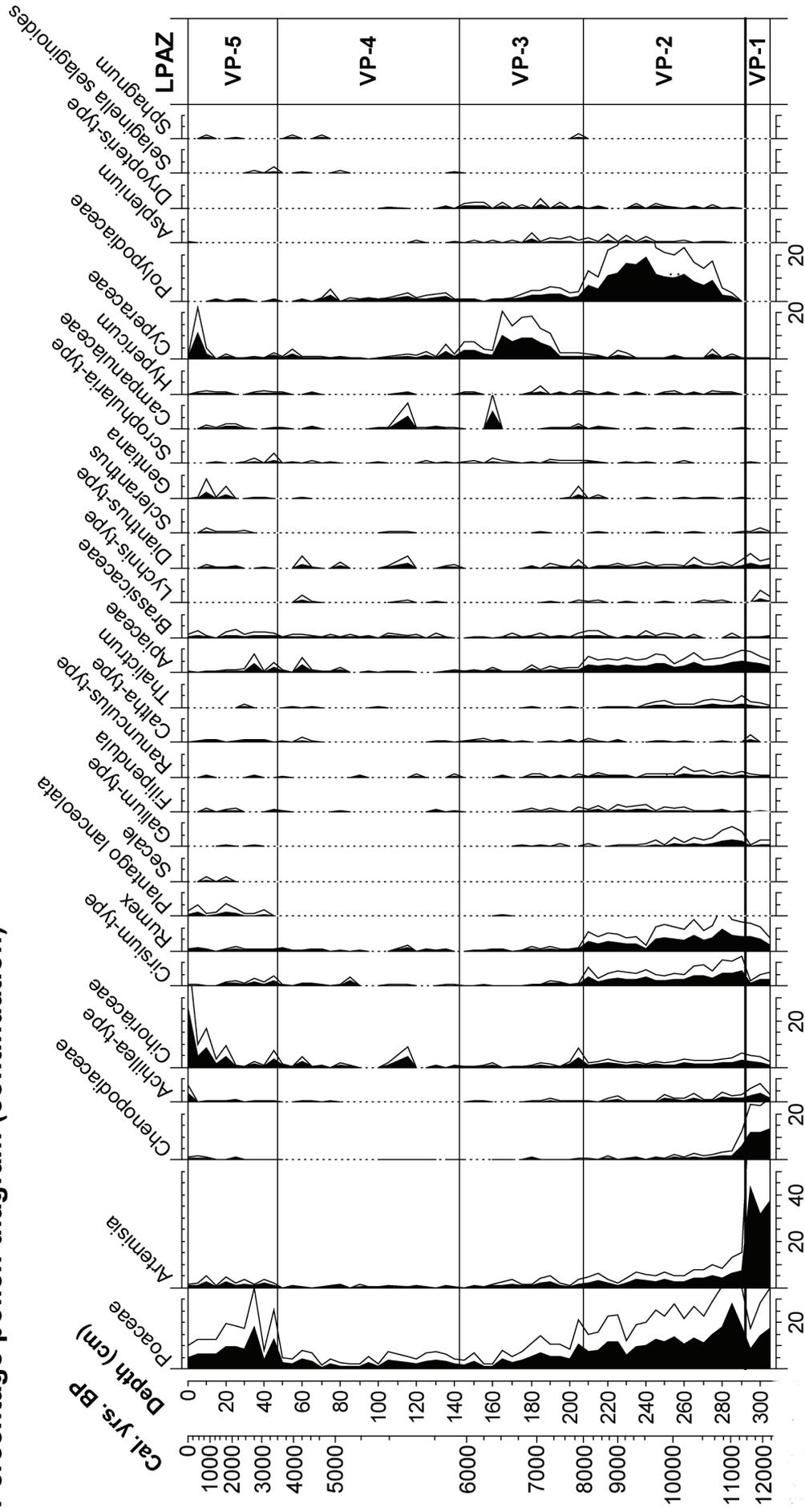


Figure 38. Percentage pollen diagram of Peat bog Vapsko-2.

Peat bog VAPSKO-2 (SW Rila Mt., 2120 m) Percentage pollen diagram (continuation)



Modified after Tonkov et al. (2019)

Figure 38. Continued.

Peat bog VAPSKO-2 (SW Rila Mt., 2120 m)

Pollen accumulation rates

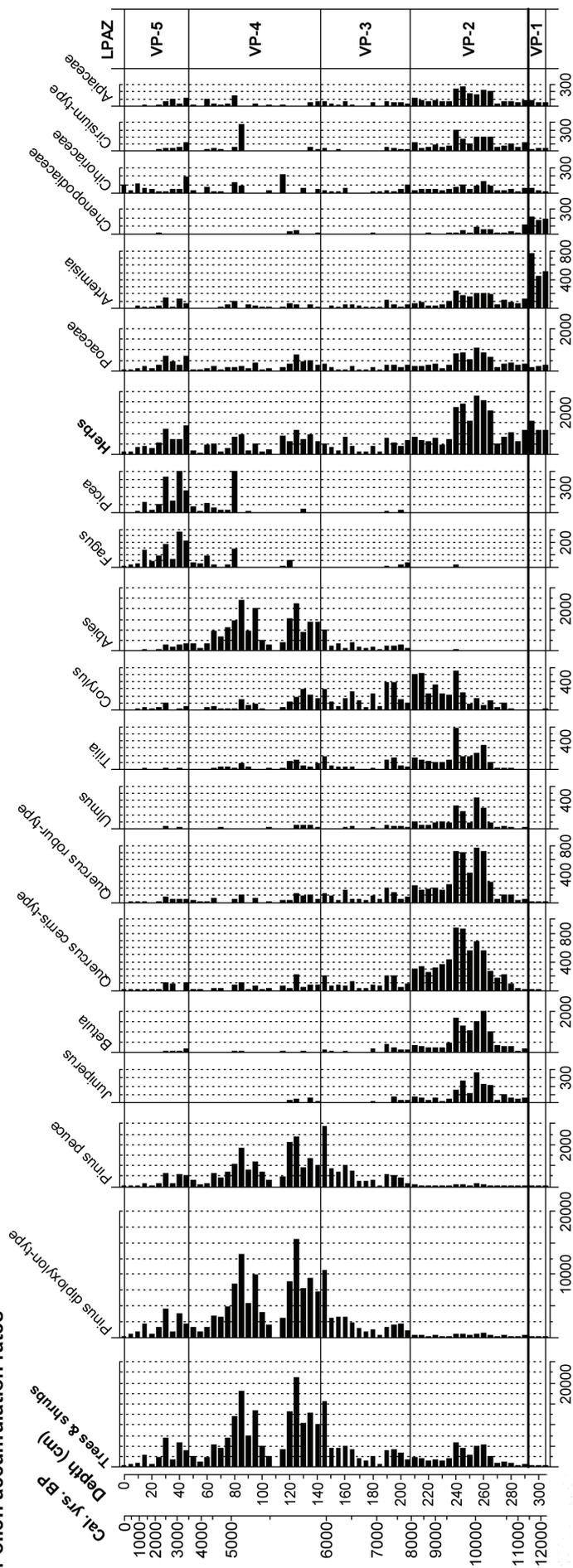


Figure 39. Pollen accumulation rates (PAR; pollen grains $\text{cm}^{-2}\text{yr}^{-1}$) for the main tree/shrub and herb taxa from Peat bog Vapsko-2 plotted against age (cal. yrs. BP).

depth/age models constructed for the peat bogs. Brief descriptions of the pollen zones are as follows:

LPAZ VP-1 (305-292 cm, *Artemisia*-Chenopodiaceae-Poaceae) (12100-11600 cal. yrs. BP)

Herb pollen dominates, attributed to *Artemisia* 35-40%, Chenopodiaceae 10-12%, Poaceae 16%, *Rumex* 6%, Apiaceae 5%, etc. Tree pollen constitutes only 20%, represented by *Pinus diploxylon*-type 10%, *Betula* and *Pinus peuce* less than 5% each, minor values for *Juniperus*, *Quercus*, *Alnus* and *Corylus*. The total PAR is rather low 1000-2000 grains cm⁻² yr⁻¹ with prevalence of the herbs such as *Artemisia* 500-750, Poaceae 250-350 and Chenopodiaceae 200.

LPAZ VP-2 (292-207 cm, *Betula*-*Quercetum* mixtum-*Corylus*-*Pinus*) (11600-7980 cal. yrs. BP)

Tree pollen quickly rises to 35-75%, due to *Betula* up to 27%, *Quercus cerris*-type 10-18%, *Quercus robur*-type 10%, *Corylus* with a maximum of 18%, *Ulmus*, *Tilia*, *Hedera*, *Vitis*, etc. Coniferous pollen is represented by *Pinus diploxylon*-type 10%, *Juniperus* 5%, *Pinus peuce* 5%. Fossil stomata of *Pinus* sp. and *Juniperus* are determined. Herb pollen values decline, contributed mainly by Poaceae 10-25%, *Artemisia*, *Rumex*, *Cirsium*-type, Apiaceae each with 5%. The maximal presence of Polypodiaceae spores with 15% is recorded in this zone. The total tree PAR increases and reaches 5000 grains cm⁻² yr⁻¹ contributed mainly by *Betula* up to 2000, *Quercus* up to 1600, *Ulmus* and *Tilia* each with 400, *Pinus* up to 400-600. The PAR of total herb pollen attains maximal values of c. 2000-2500, contributed mainly by Poaceae 1000, *Artemisia*, Chenopodiaceae and *Cirsium*-type with 100-300 each.

LPAZ VP-3 (207-142 cm, *Pinus*-*Abies*-*Betula*-*Corylus*) (7980-5900 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type rises to 65% and *Pinus peuce* displays a maximal value of 18%. The continuous pollen curve of *Abies* appears and reaches 10%. Deciduous tree pollen is represented by *Betula* and *Corylus* each up to 10%, *Quercus cerris*-type 8%, *Quercus robur*-type, *Tilia*, *Ulmus* and *Carpinus* each less than 5%. Fossil stomata of *Juniperus* and *Abies* are determined. The diversity of herb pollen taxa is high but they are pres-

ent with minor values, except for Poaceae 8%. Pollen of Cyperaceae shows a maximum of 10%. Compared to the previous zone, the total PAR of tree pollen retains its value of c. 5000 grains cm⁻² yr⁻¹ but now contributed by *Pinus diploxylon*-type c. 2500, *Pinus peuce* up to 1000, *Abies* 500, *Corylus* up to 400.

LPAZ VP-4 (142-47 cm, *Pinus*-*Abies*) (5900-3500 cal. yrs. BP)

In this zone pollen of *Pinus diploxylon*-type dominates with 75%, *Pinus peuce* 15% and *Abies* 10-15%. Fossil stomata of *Pinus* sp., *Juniperus* and *Abies* are determined. In the upper part of the zone appear the continuous pollen curves of *Fagus* and *Picea* each below 5%. There are no changes in the participation of the herb pollen taxa. The PAR of total tree pollen attains maximal values of c. 12500-20000 grains cm⁻² yr⁻¹ due to *Pinus diploxylon*-type up to 10000, *Pinus peuce* 2000-2500 and *Abies* 2000.

LPAZ VP-5 (47-0 cm, *Pinus*-*Picea*-*Fagus*-*Abies*) (3500 cal. yrs. BP-till present)

The pollen curves of *Pinus diploxylon*-type and *Pinus peuce* decline to 40-60% and 5%, respectively, while *Fagus* and *Picea* are represented with 5%. Minor values are recorded for deciduous tree pollen from *Quercus cerris*-type, *Quercus robur*-type, *Betula*, *Corylus*, *Carpinus*, etc. The quantity of herb pollen increases, attributed to Poaceae 15%, Cichoriaceae 20%, Brassicaceae, Apiaceae, *Artemisia*, *Plantago lanceolata*, *Secale*, etc. The PAR of total tree pollen declines to 2500-5000 grains cm⁻² yr⁻¹ but it is noteworthy to mention the maximal values for *Picea* and *Fagus* up to 400-600 and 200-300, respectively. The total PAR for herbs marks an increase to 1000-1500.

Vegetation history in the Southwestern Rila Mountain

Lateglacial

The palynological and macrofossil data as well as the radiocarbon dates provide reliable information on the changes in the vegetation and climate in the Southwestern Rila Mountain in postglacial time. The estimated age of Core-2 from Lake Suho

Ezero is probably close to the one for the sediment cores from the cirque of the Seven Rila Lakes, i.e. older than 16000 cal. yrs. BP. The possibility of earlier sedimentation is also not ruled out, given the lower altitude of 1900 m at which this former lake is located. The pollen stratigraphy and the radiocarbon date 10575 ± 220 ^{14}C yrs. BP (12355 cal. yrs. BP) (Fig. 33) confirm the presence of lateglacial sediments. A close age was obtained for the bottom part of the core from Peat bog Vapsko-2 (10301 ± 51 ^{14}C yrs. BP or 12110 cal. yrs. BP) (Fig. 38).

The changes in the vegetation are in many aspects similar and synchronous to those established from other parts of the mountain. The end of the Pleniglacial and the beginning of the Lateglacial was characterized by a wide distribution of cold- and drought-resistant herb vegetation of „mountain-steppe“ character with dominance of *Artemisia*, *Chenopodiaceae* and *Poaceae*, with the participation of *Cichoriaceae*, *Achillea*, *Galium*, *Cirsium* and *Caryophyllaceae* species. Isolated stands of pines (*Pinus sylvestris*, *Pinus mugo*, *Pinus peuce*), *Betula* and *Ephedra* were also found (pollen zone SE-1, Fig. 33). It is assumed that groups of deciduous trees such as *Quercus*, *Carpinus betulus*, *Corylus*, *Ulmus*, *Tilia* were preserved in suitable habitats with sufficient air and soil moisture in the mountain zone 800-1000 m.

The improvement of the climate during the Bölling/Alleröd interstadial complex is reflected in pollen zone SE-2 when a number of tree species (*Pinus sylvestris*, *Pinus peuce*, *Pinus mugo*, *Betula*, *Alnus*, *Salix*, *Quercus*, etc.) migrated along the mountain slopes and enlarged their presence. The herb communities remained dominant in the area around the Lake Suho Ezero with an increase in the participation of *Poaceae*, *Achillea*, *Apiaceae*, *Rumex* species at the expense of *Artemisia* and *Chenopodiaceae*. In addition, a change in the lithological composition of the sediments from grey clay to gyttja with a higher content of organic material is established (Fig. 33).

The last climatic deterioration at the end of the Lateglacial, the Younger Dryas stadial, is documented in the pollen and plant macrofossil records from Lake Suho Ezero (zones SE-3 and MSE-1, Figs. 33 and 34) and from Peat bog Vapsko-2

(pollen zone VP-1, Fig. 38). The re-advance of the herb vegetation has led to the retreat of the stands of coniferous and deciduous trees but in comparison to the Northwestern Rila Mountain the role of *Poaceae* has increased. Of the few macrofossil remains, represented mainly by seeds of herb plants, is important to note the find for the first time of needles of *Pinus peuce* in the Rila Mountain at 12355 cal. yrs. BP which result confirms the local survival of this tree during the last glaciation.

At higher elevation, in the area of the Vapski peat bogs, the pollen assemblages also reveal typical glacial conditions during the second half of the Younger Dryas stadial. The vegetation was dominated by open herb communities composed of *Artemisia*, *Chenopodiaceae*, *Poaceae*, and other cold-resistant species from *Achillea*, *Cirsium*, *Cichoriaceae*, *Rumex*, *Galium*, *Apiaceae* and *Dianthus*, confirmed also by their high PAR (Fig. 39). Single pine trees (*Pinus sylvestris*, *Pinus peuce*) and *Betula*, as well as shrubland of *Pinus mugo* and *Juniperus*, were also distributed. The insignificant quantities of pollen from *Alnus*, *Quercus*, *Corylus* and *Tilia*, evidently air-transported upslope, indicate that these deciduous trees were sheltered at lower altitudes (Fig. 38).

Holocene

The transition Lateglacial to Holocene is clearly evident in the pollen and macrofossil diagrams from Lake Suho Ezero with the rapid increase of the total tree pollen, the appearance of plant macrofossils from *Betula*, and, subsequently from *Pinus* sp., *Pinus peuce* and *Populus tremula*. Stands of *Betula* and *Pinus* have replaced the herb communities dominated by *Poaceae*, *Artemisia* and *Chenopodiaceae*. At lower elevations the expansion of the mixed oak forests has started with significant participation of *Ulmus*, *Tilia*, *Fraxinus excelsior*, *Acer*, and later on *Corylus* and *Carpinus betulus* (zones SE-4 and MSE-2, Figs. 33 and 34).

The palynological records from higher elevation confirm also that, initially, forests of *Betula* and stands of *Pinus* and *Juniperus*, with undergrowth of ferns, have colonized areas on barren soils (pollen zone VP-2, Figs. 36 and 38). They reached maximal distribution between 10500 and 9800

cal. yrs. BP. The total tree PAR has increased significantly contributed mainly by *Betula*, *Quercus*, *Ulmus*, *Tilia* and *Pinus*. The local presence of *Pinus* and *Juniperus* in the near vicinity of the peat bogs was justified by the finds of microscopic fragments of leaf fossils with their diagnostic stomata preserved.

Wood from *Salix* sp., fruits from *Betula* sp. and *Alnus viridis*, seeds from *Juniperus* cf. *sabina*, *Vaccinium* cf. *myrtilus*, Poaceae, Asteraceae, Apiaceae were determined, particularly after 9500 cal. yrs. BP, in the sediments of Peat bog Vapsko-1 (Hoevers, 2017).

The pollen spectra indicate widespread of oak forests with *Tilia*, *Ulmus*, *Fraxinus* below the birch zone, and the expansion of *Corylus* on more open areas started after 9800 cal. yrs. BP. Pollen of *Vitis*, *Hedera* and *Humulus/Cannabis*, originating from low altitudes, was also found. The reconstruction of the vegetation of the peat bogs revealed that it consisted mainly of Poaceae, *Artemisia*, *Achillea*, *Cirsium*, Cichoriaceae, Apiaceae, *Rumex* and Cyperaceae species.

In the vicinity of Lake Suho Ezero the vegetation was stabilized, dominated by communities of *Betula* with groups of *Pinus* and *Juniperus* which shaped the upper timber-line. Below the birch zone the mixed oak forests have climbed higher, compared to the present-day situation, but did not reach the area of the lake as plant macro-remains from deciduous trees are absent.

An important change in the composition of the vegetation cover has begun after c. 7900 cal. yrs. BP when the conifers (*Pinus*, *Pinus peuce*, *Abies*) expanded, replacing at many places the birch forests. Compared to the previous vegetation stage, the total PAR of tree pollen recorded from Peat bog Vapsko-2 retains its values but contributed now mainly by *Pinus*, *Pinus peuce*, *Abies* and *Corylus* (Fig. 39). The deciduous oak forests and *Corylus* retreated to lower altitudes and their wider distribution has ended c. 5900 cal. yrs. BP. The herb vegetation of the peat bogs was enriched with various representatives from Cyperaceae, *Artemisia*, Cichoriaceae, *Rumex*, Apiaceae, *Galium* and *Cirsium*.

The fossil record from Lake Suho Ezero (zones SE-5 and MSE-3, Figs. 33 and 34) is also characterized by the rapid spread of the conifers as well as the wider presence of *Carpinus betulus*, partly in the place of the deciduous mixed oak forests. The lake has already started to turn into a large peat bog within the boundaries of the coniferous forests. An important characteristic was the appearance of still isolated groups of *Fagus* and *Picea*. The abundance of fossil leaves and bud-scales from *Pinus peuce* and *Pinus* sp. confirms this significant change in the composition of the forest vegetation. Also, needles from *Pinus mugo/sylvestris*, *Pinus peuce* and seeds from conifers were established in the sediments of Peat bog Vapsko-1 (Hoevers, 2017).

After 5900 cal. yrs. BP *Pinus* and *Abies* retained their dominant role in the forest cover at mid-high altitudes and reached maximal distribution, as clearly supported by the increased values of PAR of coniferous trees like *Pinus mugo*, *Pinus sylvestris*, *Pinus peuce* and *Abies* (Fig. 39). In the study area *Picea abies* and *Fagus* established permanently c. 5100 cal. yrs. BP and both trees have commenced gradually to enlarge their areas after c. 4500 cal. yrs. BP. The components of the deciduous oak forests such as *Tilia*, *Ulmus*, *Carpinus* and *Corylus* participated with lower proportions.

The paleobotanical evidence from Lake Suho Ezero is quite similar in support of the dominance of the coniferous forests when the maximal distribution of *Abies*, *Pinus sylvestris* and possibly of *Pinus mugo* communities was attained. It can be assumed on the basis of the pollen data that the coniferous forest belt has climbed c. 200 m higher than nowadays. This assumption is confirmed by the determination of fossil wood from *Abies alba*, *Pinus peuce*, *Picea abies*, *Pinus mugo*, *Betula* and *Salix* between 3000 and 2220 cal. yrs. BP in Core-1 (Chakalova, Dimitrova, 1980). It is also worth to mention the beginning of a certain increase and more noticeable presence of *Fagus* in the South-western Rila Mountain.

In the course of the last three millennia the anthropogenic intervention in the natural vegetation cover has resulted in openings in the coniferous

forests. Indications of human impact, mainly of pasture activities, are documented by the presence of pollen of *Plantago lanceolata*, *Scleranthus*, *Artemisia*, Cichoriaceae, and grasses. Like in other parts of the Rila Mountain, *Picea abies* and *Fagus* expanded, and the coniferous belt was dominated by *Pinus peuce* with admixtures of *Pinus sylvestris*, *Picea abies* and *Abies alba*. Dense communities of *Pinus mugo* have spread on vast areas in the the subalpine belt.

In the area of Lake Suho Ezero *Picea abies* rapidly expanded, as confirmed by the considerable amount of pollen and macrofossils (needles and seeds) found. The enlargement of the spruce forests was dated at 3000 cal. yrs. BP (Bozilova, Smith, 1979). The later appearance and development of spruce forests in the Southern Rila Mountain can be explained by the ecological requirements of spruce, its competitive relationship with *Abies* and *Fagus*, as well as with the location of the main late-glacial refugia.

In historical time the intensification of the anthropogenic impact has resulted in destructive changes which had mainly affected the coniferous forests, with a decrease for *Pinus sylvestris*, *Picea abies*, *Pinus peuce* and *Abies alba*, and the opening of new areas occupied by herb vegetation (zones SE-7 and MSE-5, Figs. 33 and 34; pollen zone VP-5, Figs. 36 and 38). The thinning of the forest filter has promoted an increase in the air-transport of pollen from deciduous trees such as *Quercus*, *Carpinus betulus*, *Alnus* to higher altitudes. The macrofossil records from Lake Suho Ezero and Peat bog Vapsko-1 (Hoevers, 2017) appeared extremely poor in content and only needles of *Pinus* sp., *Pinus mugo/sylvestris*, *Pinus peuce* and *Picea abies* were sporadically determined. The last increase of *Fagus* and *Picea abies* was recorded after 1500 cal. yrs. BP (Bozilova, Smit, 1979) which is in conformity with the general pattern of the Holocene plant succession in the Rila Mountain.

Disturbances by fire are among the most important processes that shape forest dynamics and diversity. The first long-term Holocene record of fire regimes in the upper montane forests of the Balkans from the area of Vapski peat bogs was pre-

sented, based on macrocharcoal morphologies in combination with pollen-based reconstruction of forest dynamics and fire-related strategies. While biomass burning followed the main trends in climate, the frequency and intensity of fires were strongly linked to fire-related coping strategies of dominant tree taxa (invaders, resisters or avoiders). The invaders are species that are killed by fire but able to penetrate into freshly burned areas (*Betula*, *Alnus*, Polypodiaceae, Poaceae and all herbs). The resisters are able to survive surface fires of low to medium intensity (*Pinus sylvestris/Pinus mugo*, *Pinus peuce*, *Juniperus*) and the avoiders include shade-tolerant species easily killed by fire (*Picea abies*, *Abies alba*). The results indicated 30 fire episodes with a variable temporal distribution over the record, indicative of several distinct fire regime periods. Frequent, low-intensity fire episodes at the termination of the Lateglacial and the beginning of the Holocene between 12000 and 9000 cal. yrs. BP were concurrent with the dominance of invaders (*Betula*, *Alnus*, Poaceae, Polypodiaceae). Intermittent occurrence of low- and high-intensity surface and crown fires with longer return intervals between 9000 and 4000 cal. yrs. BP was associated with codominance of resister (*Pinus sylvestris*, *Pinus mugo*, *Pinus peuce*) and avoider (*Abies alba* and *Picea abies*) forest types. The lengthening of the fire return interval over the past 4000 years was linked to increased abundance of *Picea abies*. For the period between 4050 and 2150 cal. yrs. a lower biomass burning and small-scale surface fires was registered. A rising number of fire episodes may drive land cover towards more fire-adapted plant communities and less intense fire events with increased dominance of invaders (resprouters that rapidly reach maturity stage) as well as resisters (properties protecting from fire damage) under future warmer and drier climate. This study also showed the potential of combining charcoal morphologies with pollen records to track variability in fire intensity and plant functional attributes over long timescales that are also relevant to forest management stakeholders (Feurdean et al., 2019).

3. PIRIN MOUNTAIN

Physico-geographical characteristics and modern vegetation

Pirin Mountain (peak Vihren, 2914 m) is the third highest on the Balkan peninsula and constitutes part of the vast Rila-Rhodopes massif in Southern Bulgaria. It occupies an area of 2585 km² between 41°25′-41°55′N and 23°07′-23°53′E in the southwestern corner of Bulgaria, surrounded to the west and east by the valleys of the Struma and Mesta rivers, Rila Mountain to the north and Slavyanka Mountain (peak Gotsev, 2212 m) to the south. The mountain range stretches 70 km in a northwest-southeast direction with an average width of 30-35 km (Fig. 40). From a morphographic point of view, the Pirin Mountain is divided into Northern (2914 m), Central (2097 m) and Southern (1974 m) parts. Geologically, Pirin Mountain is a large anticline, its granite centre overlain by Palaeozoic metamorphic rocks (crystalline schist and marble). The northern part occupies 74% of the total area and is composed of granite, crystalline schist and marble. The central part is the smallest in area and is composed of crystalline schist and granite, with marble terrains in the south. The granites predominate in the southern part (Galabov et al., 1977).

At the beginning of the Quaternary Pirin Mountain was raised several times and denudation plains of different heights and ages were formed, together with steep slopes between them. The best developed denudation surfaces are the ridge and the second one from top to bottom, on which the glacial cirques and the predominant part of the lakes and peat bogs have formed. The discussion on the number of Quaternary glaciations and their characteristics continues (Velchev, 1995, 2020). Most researchers accept the opinion that here is clear evidence to support the idea of two glaciations equitable with the Riss and Würm in the Alps (Lilienberg, Popov, 1966; Popov, 1966; Grünewald, Scheithauer, 2011, etc.).

The glaciations were restricted to the Northern Pirin Mountain where typical glacial landforms such as cirques, numerous lakes (119), trough river

beds, hanging valleys and moraines were formed on the northeastern slopes. The mountain valley glaciers extended down to c. 1600-1400 m.

Pirin Mountain belongs to the South-Bulgarian climatic region where the sub-mediterranean influence penetrates along the valleys of the Struma and Mesta rivers. Above 1000 m the climate is a typically montane and the mean annual temperature depends on the hypsometric bands. The annual amount of precipitation is 800-1250 mm with a maximum in November-December, much of which is snow above 1500 m. The northwestern winds, 6-10 m/sec prevail, but during winter the frequency of southwestern winds increases (Tishkov, 1976).

The brown mountain-forest (Cambisols) and mountain-meadow soils (Umbrisols) are typical. Dark-colored mountain-forest soils (Humic Cambisols) are widespread within the subalpine belt (Ninov, 1997).

According to the last geobotanical zoning Pirin Mountain is included as a separate region within the Illyrian (Balkan) Province of the European Deciduous Forest Area (Bondev, 2002). The modern vegetation of Pirin Mountain resembles a unique combination of central-european, arctic-alpine and mediterranean species. Their distribution in several vegetation altitudinal belts is determined by the contrast between limestone and siliceous areas (Velchev, Tonkov, 1986; Bondev, 1991).

The lowest belt up to 500 m is locally represented only in the southern part of the mountain and consists of communities with mediterranean elements such as *Quercus coccifera*, *Juniperus excelsa* and *Phillyrea latifolia*. The xerothermic oak belt (up to 600-700 m) occurs on the western and southern slopes. The dominant species are *Quercus pubescens*, *Quercus frainetto* and *Carpinus orientalis*, with *Paiurus spina-christii* and numerous mediterranean and submediterranean herbs. The xeromesophilous oak and hornbeam belt (600-1000 m) is characterized by *Quercus dalechampii* and *Carpinus betulus* with an admixture of *Ostrya carpinifolia* and *Fagus sylvatica*. Vast areas are occupied by *Pinus nigra* on the western and northern slopes. The beech belt (1000-1500 m) is fragmented, identified predom-

inantly in the central and southern parts of the mountain by the 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. On both limestone and silicate areas grows *Pinus sylvestris*. The Balkan endemic *Pinus peuce* and *Picea abies* form the upper timber-line in many places. Relict communities of the Balkan subendemic *Pinus heldreichii* occur exclusively on limestone areas in the northern part. Stands of *Abies alba* are also found. The subalpine belt (2000–2500 m) is dominated by thick impenetrable stands of *Pinus mugo* with *Juniperus sibirica* and *Vaccinium myrtillus*. Calcareous areas of the alpine belt (2500–2914 m) in the northern part support herb communities of *Sesleria coeruleans*, *Carex kitaibeliana*, *Dryas octopetala* and the dwarf-willow *Salix reticulata*, while on silicate areas *Carex curvula*, *Agrostis rupestris*, *Festuca airoides* and *Empetrum nigrum* are common. A characteristic feature of the modern vegetation is the presence of a large group of Balkan and Bulgarian endemics, including 30 local endemics. They are predominantly distributed in the uppermost two vegetation belts and a part of them are termed glacial relicts. The present-day vegetation in all zones is influenced to a large extent by anthropogenic activities. A large area in the northern part of the mountain, famous for its unique landscape and flora, is protected in the Pirin National Park.

Northern Pirin Mountain – Study sites

Lake Ribno Banderishko (site 13)

The group of Banderishki Lakes on the Northern Pirin Mountain is situated in a large cirque of the same name. The Banderitsa river derives its water from all 20 lakes in the cirque. Lake Ribno Banderishko is the largest one and is situated at 2190 m (41°44'17.66"N, 28°24'53.86"E) in the subalpine belt. The lake has an elongated shape, 384 m long and 230 m wide, with a water surface of 6.5 ha. The maximum water depth is 14.2 m. The lake is fed by several upper lakes and its watershed is 3.08 km² (Figs. 2, 40 and 41). The slopes are steep and stony,

covered by groups of *Pinus mugo* and *Juniperus sibirica* within patches of herb vegetation, with the exception of the eastern slope where there is a flat strip 20 m wide (Ivanov, 1964) (Fig. 42).

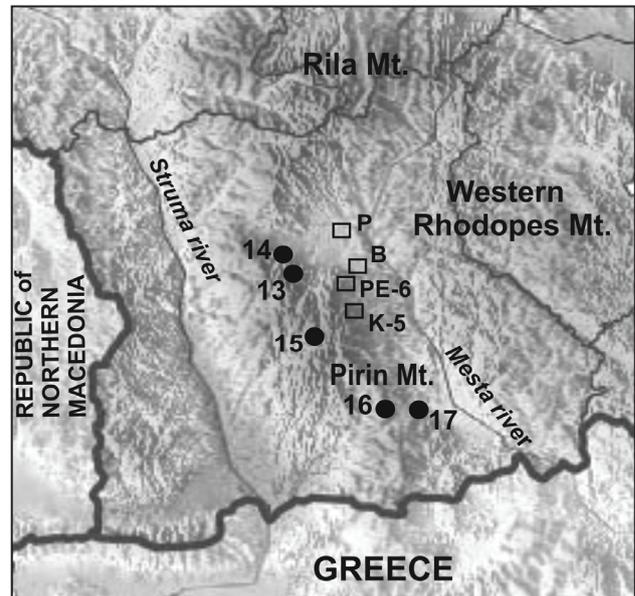


Figure 40. Map of sites in the Pirin Mountain mentioned in text: **13.** Lake Ribno Banderishko (Tonkov et al., 2002; Tonkov, Possnert, 2021); **14.** Lake Muratovo (Bozilova et al., 2004); **15.** Peat bog Mozgovitsa (Tonkov, 2003; Marinova, Tonkov, 2012); **16.** Peat bog Mutorog and **17.** Peat bog Popovi Livadi (Panovska et al., 1995); **P.** Peat bog Praso (Stefanova, Oeggl, 1993); **B.** Lake Bez bog (Stefanova et al., 2006); **PE-6.** Lake Popovo Ezero-6 (Stefanova, Bozilova, 1995); **K-5.** Lake Kremensko-5 (Atanassova, Stefanova, 2003; Stefanova et al., 2006).

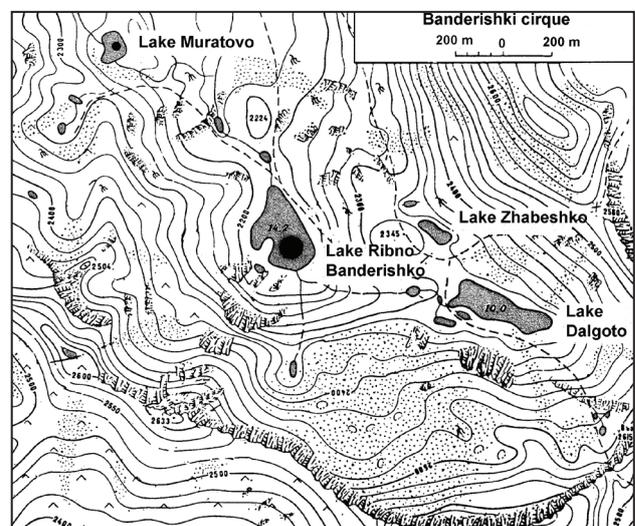


Figure 41. Map of the Banderishki cirque in the Northern Pirin Mountain.



Figure 42. A view of Lake Ribno Banderishko (Photo D. Kozuharov).

Table 12. Radiocarbon dates from Lake Ribno Banderishko.

Lab. code	Depth (cm)	^{14}C age (BP)	^{14}C age cal. BP, $\pm 2\sigma$ (mid-point)	Material dated
Ua-14001	45	1340 \pm 60	1310-1180 (1245)	<i>Pinus</i> sp. fragments of needles
Ua-13403	150	3800 \pm 135	4420-3990 (4205)	<i>Pinus peuce</i> needle, plant tissue
Ua-12855	155	4270 \pm 85	4990-4610 (4800)	chitin part of insect (<i>Otiorhyncus</i> sp.)
Ua-12856	205	5780 \pm 110	6720-6470 (6595)	<i>Pinus peuce</i> shoot
Ua-13404	230	7385 \pm 140	8320-8000 (8160)	<i>Pinus</i> sp. needles, budscale of <i>Pinus</i> sp.
Ua-13405	285	9785 \pm 360	11750-10350 (11050)	<i>Pinus</i> sp. fragments of needles, <i>Pinus peuce</i> needle
Ua-61849	290	10331 \pm 57	12410-11950 (12180)	gyttja
Ua-61850	320	11030 \pm 120	13100-12710 (12905)	silty clay

Coring, lithology and radiocarbon dating

The sediment core 3.65 m long was taken from a platform at the central part of the lake at water depth of 8 m with a square-rod piston sampler. The lithology of the sediments is: 0–295 cm brown gyttja, 295–325 cm grey silty clay, 325–365 cm grey silt (sand and gravel at 355–365 cm). The radiocarbon age of 8 samples (5 of terrestrial plant macrofossils, 2 of bulk sediment and 1 of chitin from an insect) was determined and the results are shown on Table 12. The age of the sediment core is estimated at c. 14000 cal. yrs. BP (Tonkov et al., 2002; Tonkov, Possnert, 2021).

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 43). A separate pollen diagram of the lateglacial section of the core is also presented (Fig. 43a). On the pollen diagram six local pollen assemblage zones (LPAZ) are recognized (RB-1 to RB-6) (Figs. 43 and 44). Brief descriptions are as follows:

Lake RIBNO BANDERISHKO (Northern Pirin Mt., 2190 m)

Percentage pollen diagram

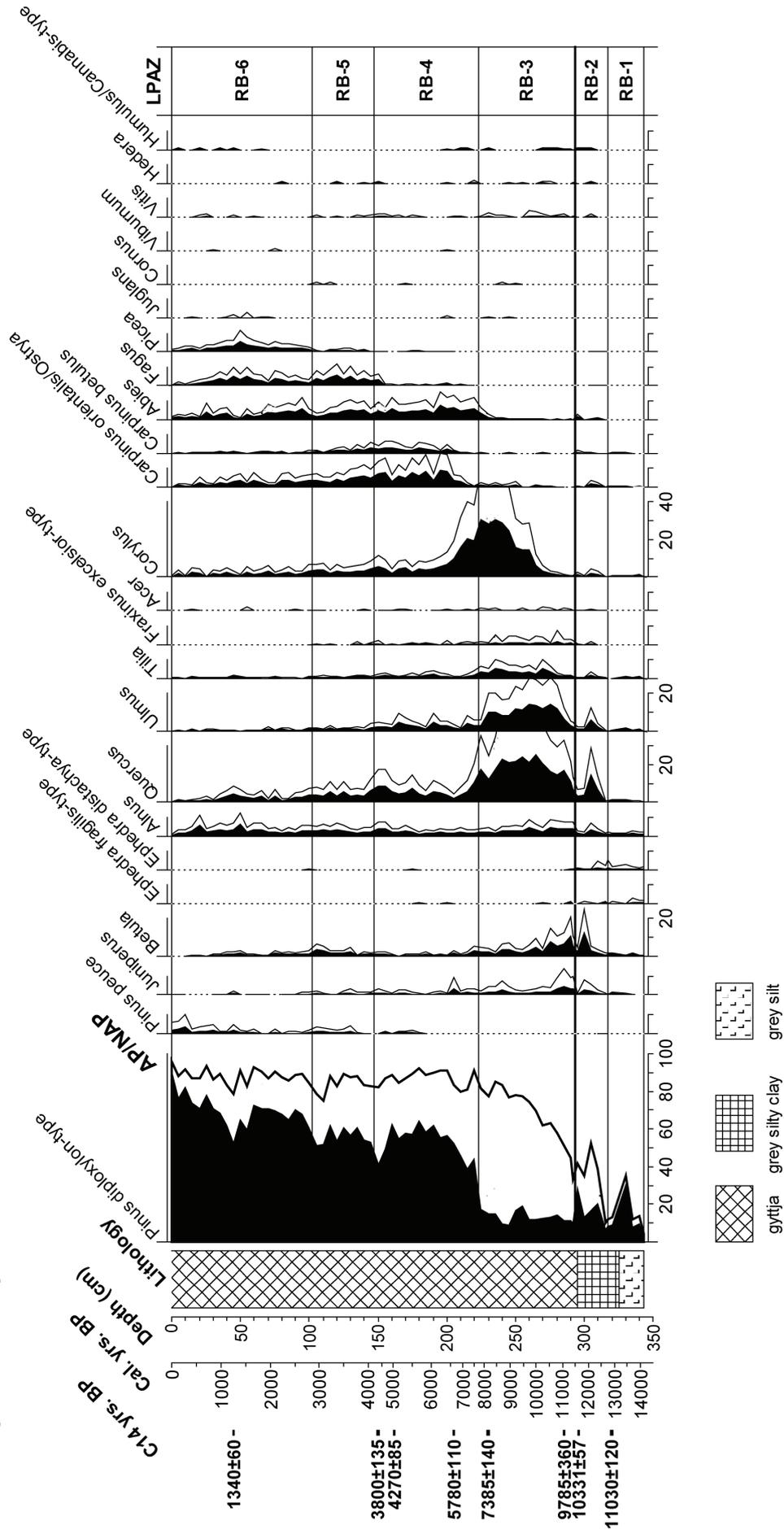
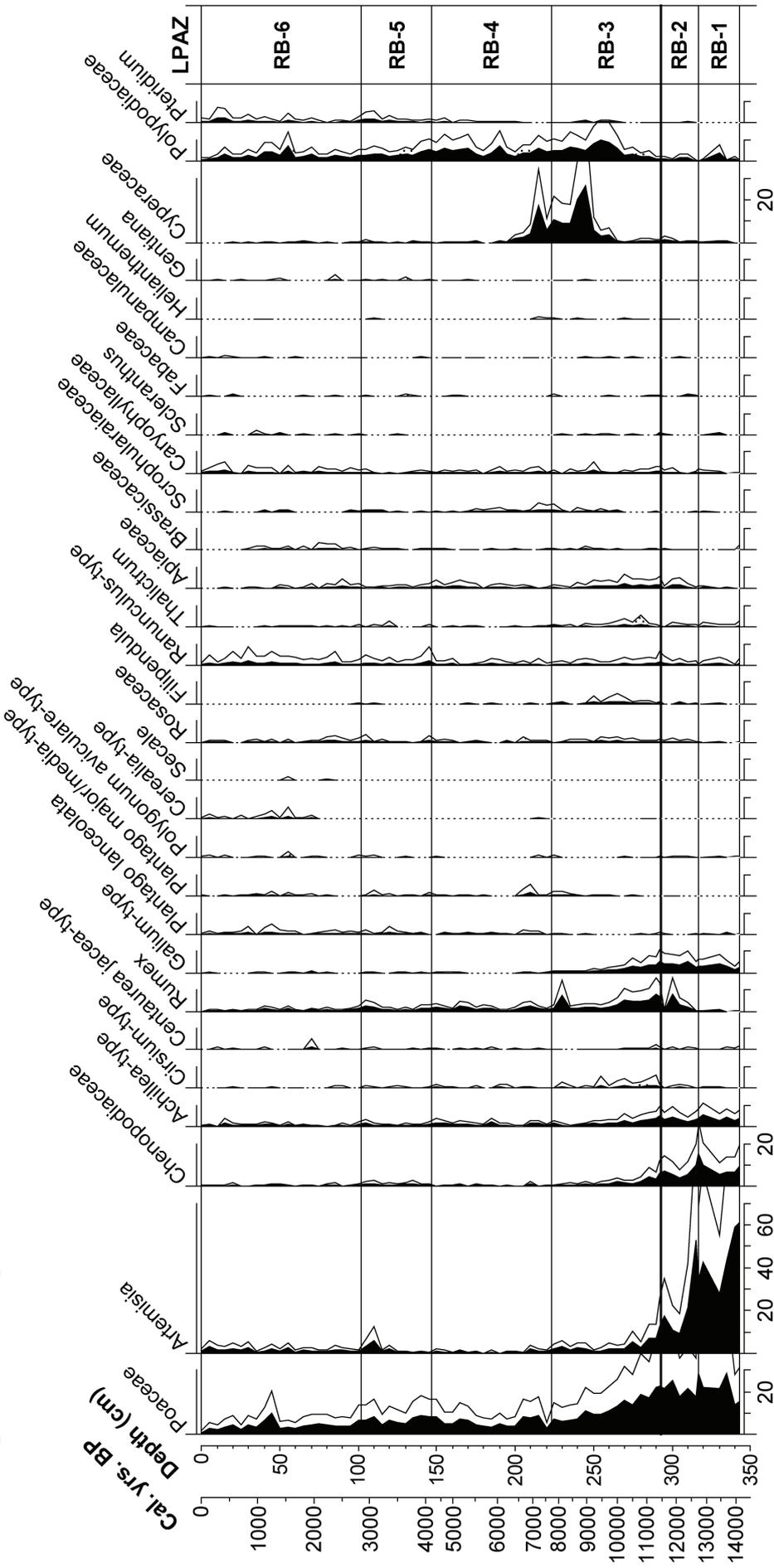


Figure 43. Percentage pollen diagram of Lake Ribno Banderishko.

Lake RIBNO BANDERISHKO (Northern Pirin Mt., 2190 m)

Percentage pollen diagram (continuation)



Modified after Tonkov et al. (2002) and Tonkov, Possnert (2021)

Figure 43. Continued.

Lake RIBNO BANDERISHKO (Northern Pirin Mt., 2190 m)

Percentage pollen diagram - Lateglacial section

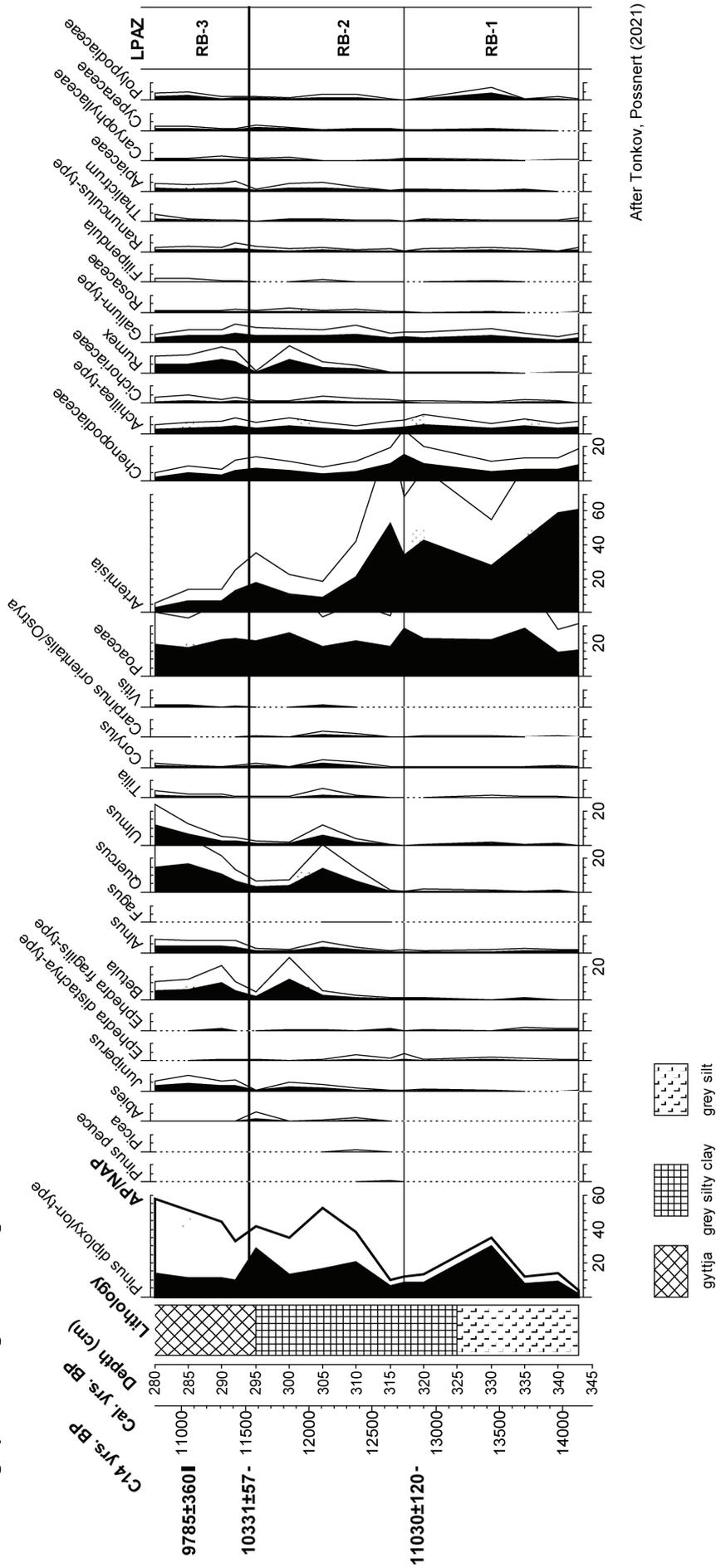


Figure 43a. Percentage pollen diagram of Lake Ribno Banderishko - Lateglacial section.

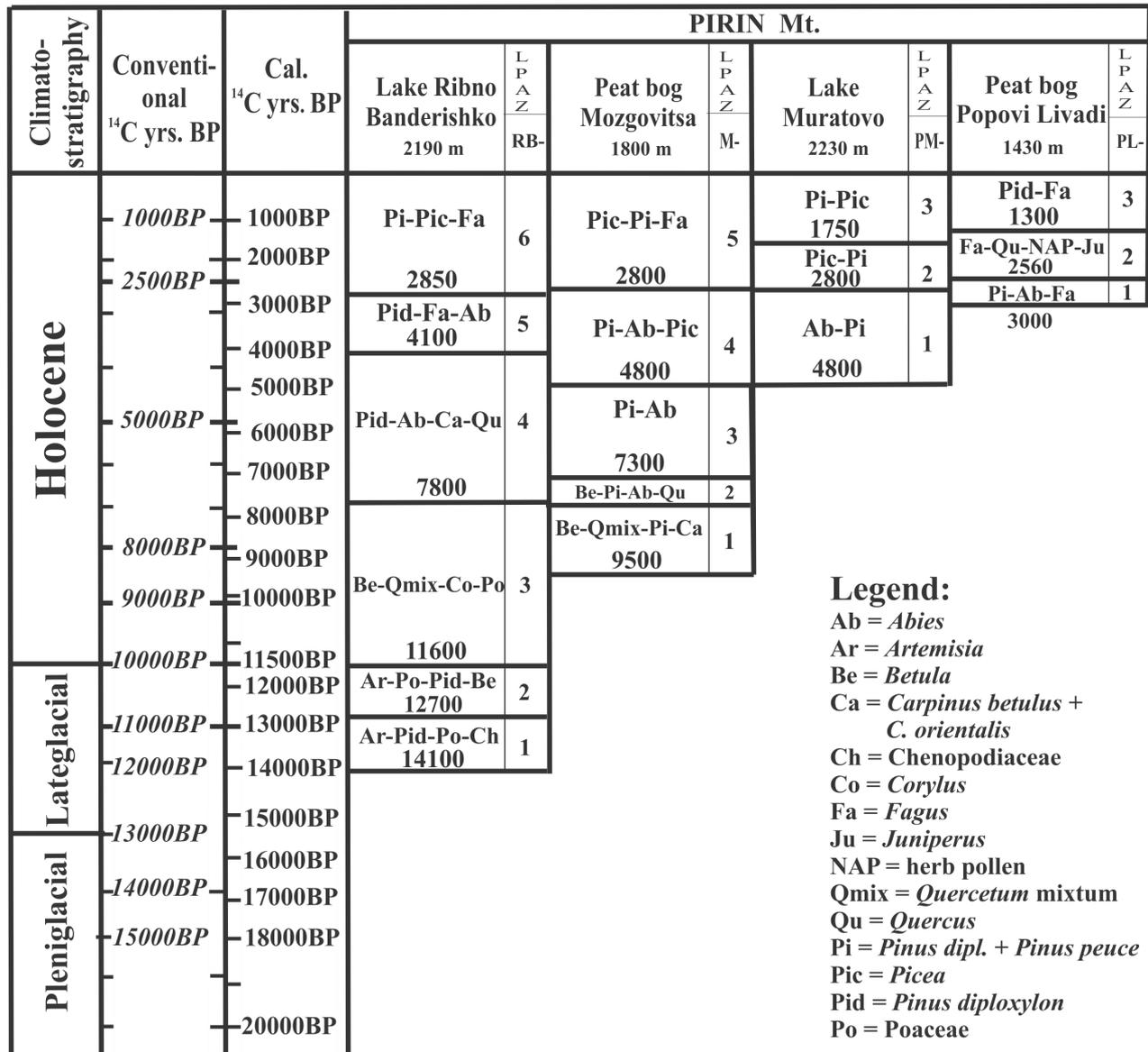


Figure 44. Comparison of the palynostratigraphy and chronology for sites in the Pirin Mountain.

LPAZ RB-1 (343-317 cm, *Artemisia-Pinus diploxylon-Poaceae-Chenopodiaceae*) (~14100-12700 cal. yrs. BP)

High percentages from herb pollen are attributed to *Artemisia* 40-60%, *Poaceae* 20-25%, *Chenopodiaceae* up to 15%, and a variety of herbs such as *Achillea*-type, *Galium*-type, *Rumex*, *Thalictrum*, etc. Pollen of trees and shrubs is recorded from *Pinus diploxylon*-type 30% (level 330 cm), *Betula*, *Quercus*, *Alnus*, *Corylus* and *Juniperus* with minimal values. There are regular finds of *Ephedra* pollen (*distachya*-type and *fragilis*-type).

LPAZ RB-2 (317-293 cm, *Artemisia-Poaceae-Pinus diploxylon-Betula*) (12700-11600 cal. yrs. BP)

The steep decline of *Artemisia* pollen from 55% to 20% is accompanied by a rise of tree pollen, reaching 50%, due to *Pinus diploxylon*-type 20%, *Quercus* 15%, *Betula* 12%, *Ulmus* 5% and other deciduous taxa. Single pollen grains of *Pinus peuce*, *Abies* and *Picea* are also recorded. Herb pollen is dominated by *Poaceae* 20%, *Artemisia* 10-15% and *Chenopodiaceae* 5%.

LPAZ RB-3 (293-223 cm, *Betula-Quercetum mixtum-Corylus-Poaceae*) (11600-7800 cal. yrs. BP)

Tree pollen reaches 60-75%, attributed to *Quercus* 25%, *Corylus* 20%, *Ulmus* 15% and *Betula* 5-10%. Pollen of *Pinus diploxylon*-type is 10-15% in the entire zone. *Poaceae* pollen drops from 17%

to 5% and low values are recorded for *Artemisia*, *Chenopodiaceae*, *Achillea*-type and *Galium*-type. Slightly higher pollen frequencies are present for *Rumex* 3-5%, *Apiaceae*, *Filipendula* and *Cirsium*-type. *Cyperaceae* pollen reaches its maximum of 20% and *Polypodiaceae* spores are quite abundant with up to 10%.

LPAZ RB-4 (223-147 cm, *Pinus diploxylon*-*Abies*-*Carpinus*-*Quercus*) (7800-4100 cal. yrs. BP)

The pollen curve of *Pinus diploxylon*-type rises steeply to 60%, while *Corylus*, *Quercus* and *Ulmus* pollen frequencies decline to 2-5% each. Notable are the establishment of *Abies* pollen curve and the appearance of *Carpinus betulus* and *Carpinus orientalis*/*Ostrya* pollen with values around 5%. At several depths pollen of *Fagus*, *Picea*, *Vitis* and *Hedera* is recorded. Total herb pollen drops to 10%.

LPAZ RB-5 (147-102 cm, *Pinus diploxylon*-*Fagus*-*Abies*) (4100-2850 cal. yrs. BP)

This zone is characterized by the establishment of *Fagus* with 5%. High pollen values are recorded for *Pinus diploxylon*-type 55-75%, accompanied by *Abies* 5-7%, *Betula* 3% and *Alnus*. The herb pollen taxa are represented by *Poaceae* 8-10%, *Artemisia* up to 7%, *Rumex*, *Ranunculus*-type, *Plantago lanceolata*, and the first finds of *Secale* and *Cerealialia*-type.

LPAZ RB-6 (102-0 cm, *Pinus*-*Picea*-*Fagus*) (2850 cal. yrs. BP-till present)

Pollen of *Pinus diploxylon*-type dominates with 80-90% at the uppermost samples, while *Pinus peuce* slightly increases. A characteristic feature is the rise of *Picea* pollen curve up to 8%. Pollen of *Juglans*, *Vitis* and *Humulus*/*Cannabis*-type is quite common. The herb pollen taxa are represented by *Poaceae*, *Artemisia*, *Achillea*-type, *Ranunculus*-type, *Caryophyllaceae*, *Plantago lanceolata*, *Secale*, *Cerealialia*-type, etc.

Lake Muratovo (site 14)

This lake belongs also to the group of Banderishki Lakes and is located at 2230 m (41°44'44.39"N, 23°24'21.85"E) on a small secondary cirque in the subalpine belt (Figs. 2, 40 and 41). The lake has almost a circular shape, 133 m long and 114 m wide, with water surface of 1.23 ha, maximum water 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. 45).

Coring, lithology and radiocarbon dating

Two sediment cores were obtained from a platform at the deepest part of the lake with a square-rod piston sampler. The first core PMa 1.1 m long was collected at a water depth of 3.15 m. The second core PMb 1.85 m long was collected at a water depth of 2.85 m. Both cores stopped at very hard clay material and stones. The sediment lithology is silty clay at the bottom, overlain by clay gyttja, and grey clay at the top. The radiocarbon age of 7 samples of bulk sediment was determined and the results are shown on Table 13. They indicate that the deposition of sediments has started c. 4500 cal. yrs. BP which questions the opinion that Lake Muratovo, like other large lakes in the Banderishki cirque, is of glacial origin. Quite probably, the lake was formed either after a tectonic movement or a landslide, after which the accumulation of sediments has become possible (Bozilova et al., 2004).

Pollen analysis

Pollen analysis was performed at 5 cm interval and two percentage pollen diagrams are constructed (Figs. 46 and 47). Pollen accumulation rates for the

Table 13. Radiocarbon dates from Lake Muratovo.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Core PMa				
Hela-557	23-25	1695±95	1830-1380 (1605)	clay gyttja
Hela-558	63-65	2365±70	2710-2240 (2475)	clay gyttja
Hela-559	103-105	3800±75	4420-3980 (4200)	clay gyttja
Core PMb				
Hela-692	28-30	1215±35	1270-1050 (1160)	clay gyttja
Hela-693	68-70	1885±35	1900-1720 (1810)	clay gyttja
Hela-694	143-150	3485±40	3860-3640 (3750)	clay gyttja
Hela-695	173-175	3915±45	4520-4160 (4340)	clay gyttja



Figure 45. A view of Lake Muratovo (Photo: P. Ivanov).

main tree/shrub and herb taxa are also calculated for core PMb (Fig. 48). On the pollen diagrams three local pollen assemblage zones (LPAZ) are recognized (PM-1 to PM-3) which are easily correlated (Figs. 46, 47 and 44). Brief descriptions are as follows:

LPAZ PM-1 (*Abies-Pinus diploxylon-Pinus peuce*) (4600-2800 cal. yrs. BP)

Core PMa (110-67 cm) and Core PMb (185-112 cm)

Pollen of *Pinus diploxylon*-type dominates with 50-68% (Fig. 46) and 35-50% (Fig. 47). 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* and *Alnus* are below 5% each. Pollen of *Quercus*, *Ulmus*, *Tilia*, *Corylus* and *Carpinus betulus* is of low importance. Single pollen grains of *Juglans*, *Fraxinus excelsior*-type, *Acer*, *Vitis* are also recorded. The herb pollen taxa are represented by *Poaceae* 5%, *Artemisia*, *Cichoriaceae*, *Achillea*-type, *Centaurea jacea*-type, *Rumex*, *Ranunculaceae*, *Apiaceae* and *Brassicaceae*.

In core PMa the quantity of *Isoetes* spores is higher 2-6% (Fig. 46) compared to the corresponding interval in core PMb (Fig. 47). The total arboreal PAR is 5000 to 6500 grains⁻¹ cm⁻², contributed mainly by *Pinus diploxylon*-type 2000-3500, *Abies* 1250-1750, *Pinus peuce* 500-750, *Picea* c. 150, and for deciduous tree taxa like *Fagus*, *Betula*, *Alnus*, *Corylus* c. 100 each. The PAR of total herb taxa is c. 1000 (Fig. 48).

PAZ PM-2 (*Picea-Pinus diploxylon-Pinus peuce*) (2800-1750 cal. yrs. BP)

Core PMa (67-27 cm) and Core PMb (112-65 cm)

The pollen curve of *Picea* rises to 15-20% in both diagrams. A slight increase for *Fagus* is accompanied by a decline for *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 taxa continues, together with a slight increase for *Chenopodiaceae*, *Rumex*, *Polygonum avicu-*

Lake MURATOVO (Northern Pirin Mt., 2230 m)
Percentage pollen diagram (Core PMa)

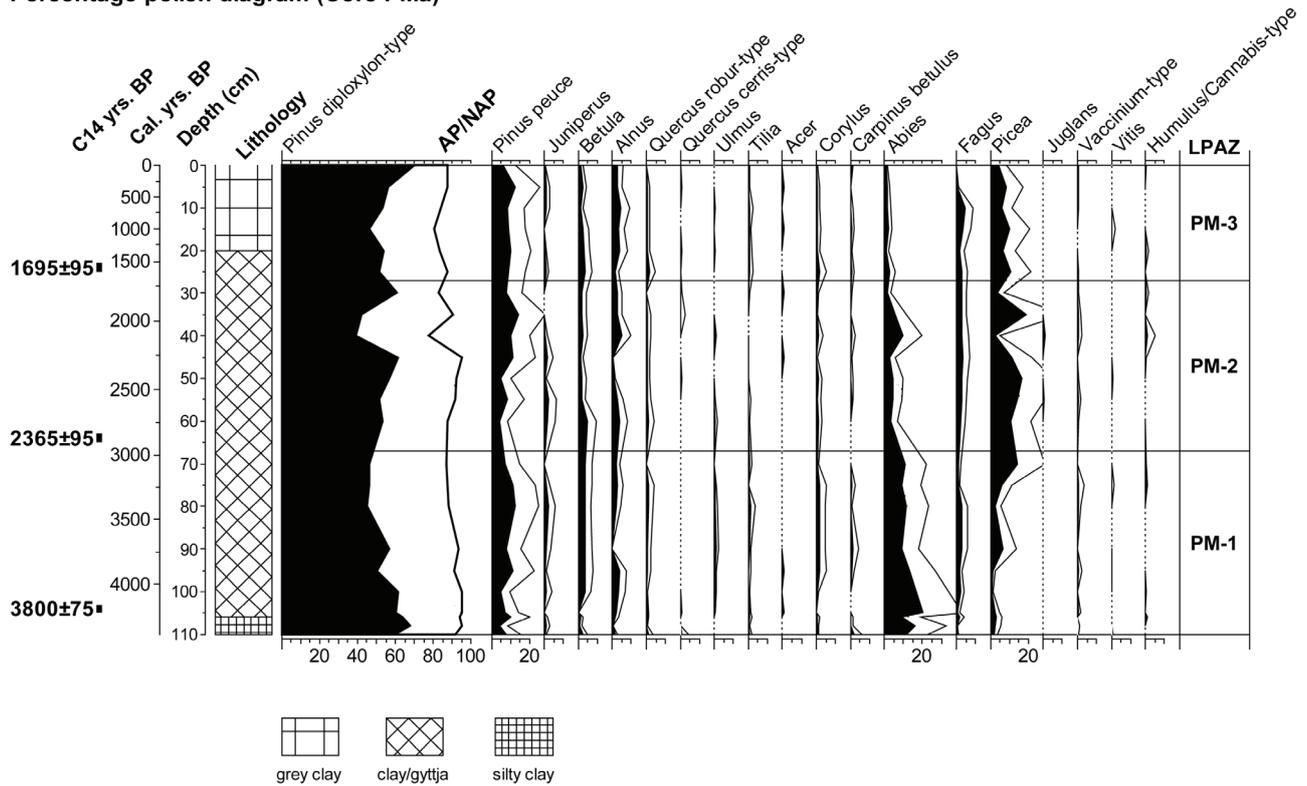
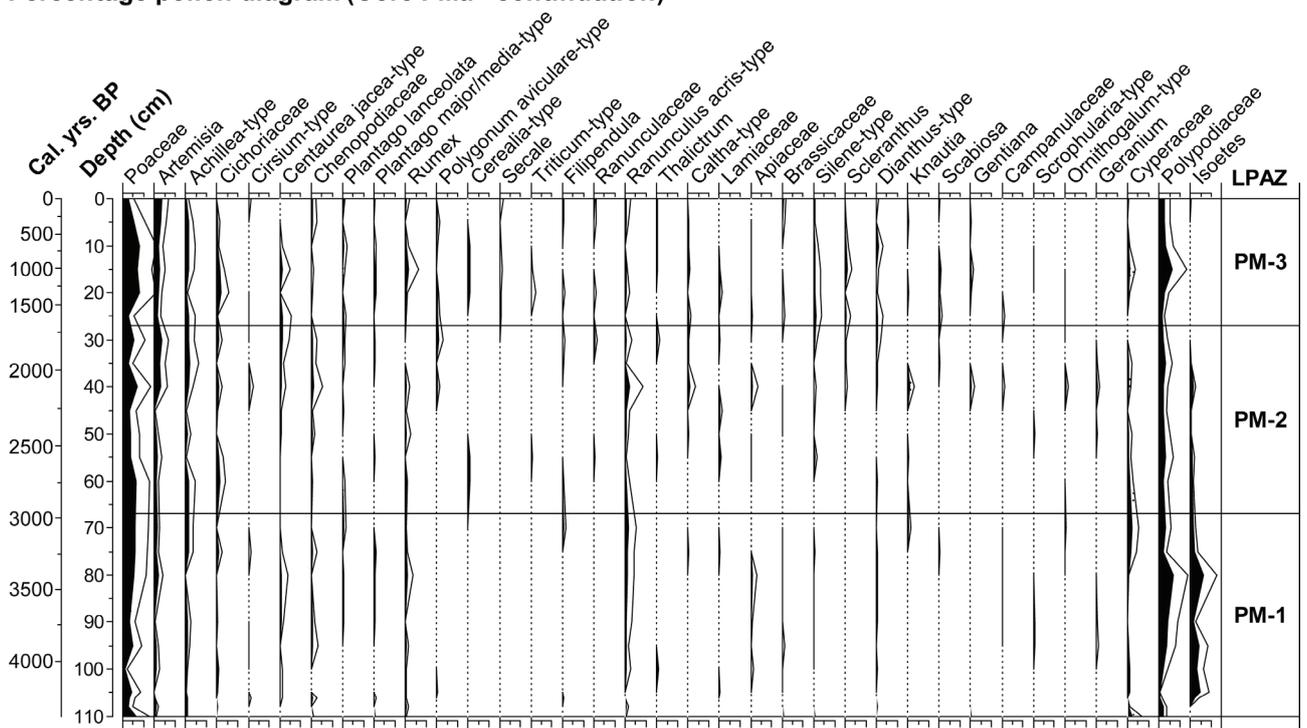


Figure 46. Percentage pollen diagram of Lake Muratovo (Core PMa).

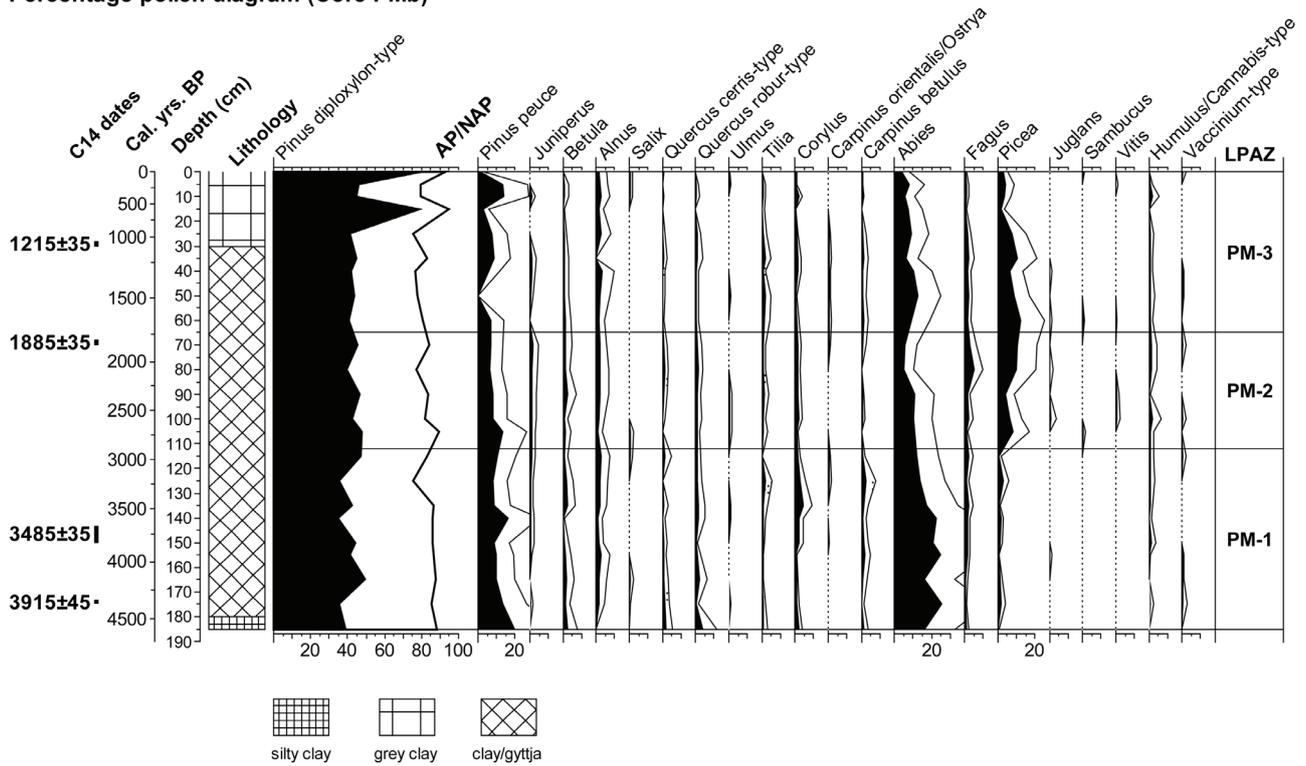
Lake MURATOVO (Northern Pirin Mt., 2230 m)
Percentage pollen diagram (Core PMa - continuation)



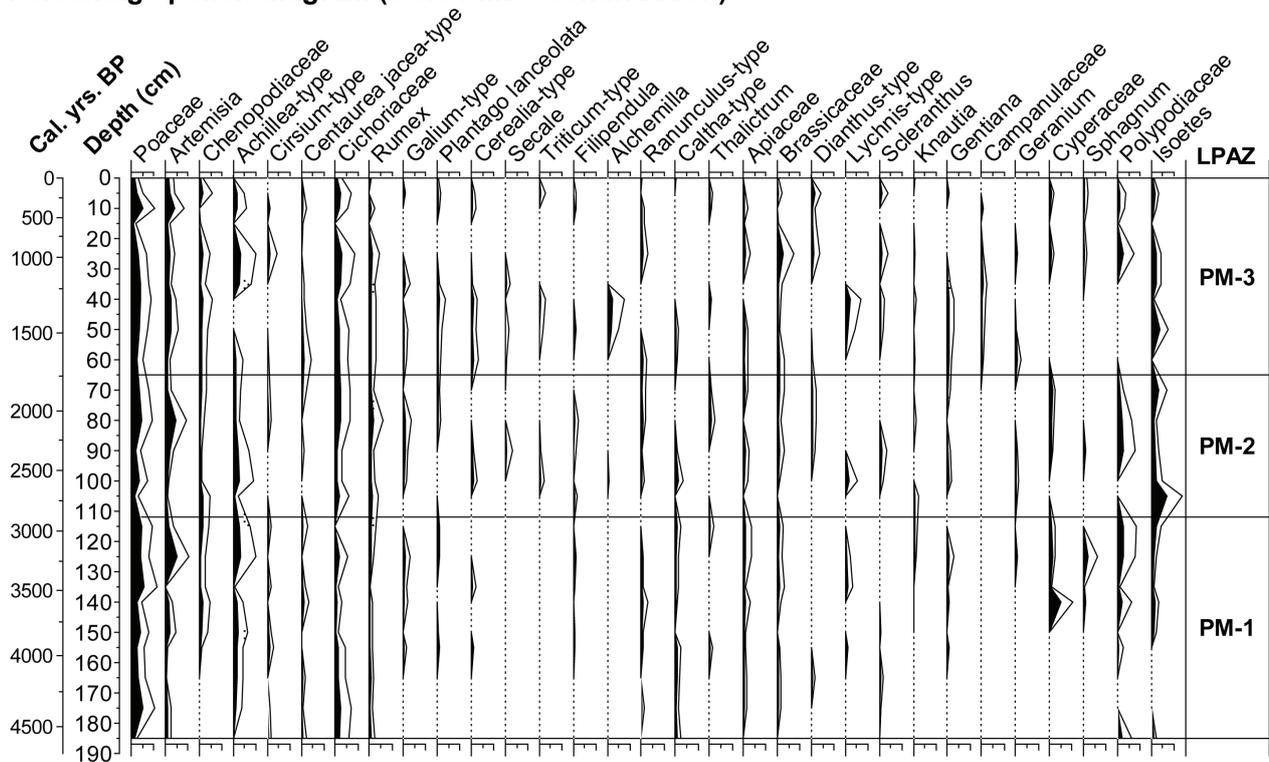
Modified after Bozilova et al. (2004)

Figure 46. Continued.

Lake MURATOVO (Northern Pirin Mt., 2230 m)
Percentage pollen diagram (Core PMb)



Lake MURATOVO (Northern Pirin Mt., 2230 m)
Percentage pollen diagram (Core PMb - continuation)



Modified after Bozilova et al. (2004)

Lake MURATOVO (Northern Pirin Mt., 2230 m)

Pollen accumulation rates (Core PMb)

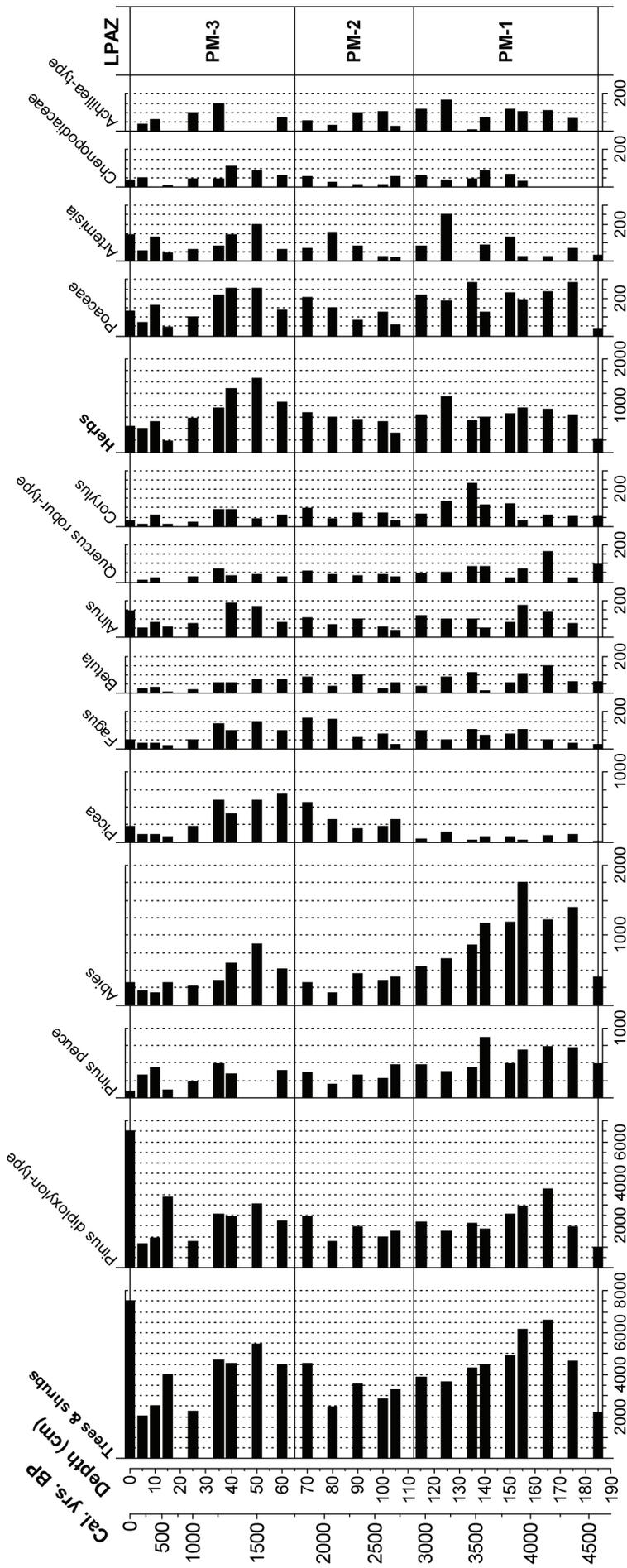


Figure 48. Pollen accumulation rates (PAR; pollen grains $\text{cm}^{-2}\cdot\text{yr}^{-1}$) for the main tree/shrub and herb taxa from Lake Muratovo (Core PMb) plotted against age (cal. yrs. BP).

lare-type, *Scleranthus*, *Plantago lanceolata*. Pollen of *Cerealia*-type and *Triticum*-type is also noted. The presence of *Isoëtes* spores in core PMa (Fig. 46) declines and in core PMb (Fig. 47) is 1-5%. The most characteristic feature is the quick increase of PAR for *Picea* up to 500 grains⁻¹ cm⁻², while the corresponding values for *Pinus diploxylon*-type, *Pinus peuce*, *Fagus*, *Betula* and *Corylus* are nearly the same like in the previous zone. A gradual decline to 250 is observed for *Abies* (Fig. 48).

PAZ PM-3 (*Pinus diploxylon*-*Pinus peuce*-*Picea*) (1750 cal. BP-till present)

Core PMa (27-0 cm) and Core PMb (65-0 cm).

The pollen curve of *Pinus diploxylon*-type rises 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 and Chenopodiaceae. The permanent presence of anthropophytes is characteristic like *Cerealia*-type, *Triticum*-type, *Secale*, *Polygonum aviculare*-type, *Plantago lanceolata*, *Scleranthus* and *Rumex*. The total arboreal PAR increases again to 5500 grains⁻¹ cm⁻² with a

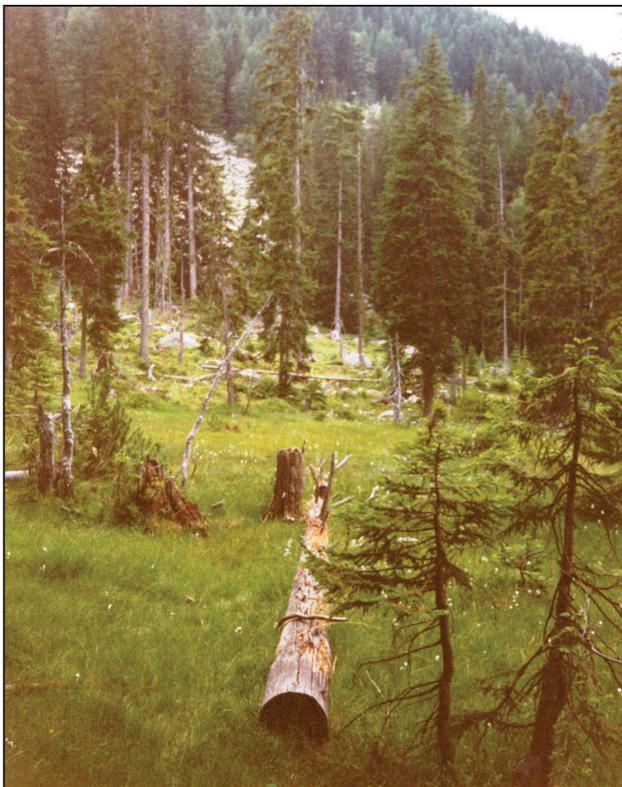


Figure 49. A view of Peat bog Mozgovitsa (Photo S. Tonkov).

maximum of 6500 in the uppermost sample, contributed mainly by *Pinus diploxylon*-type. The PAR of *Picea* and *Abies* rise to 750 each. The total PAR of herbs reaches 1500 (Fig. 48).

Peat bog Mozgovitsa (site 15)

The deep valley of the Mozgovitsa river is located in the central part of the Northwestern Pirin Mountain. It runs about 10 km in an east-west direction between 2800 and 1250 m passing through the alpine, subalpine and coniferous belts. The river takes its source from a cirque built up of five tiers with lakes in them. In the lowermost tier, below 1900 m, there are no lakes and peat bogs are formed in depressions, linked by streams of running water (Velchev, Kenderova, 1994). One of these peat bogs, with an area of c. 0.15 ha, located at 1800 m on the left river bank within a thin spruce forest, was selected for research (Figs. 2 and 40). The steep slopes of the valley are occupied by communities of *Betula pendula* and *Pinus sylvestris*, mixed in places with *Picea abies* and *Pinus peuce*. The bog vegetation is composed of *Shagnum* sp., *Carex acutiformis*, *Carex flava*, *Carex echinata*, *Triglochin palustris*, *Juncus effusus*, *Deschampsia caespitosa*, *Caltha palustris*, *Potentilla palustris*, *Cirsium appendiculatum*, etc. (Tonkov, 2003; Marinova, Tonkov, 2012) (Fig. 49).

Coring, lithology and radiocarbon dating

The core 1.5 m long was obtained with Dachnowsky hand-corer equipment. The lithology of the sediments is: 0-145 cm peat and 145-150 cm clay with sand. The radiocarbon age of 2 bulk sediment samples was determined and the results are shown on Table 14. The basic correlation is performed with the detailed radiocarbon chronology from Lake Ribno Banderishko and the age of the sediment core is estimated at c. 9500 cal. yrs. BP.

Table 14. Radiocarbon dates from Peat bog Mozgovitsa.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Lu-4036	52-68	5700±80	6670-6310 (6490)	peat
Lu-4035	124-136	8040±100	9250-8600 (8925)	peat

Pollen and plant macrofossil analyses

Pollen analysis was performed at 5 cm interval and the core was also sampled at 10 cm intervals for plant macrofossil analysis. Two fractions of macrofossils after sieving through meshes of 0.4 mm and 0.16 mm were analyzed at magnification 10-40x. Charred wood (> 2 mm) and non-charred (>5 mm) particles were studied under reflected light and light microscopes. Their determination was based on sections in three anatomical plains (transversal, tangential and radial). The plant macrofossils are represented as absolute numbers of determinable items (needles, seeds, nutlets, etc.) per sample volume of 20 ml plotted as histograms on a composite diagram together with the percentage values of the most common pollen taxa. On the diagram five local assemblage zones (LAZ) are recognized (M-1 to M-5) (Figs. 50 and 44). Brief descriptions are as follows:

LAZ M-1 (150-100 cm, *Betula-Quercetum mixtum-Pinus-Carpinus*) (9500-7800 cal. yrs. BP)

The samples are dominated by *Betula* pollen up to 30%, *Pinus diploxylon*-type 20% and *Quercus* up to 30%. Pollen of coniferous (*Pinus peuce*, *Juniperus*, *Picea*, *Abies*) and deciduous tree taxa (*Carpinus orientalis/Ostrya*, *Carpinus betulus*, *Tilia*, *Ulmus* and *Fagus*) is continuously recorded. The herb pollen taxa are represented by Poaceae 5-15%, *Artemisia*, Cichoriaceae, *Plantago lanceolata*, *Ranunculus*-type, Apiaceae, etc. Pollen of Cyperaceae reaches 20% and maximal values of 40-45% are recorded for Polypodiaceae spores.

The macrofossil samples are rich in nutlets of *Betula*. Seeds and needles from conifers (*Pinus peuce*, *Pinus sylvestris/mugo*) and in one sample needles of *Picea abies* are found. Except subfossil wood of *Pinus* sp. charcoal particles are also present. The constituents of the bog vegetation are represented by nutlets of *Scirpus sylvaticus*, fruits of *Carex* sp., *Carex echinata* and *Carex acuta*.

LAZ M-2 (100-80 cm, *Betula-Pinus-Abies-Quercus*) (7800-7300 cal. yrs. BP)

The pollen curves of *Abies* and *Picea* reach 10% and 5%, respectively. Pollen of deciduous trees such as *Quercus*, *Carpinus*, *Corylus* and *Betula* declines. The transition to the next zone is marked by the quick rise of the pollen curves of *Pinus*

diploxylon-type and *Pinus peuce*. The variety of herb pollen taxa remains like in the previous zone.

The macrofossil record is dominated by nutlets of *Betula* which subsequently disappear. Subfossil wood of *Salix* and *Alnus* is also found. A substantial increase in the presence of fruits/nutlets of various *Carex* species, *Scirpus sylvaticus* and *Juncus effusus*-type is observed.

LAZ M-3 (80-50 cm, *Pinus-Abies*) (7300-4800 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type 50% and *Pinus peuce* 28% reaches maximal values while *Abies* and *Picea* are represented with 5-10% each. Pollen of various deciduous tree taxa is below 3%.

The macrofossil record comprises needles and seeds of *Pinus peuce*, *Pinus sylvestris/mugo* and *Pinus* sp. Nutlets of *Carex* sp., *Carex acuta*, *Carex echinata* and *Juncus effusus*-type are also determined.

LAZ M-4 (50-28 cm, *Pinus-Abies-Picea*) (4800-2800 cal. yrs. BP)

Apart from the steady presence of *Pinus diploxylon*-type and *Pinus peuce* pollen, a slight increase for pollen of *Picea*, *Abies*, *Juniperus*, *Betula* and *Carpinus betulus* is established. Pollen grains of *Juglans* are also determined. The total quantity of herb pollen starts to increase.

Wood and needles of *Picea abies*, as well as wood of *Pinus* sp., *Salix*, *Juniperus*, needles and seeds of *Pinus peuce* are found. Nutlets of various *Carex* species are present in the fossil record.

LAZ M-5 (28-0 cm) (*Picea-Pinus-Fagus*) (2800 cal. yrs. BP-till present)

In the uppermost samples pollen of *Picea* with 13% and *Fagus* with 5% reaches maximal values. Pollen of *Pinus diploxylon*-type is c. 40%, while *Pinus peuce* declines to 6-10%. Higher pollen frequencies are recorded for Poaceae 20-23%, for the anthropogenic pollen indicators such as *Urtica*, *Rumex*, *Plantago lanceolata*, *Cerealia*-type, and other herb taxa like Rosaceae, *Filipendula* and *Artemisia*. Pollen of Cyperaceae reaches 25%.

The macrofossil record is dominated by needles and wood of *Picea abies*, scattered finds of wood of *Pinus* sp., *Juniperus* and *Salix*. Nutlets and fruits of *Carex echinata*, *Carex canescens* and *Carex acuta* are determined.

Peat bog MOZGOVITSA (Northern Pirin Mt., 1800 m)
Percentage pollen and plant macrofossil diagram

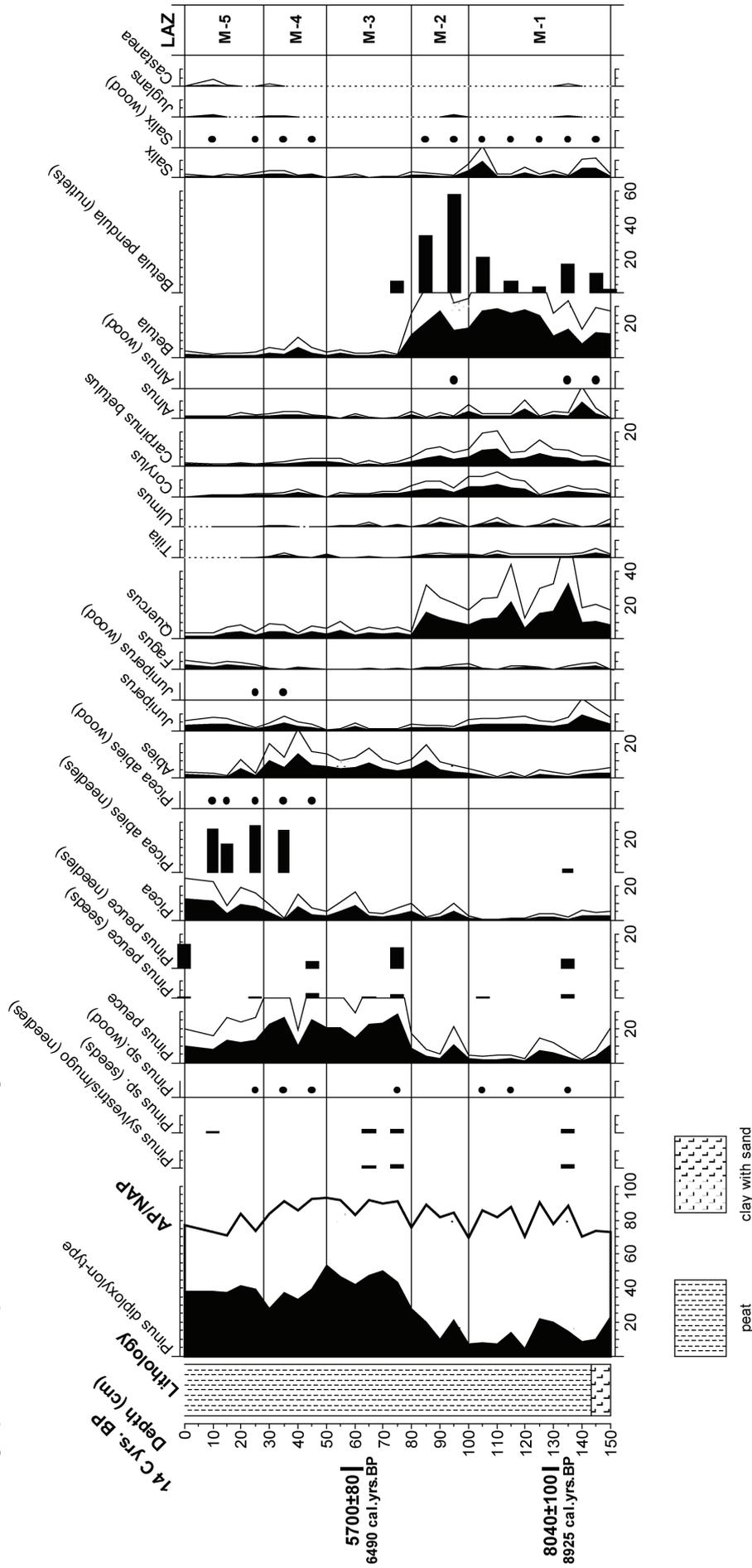
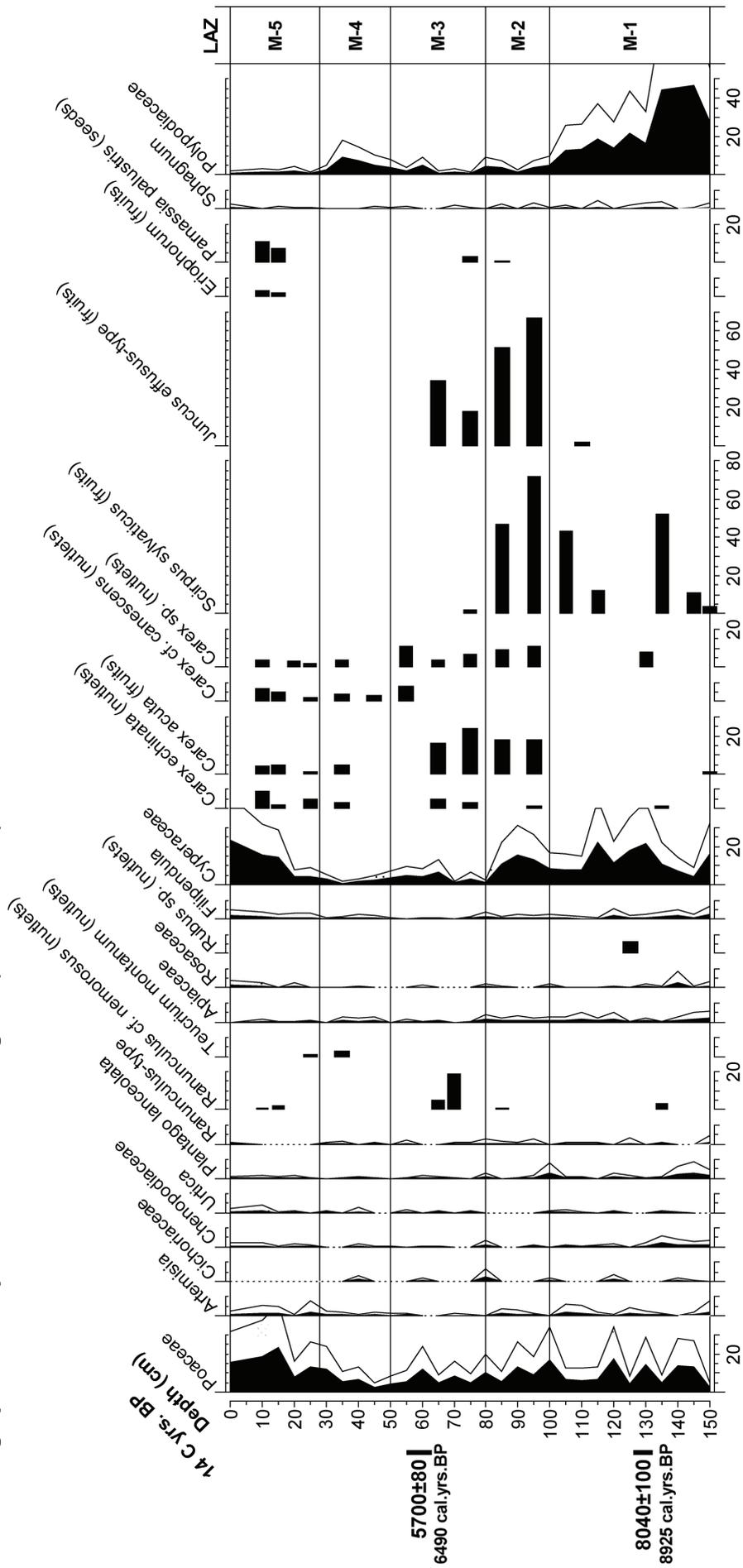


Figure 50. Percentage pollen and plant macrofossil diagram of Peat bog Mozgovitsa.

Peat bog MOZGOVITSA (Northern Pirin Mt., 1800 m)
Percentage pollen and plant macrofossil diagram (continuation)



Modified after Marinova, Tonkov (2012)

Figure 50. Continued.

Vegetation history in the Northern Pirin Mountain

Lateglacial

The core from Lake Ribno Banderishko is the first investigated continuous postglacial sequence from the Pirin Mountain. It spans most of the Lateglacial and the entire Holocene, thus providing an opportunity to reconstruct high altitudinal vegetation and climate changes on the northern part of the mountain.

The pollen stratigraphy of the lateglacial section of the core reveals the changes for the time period 14000–11600 cal. yrs. BP (pollen zones RB-1 and RB-2; Fig. 43a). The oldest pollen zone RB-1, which covers the time window 14000–12750 cal. yrs. BP, can be related to the lateglacial interstadial complex Bölling/Alleröd. The high values of herb pollen taxa with the dominance of *Artemisia*, Poaceae and Chenopodiaceae imply the existence of treeless “mountain-steppe” vegetation composed of cold-tolerant and heliophilous species. Stands of pines (*Pinus mugo*, *Pinus sylvestris* and *Pinus peuce*), *Betula* and shrubland of *Juniperus*, and *Ephedra*, thrived in sheltered places in the vicinity of the lake. Both *Ephedra* species, indicative of the lateglacial mountain flora, had probably occupied open base-rich places. Later on, in the Holocene, these plants disappeared from the flora of the Pirin Mountain like in the Rila Mountain. In the paleovegetation reconstruction attention should be drawn that the pollen grains produced by the Balkan subendemic pine *Pinus heldreichii* fall within *Pinus diploxylon*-type group. Unfortunately, it is not possible to estimate the proportion of *Pinus heldreichii* in the total quantity of pine pollen recorded. Evidently, this tree was present far from the lake at lower altitudes, bearing in mind that its present-day distribution is below 1800 m. The occurrence of deciduous tree pollen from *Quercus*, *Ulmus*, *Corylus*, and *Carpinus*, though in low quantities, suggests that these trees have survived the harsh lateglacial conditions in places, where moisture and humidity appeared sufficient for their growth.

The next time interval 12750–11600 cal. yrs. BP (pollen zone RB-2) can be chronologically correlated with the last climatic reversal, the Younger Dryas stadial. The “mountain-steppe” herb vegetation continued to dominate until c. 12200 cal. yrs. BP and after that it was partly replaced for a short period of time by stands of *Pinus*, *Betula* and *Juniperus*. A signal for climate improvement has resulted in the spread of mixed oak forests from their refuges at low altitudes and the appearance of moisture-demanding trees and climbers such as *Abies*, *Picea*, *Fagus* and *Vitis*. Quite probably, populations of fir, spruce and beech were present during the Lateglacial in refuges on the Pirin Mountain. After this short-term climate improvement, typical lateglacial conditions returned in the highest parts of the mountain and the tree stands probably moved down along the mountain slopes.

Other studies of lateglacial sites from the Northern Pirin Mountain complement the picture of vegetation and climate changes (Fig. 40). Sediments of lateglacial age consisting of 20 cm grey silt, not radiocarbon dated, from Lake Dalgoto located at 2310 m above Lake Ribno Banderishko (Fig. 41), were assigned to the stadial Younger Dryas on the basis of their palynostratigraphy. It indicated the existence of open xerophytic herb vegetation with *Artemisia*, Chenopodiaceae, together with species of the Asteraceae (*Achillea*, *Aster*, *Centaurea*), Caryophyllaceae (*Dianthus*, *Silene*), Apiaceae, Ranunculaceae and Brassicaceae. At the termination of the Lateglacial are recorded increasing values of arboreal taxa (*Pinus diploxylon*-type, *Quercus* and *Betula*) and strong decrease of *Artemisia* and Chenopodiaceae (Stefanova, Ammann, 2003).

The core of Lake Kremensko-5 which is situated at 2124 m (Fig. 40) yielded sediments from more than 13500 ¹⁴C yrs. BP and a pollen stratigraphy that can be correlated with the interstadial/stadial cycle of the Lateglacial. The radiocarbon date of 16000 cal. yrs. BP points to a stadial phase that can be correlated with the Oldest Dryas. The climate amelioration during the interstadial is confirmed by the higher importance of tree taxa, leading to enlargement of the coniferous woods around the lake at 14420 cal. yrs. BP. The upper

part of the lateglacial record of Lake Kremensko-5 remained without absolute age determination, but the Younger Dryas stadial c. 25 cm in thickness is delimited on the basis of the dominance of *Artemisia*, *Chenopodiaceae* and other various characteristic herb taxa, and the occurrence of the *Juniperus-Ephedra* assemblages (Atanassova, Stefanova, 2003).

Later studies in the Northern Pirin Mountain attempted to provide a chronological framework for the Lateglacial based on new pollen and plant macrofossil sequences recovered from Lake Kremensko-5 and Lake Bezbog located at 2250 m (Fig. 40). The reconstruction of the lateglacial vegetation revealed a wide distribution and dominance of *Artemisia-Chenopodiaceae-Poaceae* with *Ephedra* shrubland at higher altitudes during the Oldest Dryas. Subsequently, the Bölling/Alleröd interstadial was characterized by the spread of *Pinus* (*Pinus peuce*, *Pinus diploxylon*-type) and *Juniperus* with a partial retreat of the herb vegetation in the conditions of a milder climate. The palynostratigraphy for the Younger Dryas stadial featured a re-advance of the herb vegetation and the presence of several trees and shrubs such as *Betula pendula*, *Pinus peuce* and *Juniperus sibirica* was confirmed by macrofossils finds. Following the depth-age models constructed and the changes in biostratigraphy, the identification of the Bölling/Alleröd interstadial between 13800 and 12600 cal. yrs. BP at Lake Bezbog, and between 14100 and 12600 cal. yrs. BP at Lake Kremensko-5, was correlated with the Greenland Interstadial GI-1. The proposed lower boundary of the interstadial differs considerably from the ice-core records which might be explained either by a time-lag in the vegetation response or certain disadvantages of the depth-age models due to the still insufficient number of radiocarbon dates. For the Younger Dryas stadial, when the final reversal of the typical lateglacial conditions has occurred, a radiocarbon date of 11920 cal. yrs. BP was obtained from Lake Bezbog (Stefanova et al., 2006).

All the lateglacial pollen sequences analysed so far indicated that the vegetation type characteristic of localities at mid-high altitudes could be defined as "montane steppe-forest". Most proba-

bly, at lower elevations the ecological conditions favored the survival in refuges of populations of various thermophilous trees and shrubs with their subsequent vertical immigration in the Holocene. The available evidence supports the idea that the Balkans served as one of the main refugial areas in Southern Europe (Huntley, Birks, 1983; Bennett et al., 1991; Lang, 1994; Tzedakis, 2004, etc.).

Holocene

The onset of the Holocene after 11600 cal. yrs. BP is manifested by a rise in the total tree pollen, namely contributed by deciduous trees (pollen zone RB-3, Fig. 43). A period of dynamic changes in the vegetation cover has started in response to rapid climate amelioration. There was a noticeable decline in the "mountain-steppe" vegetation composed of species of *Poaceae*, *Artemisia*, *Chenopodiaceae*, *Achillea*, *Galium*, etc. The remnants of this vegetation type were replaced by species-rich herb pioneer vegetation of *Apiaceae*, *Filipendula*, *Ranunculaceae*, *Caryophyllaceae*, *Brassicaceae*, and *Helianthemum*. The reforestation started with the spread of *Betula* accompanied by *Juniperus* and *Alnus*. It is likely, that birch and some pines (*Pinus sylvestris*, *Pinus peuce*) have formed the upper timber-line in the Early Holocene. The determination of fragments of needles from *Pinus* sp. (*Pinus mugo* and/or *Pinus sylvestris*) and *Pinus peuce* in the sediments of Lake Ribno Banderishko (Table 12) supports this assumption. On the other hand, reliable information on the proximate position of the timber-line could only be obtained after a detailed macrofossil analysis is performed. A comparison with the Early Holocene plant macrofossil record from Lake Suho Ezero on the Southwestern Rila Mountain (Fig. 34) reveals an abundance of fruit/bud scales of *Betula* and sporadic finds of *Pinus peuce* and *Pinus* sp. needles, suggesting that the timber-line was passed around 1900 m altitude. It is logical to assume that the position of the timber-line on the Northern Pirin Mountain did not differ much from the situation on the Rila Mountain.

The palynological record from Lake Ribno Banderishko implies that mixed oak forests with abundant *Ulmus*, less *Tilia*, and some *Acer* and *Fraxinus excelsior*, have reached their maximal distribution

in the lower parts of the mountain c. 10000-9000 cal. yrs. BP. Later on, *Corylus* expanded and became widespread c. 8500-8000 cal. yrs. BP. The presence of climbers such as *Vitis* and *Hedera* in the deciduous forests indicates an increase of humidity and a rise in the mean annual temperature.

Around 9500 cal. yrs. BP the paleoecological evidence, comprising pollen and plant macrofossils from the Peat bog Mozgovitsa, reveals that the primary role in the initial phase of afforestation was taken by *Betula* that has occupied large areas, together with groups of pines (*Pinus sylvestris*, *Pinus peuce*, *Pinus mugo*), *Juniperus*, *Alnus* and *Salix* (zone M-1, Fig. 50). Birch as a pioneer tree has invaded barren soils and gradually has formed the upper timber-line. Below the birch forests with stands of pines, deciduous oak forests with *Ulmus*, *Tilia*, *Acer*, *Corylus* and *Carpinus* started to expand. The relatively high values for deciduous tree pollen recorded presume an easier pollen transport upslope. Hazel, like birch, appeared as a pioneer element on open areas prior to the other trees. Natural fires were also quite common as indicated by the presence of macro-charcoal fragments, some of them identified as from *Pinus* sp. In addition, oak macrofossils found in the Northeastern Pirin Mountain at Peat bog Praso located at 1900 m (Fig. 40) as much as 800 m above the present range of oak (Stefanova, Oeggl, 1993) demonstrate that the temperate forests have reached higher elevations during the Early Holocene, perhaps in response to the warmer summer conditions (Wright et al., 2003).

The Early Holocene pollen assemblages from Peat bog Mozgovitsa contain also minor, but steady quantities of pollen of mesophilous trees such as *Abies*, *Fagus* and *Picea*. The needles of *Picea abies* dated to 9000 cal. yrs. BP are the oldest ones, established so far, from the mountains in Bulgaria (zone M-1, Fig. 50). These records imply that groups of the above mentioned moisture-demanding trees had survived in environmentally favourable habitats like the deep mountain valley of the Mozgovitsa river. This is not unexpected as part of the lateglacial pollen record from Lake Ribno Banderishko contains pollen of trees and climbers like *Abies*, *Picea*, *Fagus* and *Vitis* (Fig. 43a).

The vegetation development after 7800 cal. yrs. BP was characterized by important changes in forest composition (pollen zone RB-4, Fig. 43; zone M-2, Fig. 50). The rapid fall of pollen and plant macrofossils from *Betula* indicates that birch forests have retreated and at many places have given way to the coniferous vegetation. The vertical migration of the conifers and the enlargement of their area were facilitated by the formation of humus rich soils and increase in precipitation and humidity (Bennett, Willis, 1995; Davis et al., 2003). Such favorable climatic and edaphic conditions initiated the formation of a coniferous belt dominated by *Pinus sylvestris*, *Pinus peuce*, *Abies alba*, while communities of *Pinus heldreichii* and *Pinus nigra* spread on calcareous areas. At the same time in many places the mixed deciduous forests were replaced by *Carpinus orientalis*/*Ostrya carpinifolia*, and by *Carpinus betulus*. The appearance of *Carpinus orientalis*/*Ostrya* pollen is indicative of the establishment of sub-mediterranean conditions in the foothills of the Pirin Mountain after c. 7500 cal. yrs. BP.

The results of plant macrofossil analyses from other sites on the Northern Pirin Mountain for the time after 7500 cal. yrs. BP show the appearance of needles of *Pinus peuce*, bud-scales and microsporophylls of *Pinus* sp. in the surroundings of Lake Popovo Ezero-6 located at 2185 m (Fig. 40) (Stefanova, Bozilova, 1995). An abundance of needles and seeds of *Pinus peuce*, needles of *Abies alba*, bud-scales and microsporophylls of *Pinus* sp. was recorded in the sediments of the Peat bog Praso (Stefanova, Oeggl, 1993). This evidence suggests that during the Holocene climatic optimum the timber-line on the Northern Pirin Mountain has reached its maximum height compared to the present-day situation.

The palynological data from Lake Muratovo c. 4600 cal. yrs. BP present a wide distribution of coniferous forests, not far away from the lake, composed of *Pinus peuce*, *Pinus sylvestris*, *Abies alba*, and quite probably *Pinus heldreichii* (Figs. 46 and 47). Groups of *Pinus mugo* and *Juniperus* within the herb vegetation dominated by Poaceae species, and various representatives of Ranunculaceae, Brassicaceae, Apiaceae, Caryophyllaceae, have thrived in the subalpine zone above the timber-line. Along

mountain brooks stands of *Alnus* spread and on poor soils on steep stony slopes *Betula* was growing as a pioneer tree. Possibly, by that time, isolated localities with sufficient moisture sheltered small populations of *Picea* and *Fagus*.

It is important to point out that the time interval 4300–3700 cal. yrs. BP is related to the final phase of the wider distribution of *Abies alba* in the coniferous forests that existed since 7900 cal. yrs. BP. Around 3000/2800 cal. yrs. BP a decrease in the participation of *Abies alba* is observed due to the increasing occurrence of *Picea abies*. Meanwhile, the dense coniferous forests acted as a filter for the airborne upslope transport of deciduous tree pollen of *Quercus*, *Ulmus*, *Tilia*, *Carpinus* and *Corylus* from lower altitudes.

The spread of *Fagus* on the Northern Pirin Mountain has started at 4400 cal. yrs. BP (pollen zone RB-5, Fig. 43), although this tree was established at low altitudes rather earlier c. 8000 cal. yrs. BP (zone M-1, Fig. 50). Beech formed either pure or mixed stands with *Abies alba*, and grew partly with *Carpinus betulus* in place of other deciduous trees, predominantly on north-facing slopes. Around 4500–4000 cal. yrs. BP beech started to become an important constituent in the forest cover of almost all mountains in Bulgaria, and subsequently expanded in Subatlantic time (Filipova–Marinova, 1995).

In the course of several millennia *Pinus sylvestris*, *Pinus peuce*, and partly *Abies alba* were the main constituents of the coniferous belt in the Mozgovitsa river valley. Spruce was still less abundant in these forests, but the slow increase in its pollen frequencies signalled that it has started to gain importance after c. 4600 cal. yrs. BP (pollen zone RB-5, Fig 43; zone PM-1, Figs. 46 and 47).

Later on, after 2800 cal. yrs. BP, *Picea abies* invaded new areas and shaped the timber-line at many places, solely or with *Pinus sylvestris* and *Pinus peuce*. As a main reason for this event a change of climate with lower temperatures and higher precipitation is considered likely in the temperate regions, synchronous with an abrupt increase in radiocarbon in the atmosphere c. 850 cal. BC as a result of increased solar activity (van Geel et al., 1998).

The reasons for this late establishment and subsequent expansion of spruce are still debatable

and are most probably of complex character. The rather late Holocene arrival of spruce in the high central montane parts of the Balkan peninsula, Rila and Pirin mountains included, has led to the idea that the closest refugial areas for *Picea abies* from where it has migrated at a slow rate to the south and southeast were located in the northernmost parts of the Balkan peninsula - Southeast Alps, Dinaric Mountains and Carpathian Mountains (Lang 1994; Farcas et al. 1999; Björkman et al. 2003; Latalowa, van der Knaap, 2006). The hypothesis that local refugia with residual populations of spruce could have also existed in isolated interior or montane areas of the peninsula with sufficient moisture, also deserves attention (Ravazzi, 2002; Tonkov, 2003).

It should be pointed out that 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 (Beaulieu et al., 1994). Such a tendency is also recorded in the pollen diagrams from Lake Muratovo. The estimated age for when spruce became one of the dominant trees in the coniferous belt is in good agreement with other palynological studies from the Northern Pirin Mountain (Bozilova, 1975, 1986; Stefanova, Oeggli, 1993; Stefanova, Bozilova, 1995; Stefanova et al., 2006).

In the profile from Peat bog Mozgovitsa the rise of *Picea* pollen curve is preceded by an increase of *Artemisia*, Poaceae and other herbs. A characteristic feature is the abundance of macrofossils from *Picea abies* such as needles and charred wood, and occasional finds of seeds of *Pinus* sp., needles and seeds of *Pinus peuce*, and subfossil wood of *Pinus* sp., *Juniperus*, *Salix* and charred wood of *Pinus*. Seeds and nutlets of *Teucrium montanum*, *Ranunculus nemorosus* point to the existence of mountain meadows, and those of *Potentilla palustris*, *Carex* and *Eriophorum* species originated from the local vegetation of the peat bog (zones M-4 and M-5, Fig. 50). A comparison with the palynological and plant macrofossil results obtained from Late Holocene peat profiles, located between 1600 and 2000 m in the adjacent Begovitsa river valley, confirms that after c. 2200 cal. yrs. BP deforestation in the coniferous belt has resulted in the lowering

of the upper timber-line and the appearance of new pasture land (Bozilova et al., 2000). The occurrence of charcoal particles, wood of *Picea abies* and *Pinus* sp., and the regular presence of pollen of anthropophytes suggest human induced fires. The basic means of livelihood of the native population was animal husbandry, including livestock-grazing in the high-mountain pastures. Even nowadays remains of old sheep pens are visible on the river terraces.

Likewise, after c. 1750 cal. yrs. BP the vegetation development bears the features of an increasing anthropogenic activity, although traces of human impact may have been detected even earlier, during the Late Bronze Age and Hellenistic periods (pollen zones PM-2 and PM-3, Figs. 46 and 47). The increasing values of pollen of *Rumex*, *Plantago lanceolata*, *Scleranthus*, some Asteraceae, indicate the existence of seasonal subalpine pastures, trampling and ruderal communities. The pollen grains of *Cerealia*-type, *Triticum*-type and *Secale* testify to agricultural activity in the mountain foothills.

At many places in most recent times after 900 cal. yrs. BP *Pinus peuce* and *Picea abies* shaped the upper timber-line, while *Pinus mugo* spread in the subalpine zone (pollen zone RB-6, Fig. 43; pollen zone PM-3, Figs. 46 and 47). Clear indications of human activity at lower altitudes and expansion of agriculture are connected with finds of pollen of *Cerealia*-type, whereas the pollen frequencies of *Scleranthus*, *Rumex* and *Plantago lanceolata* suggest livestock-grazing in the high-mountain pastures. The presence of *Juglans* pollen also testifies to the existence of settlements on the mountain foothills where walnut was cultivated. The decline in the pollen frequencies of almost all tree taxa, with the exception of *Pinus*, suggests pronounced human interference in all vegetation belts during the last centuries.

The patterns of the postglacial vegetation dynamics in the Northern Pirin Mountain appear quite similar to those established for the Rila Mountain (Figs. 6 and 44) and additional palynological and plant macrofossil investigations of lake sediments in this area will provide further details on the environmental changes.

Southern Pirin Mountain – Study sites

Peat bog Mutorog (site 16)

The peat bog is located at 1700 m in northeast direction from peak Mutorog in the depths of a forest of *Picea abies* with an admixture of *Pinus sylvestris*, *Abies alba* and *Pinus peuce*. The bog vegetation is composed of *Carex leporina*, *Carex flava*, *Carex stellulata*, *Nardus stricta*, *Deschampsia caespitosa*, *Potentilla palustris*, *Geum coccineum*, *Galium palustre*, *Saxifraga rotundifolia*, etc. (Panovska et al., 1995).

Coring, lithology and radiocarbon dating

The core 1.1 m long was collected with Dachnowsky hand-corer equipment. The lithology of the sediments is: 0-30 cm peat, 30-35 cm sand, 35-45 cm peat, 45-55 cm peat with sand, 55-65 cm peat, 65-80 cm peat with sand, 80-90 cm peat and 90-110 cm peaty gyttja. The radiocarbon age of one bulk sediment sample was determined and the result is shown on Table 15. The age of the sediment core was determined at 3500 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 10 cm interval and a percentage pollen diagram is constructed (Fig. 51). On the pollen diagram two local pollen assemblage zones (LPAZ) are recognized (MT-1 and MT-2). Brief descriptions are as follows:

LPAZ MT-1 (110-63cm, *Fagus-Corylus-Pinus diploxylon*)

Tree pollen prevails with 45-70%, attributed to *Fagus* 27-37%, *Corylus* 20-10%, *Tilia* 10% and

Table 15. Radiocarbon dates from Peat bog Mutorog and Peat bog Popovi Livadi.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Cal. BC/AD (mid-point)	Material dated
Mutorog					
KL-3416	90-110	3240±120	3830-3170 (3500)	1880-1220 (1550) BC	peaty gyttja
Popovi Livadi					
Hv-17896	80-100	1400±90	1530-1090 (1310)	420-860 (640) AD	peat
Hv-17895	250-270	2610±70	2870-2470 (2670)	920-520 (720) BC	peaty gyttja

Peat bog MUTOROG (Southern Pirin Mt., 1700 m)
Percentage pollen diagram

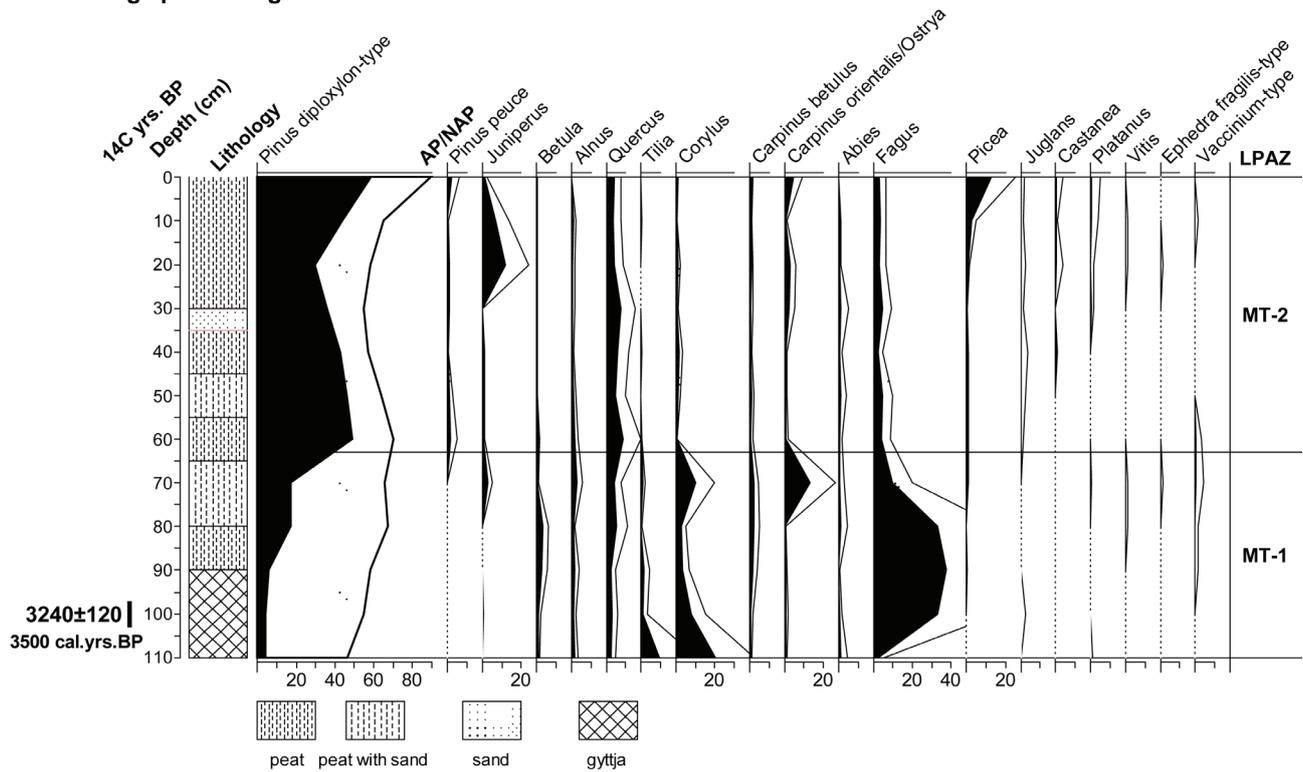
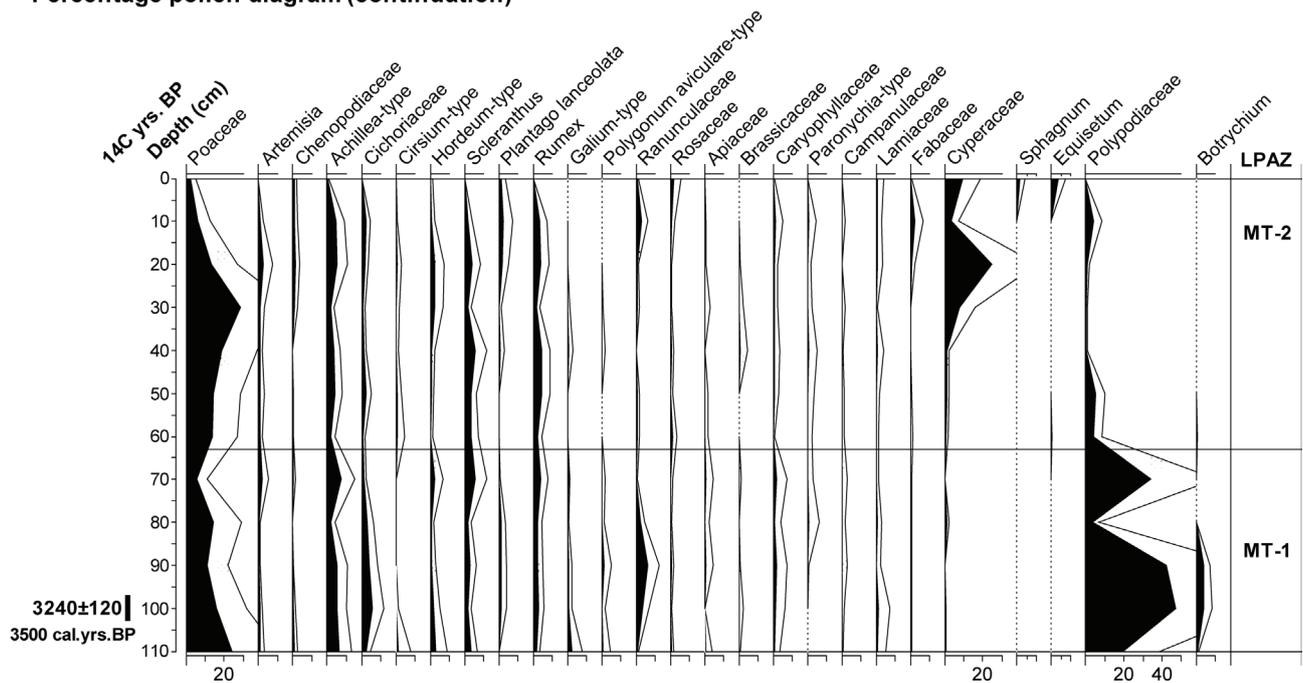


Figure 51. Percentage pollen diagram of Peat bog Mutorog.

Peat bog MUTOROG (Southern Pirin Mt., 1700 m)
Percentage pollen diagram (continuation)



Modified after Panovska et al. (1995)

Figure 51. Continued.

Carpinus orientalis/*Ostrya* 15%. Pollen of *Pinus diploxylon*-type is present with 5-17%, *Juniperus* and *Pinus peuce* each with 2-4%. The participation of *Picea* and *Abies* is insignificant. The herb pollen taxa are represented by Poaceae 22-10%, Cichoriaceae, *Achillea*-type, Ranunculaceae, *Scleranthus* and *Rumex* each with 3-7%. Spores of Polypodiaceae 35-45% are also found.

LPAZ MT-2 (63-0cm, *Pinus diploxylon*-*Quercus*-NAP)

The dominant pollen type is *Pinus diploxylon* with 50-60%. The presence of *Quercus*, *Fagus*, *Pinus peuce*, *Alnus*, *Corylus*, *Abies*, *Juniperus* pollen is each with 3-7%. In the uppermost samples *Picea* reaches 13% and *Juniperus* 10%. The pollen curve of Poaceae displays a maximum of 30% and then declines to 3-5%. The variety of herb pollen taxa is considerable. The presence of *Achillea*-type, Cichoriaceae, *Rumex*, *Plantago lanceolata*, *Scleranthus*, *Hordeum*-type, Ranunculaceae and Cyperaceae pollen is worth mentioning.

Peat bog Popovi Livadi (site 17)

This peat bog is located at 1430 m (41°32'55.24"N, 23°38'24.34"E) in a large depression. It borders to the south a forest of *Pinus sylvestris* with an admixture of *Picea abies* and *Abies alba*. The understory is composed of *Juniperus communis*, *Juniperus sibirica*, *Vaccinium myrtillus*. On the steep northern slopes an inverse distribution of beech over the coniferous communities is observed. The bog vegetation is composed of *Sphagnum* sp., *Carex rostrata*, *Carex hirta*, *Carex canescens*, *Carex acuta*, *Juncus compressus*, *Juncus alpigenus*, *Eriophorum vaginatum*, *Eriophorum latifolium*, *Luzula nigricans*, *Deschampsia flexuosa*, *Deschampsia caespitosa*, *Geum coccineum*, *Cardamine palustris*, *Veronica scutellata*, *Menyanthes trifoliata*, *Caltha palustris*, *Potentilla palustris*, etc. (Panovska et al., 1995).

Coring, lithology and radiocarbon dating

The core 2.9 m long was collected with Dachnowsky hand-corer equipment. The lithology of the sediments is: 0-30 cm slightly decomposed *Sphagnum* peat, 30-100 cm peat, 100-110 cm peaty gyttja, 110-230 cm peat, 230-270 cm peaty gyttja, 270-290 cm peat with sand. The radiocarbon age

of 2 bulk sediment samples was determined and the results are shown on Table 15.

Pollen analysis

Pollen analysis was performed at 10 cm interval and a percentage pollen diagram is constructed (Fig. 52). On the pollen diagram three local pollen assemblage zones (LPAZ) are recognized (PL-1 to PL-3) (Fig. 44). Brief descriptions are as follows:

LPAZ PL-1 (290-235 cm, *Fagus*-*Abies*-*Pinus diploxylon*) (~3000-2560 cal. yrs. BP)

Tree pollen dominates with 60-80%, contributed by *Pinus diploxylon*-type 20-30%, *Abies* up to 20%, *Fagus* up to 20%, *Quercus* 5-18%. The presence of *Pinus peuce*, *Picea*, *Juniperus*, *Salix* and *Ulmus* is insignificant. The herb pollen taxa are represented mainly by Poaceae 10-20%, Cichoriaceae, *Achillea*-type, *Rumex* and Ranunculaceae each with 2-4%. Local maxima are recorded for spores of Polypodiaceae 60-80% and *Equisetum* 40%.

LPAZ PL-2 (235-95 cm, *Fagus*-*Quercus*-NAP-*Juniperus*) (2560-1300 cal. yrs. BP)

This zone is well defined by the ratio AP/NAP=40/60%. Pollen of *Pinus diploxylon*-type is below 10%, *Juniperus* 3-8%, *Betula* 3-7%, *Quercus* 10-15% and *Fagus* 5-7%. The variety of herb pollen taxa is high represented by Poaceae up to 37%, *Scleranthus* 19%, *Hordeum*-type 10-15%, *Rumex* 12%, *Artemisia*, Brassicaceae, Ranunculaceae, *Plantago lanceolata*, etc.

LPAZ PL-3 (95-0 cm, *Pinus diploxylon*-*Fagus*) (1300 cal. yrs. BP-till present)

Tree pollen prevails again with 60-90%, attributed to *Pinus diploxylon*-type 60-80%. A local maximum is registered for *Fagus* 10-12%, while *Picea* and *Abies* are present each with 1-3%. The pollen curve of *Quercus* declines to 2-4%. Among the herb pollen taxa Poaceae participates with 5-10%. In several samples local maxima are established for *Scleranthus* 10%, *Plantago lanceolata* 35%, *Hordeum*-type 5%, Cyperaceae 80% and spores of *Sphagnum* 220%.

Plant macrofossil analysis

The core was also sampled at 10 cm interval for determination of plant macrofossils. The results are presented on a macrofossil diagram in abso-

Peat bog POPOVI LIVADI (Southern Pirin Mt., 1430 m)

Percentage pollen diagram

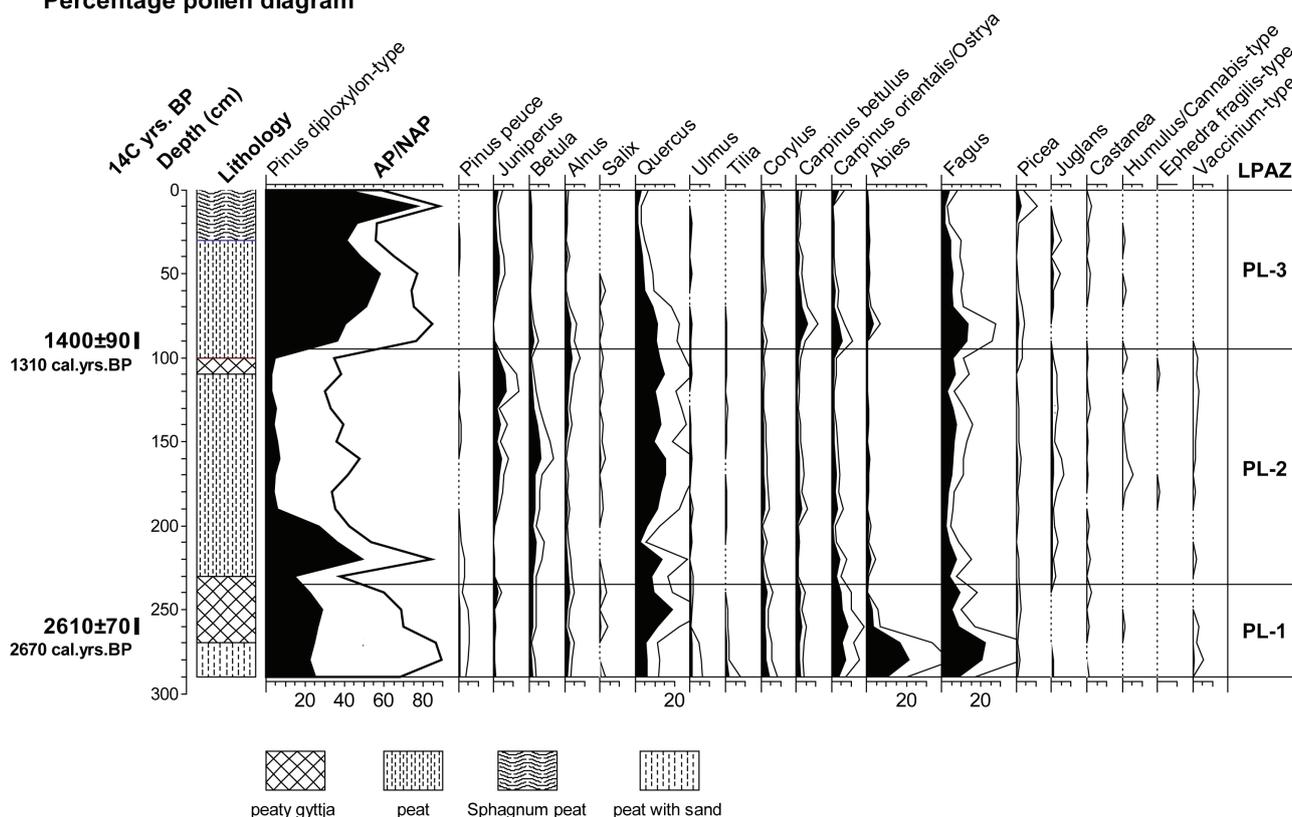


Figure 52. Percentage pollen diagram of Peat bog Popovi Livadi.

lute numbers for flowers, fruits and needles, while the occurrence of wood is indicated by dots (Fig. 53). Three local macrofossil assemblage zones (LMAZ) can be recognized (MPL-1 to MPL-3). Brief descriptions are as follows:

LMAZ MPL-1 (290–245 cm)

Macrofossils from tree taxa are quite common such as *Abies alba* (wood, needles), *Carpinus betulus* and *Corylus* (wood), *Carpinus orientalis* (fragments of leaves), *Fagus* (wood, flowers). All these finds were extracted from the sample radiocarbon dated at 2610 ± 70 C¹⁴ yrs. BP (2760 cal. yrs. BP). Fruits from *Potentilla palustris*, *Potentilla* sp., *Ranunculus*, *Carex* sp. and *Scirpus sylvaticus* are found.

LMAZ MPL-2 (245–135 cm)

Macrofossils from tree taxa are absent. In the lower part of the zone fruits of *Carex* sp. are abundant. Fruits from *Potentilla* sp., *Menyanthes trifoliata*, *Chenopodium album* are also determined.

LMAZ MPL-3 (135–0 cm)

Charred wood is found in almost all samples and a seed from *Pinus sylvestris*. Fruits from *Carex*

sp., *Menyanthes trifoliata*, *Potentilla* sp. and *Potentilla palustris* are determined.

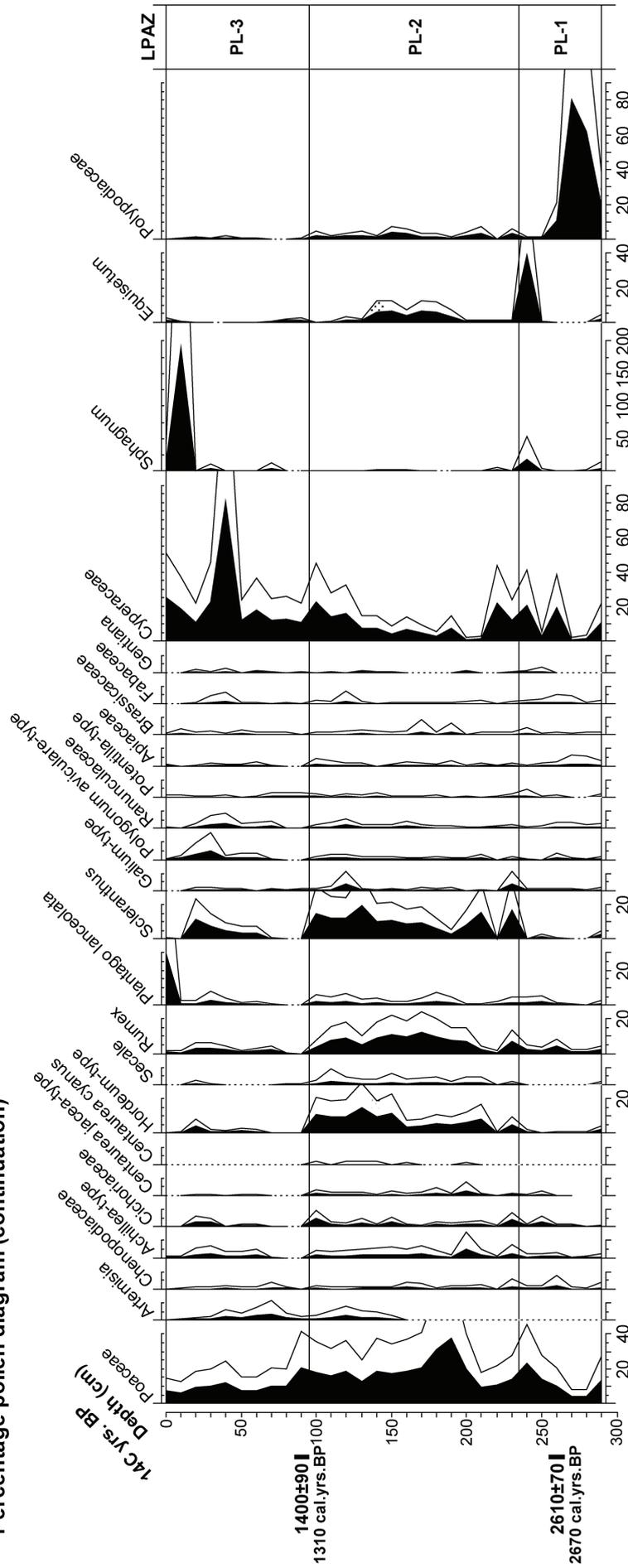
Vegetation history in the Southern Pirin Mountain

The pollen diagrams and the plant macroremains reflect the changes in the vegetation cover during the last 3500 years. The paleobotanical data from the two peat bogs and the periods of increased anthropogenic activities correlate very well supported by the radiocarbon dates.

In the area of Peat bog Mutorog the spread of almost pure *Fagus* communities started at 3500 cal. yrs. BP and deciduous trees such as *Tilia*, *Corylus* and *Ulmus* retreated at lower altitudes. The participation of *Pinus* (most probably *Pinus sylvestris*) was negligible, as was that of *Abies*, while on more open terrains were found groups of *Betula*.

In the vicinity of Peat bog Popovi Livadi mixed *Abies-Fagus* forests were present, proved by the find of macroremains (needles, wood and flowers). *Corylus* and *Carpinus orientalis* were also growing as

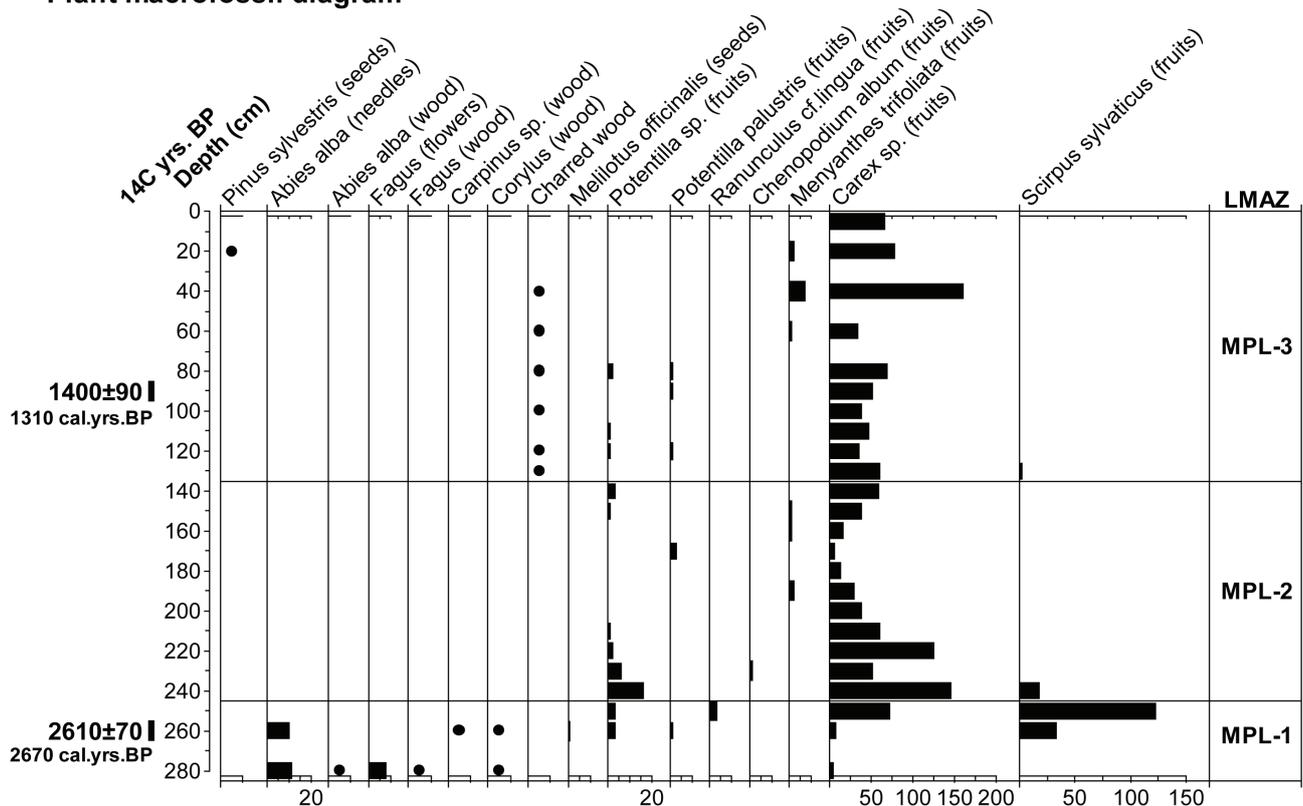
Peat bog POPOVI LIVADI (Southern Pirin Mt., 1430 m)
Percentage pollen diagram (continuation)



Modified after Panovska et al. (1995)

Figure 52. Continued.

Peat bog POPOVI LIVADI (Southern Pirin Mt., 1430 m) Plant macrofossil diagram



Modified after Panovska et al. (1995)

Figure 53. Plant macrofossil diagram of Peat bog Popovi Livadi.

confirmed by the determination of fossil wood. The pollen grains from *Ephedra fragilis*-type suggest long-distant air transport but do not rule out the possibility that *Ephedra* was occurring in the eastern parts of the Southern Pirin Mountain by that time (pollen zone PL-2, Fig. 52). After 2700 cal. yrs. BP the forests of *Abies* and *Fagus* were destroyed to a large extent in the more easily accessible areas.

There is strong evidence of anthropogenic interference in the Popovi Livadi area between 2100 and 1300 cal. yrs. BP. The flat land around the peatbog has proven to be suitable for practicing mountain farming with cultivation of *Hordeum* and *Secale*, as well as for the development of animal husbandry. The participation of pollen indicators for grazing, ruderal communities and forest paths such as *Scleranthus*, *Rumex*, *Plantago lanceolata*, *Juniperus*, some Asteraceae species exceeds significantly the amount of pollen from cultivated cereals for a long period. This proves that the area has been extremely suitable for grazing since early historical times.

It was difficult for the local population to exploit the beech forests on the steep slopes above 1500-1000 m and this was probably one of the reasons for the recent inverse distribution of fragments of beech forests over the coniferous forests in this part of the mountain.

A significant change in the composition of the forest vegetation is noted after 1300 cal. yrs. BP (VIIIth cent. AD) when the anthropogenic influence in the area weakened and a large part of the land used by humans was abandoned. This has led to the enlargement of forests of *Pinus sylvestris* and some restoration of *Fagus* communities.

The last tree species that permanently settled in the area after 700 cal. yrs. BP (XIIIth cent. AD) in many places was *Picea abies*. The subsequent presence of spruce in this part of the mountain in the zone between 1400 and 1700 m like in the Northern Pirin Mountain and in the Rila Mountain can be associated with changes in the climatic conditions during the Little Ice Age.

4. KONYAVSKA MOUNTAIN

Physico-geographical characteristics and modern vegetation

Konyavska Mountain (peak Viden, 1487 m) is located in the north of Southwestern Bulgaria, in an area representing a complex mosaic of mountains and small valleys with various directions of extension, with the prevailing being northwest-southeast (Fig. 1). As a morphostructural unit the mountain is separated between the Radomir Basin from the northeast, the gorges of the Struma river from the north and northwest. To the south, the mountain runs to the Kyustendil Basin and to the east and northeast ends to the Bobovdol Paleogene Basin. Geologically and geotectonically, the mountain is well investigated and generally refers to the Transitional block fractured geomorphological area (Bonchev et al., 1960).

The deeply cut valleys of the Uglyarska, Blateshnitsa, Konyavska and Klisurska rivers divide the mountain orographically into four parts: Viden (1487 m), Risha (1443 m), Kolosh (1314 m) and Korilovski (991 m). The total area of the mountain is 237 km² with an average altitude of 929 m. The age of the lithological base ranges from the Paleozoic metamorphic rocks to the Neogene sedimentary complexes. Several lithological formations have had a decisive influence on the modern morphological appearance, namely, the Triassic carbonate complex, the Late Jurassic complex, the Late Eocene conglomerate-breccia and conglomerates (Bonchev et al., 1960).

During the Tertiary some of the deep valleys became lake basins which were gradually filled with deposits from the surrounding mountains. As a central negative form within the mountain stands the Tschokljovo structural depression which is now occupied by a marshy peatland. It covers an area of 1.8 km² at an average altitude of 870 m. In general, the main relief of the Konyavska Mountain was formed at the beginning of the Quaternary (Konstantinov, 1979).

Konyavska Mountain falls on the border between the temperate continental climate and the

transitional continental climate (Dimitrov, 1974). The average maximal temperature for the warmest month is 28°C and for the coldest is -6°C. The average annual precipitation is between 500 and 750 mm, with a minimum in February and a maximum in June (Stanev et al., 1991).

The soils are mainly cinnamomic-forest (chromic Cambisols) and humus-carbonate rich (rendzic Leptosols) (Ninov, 1997). The soil erosion is highly developed, where the main rocks are discovered in places there are screes, tunnels and collapses.

According to the last geobotanical zoning, Konyavska Mountain is included as a separate region in the Sofia District of the Illyrian (Balkan) Province (Bondev, 2002). The modified mediterranean climate along the Struma river gorge and the interaction between different climatic influences have left their mark on the nature, composition and distribution of the vegetation. The general characteristics of the vegetation cover of the mountain and the adjacent calcareous areas are presented in several publications and floristic reports (Stojanov, 1935, 1941; Bondev, 1991, etc.).

On the western and southwestern slopes of the Risha part where along the Struma gorge penetrates the mediterranean influence the basic plant communities are those of *Quercus cerris*, *Quercus pubescens* and *Carpinus orientalis*. In their composition are found also some transitional-mediterranean elements as *Jasminum fruticans*, *Juniperus oxycedrus*, *Paliurus spina christii*, *Coronilla emerus*, etc. Shrub and herb xerothermic formations are distributed on limestone deforested areas. In the rest of the Risha and Korilovski parts the communities of *Quercus cerris* are most widespread, including *Quercus pubescens*, *Quercus dalechampii*, *Carpinus betulus*, *Acer platanoides*, *Acer pseudoplatanus*, *Corylus avellana*, *Ostrya carpinifolia*. The mixed oak forests occupy large areas along the northern and derived slopes of the Kolosh and Viden parts. The communities of *Fagus sylvatica* are characteristic above 1000-1200 m. The natural vegetation of the mountain is strongly disturbed by the anthropogenic impact which has resulted in large scale deforestation, the replacement of the natural plant communi-

ties by secondary in origin. Partial measures have been taken to afforest some areas with Scots pine and black pine.

The vegetation of Tschokljovo marsh in the middle of the Konyavska Mountain is of particular interest. A detailed description of the higher aquatic vegetation, its floristic composition, formations and associations prior to the beginning of the drainage activities and the extraction of peat during the middle of the past century, is presented in several publications (Jordanov, 1929, 1931, 1947). The vegetation of the marsh resembled a specific combination of the lowland fens, swampy shrubs and reed swamps. From the first vegetation type were distributed *Heleocharis pauciflora*, *Juncus articulatus*, *Triglochin palustre*, *Menyanthes trifoliata*, *Potentilla palustris*, etc. Characteristic elements for the vegetation of the swampy shrubs were *Salix pentandra*, *Salix cinerea*, *Salix rosmarinifolia* along with *Thelyptheris palustris*, *Sparganium erectum*, *Lathyrus palustris*, *Peucedanum palustre*, *Carex acuta*, *Calamagrostis epigeios*, *Thalictrum flavum*, etc. The reed-swamp vegeta-

tion was distributed in the central and partly in the northern and southern parts of the marsh represented by *Typha latifolia*, *Phragmites australis*, *Alisma plantago-aquatica*, *Iris pseudacorus*, *Mentha aquatica*, etc.

The extensive exploitation of the peat deposits has resulted in the destruction of the local vegetation from which only separate fragments had remained. The marsh was flooded again in 1980 with the drainage channels removed and the extraction of peat has stopped. It was declared a protected area in 1992 on a territory of 320 ha in order to protect the habitats of rare and endangered birds and the peatland itself (Fig. 54).

Study site

Tschokljovo marsh (site 18)

Coring, lithology and radiocarbon dating

Two cores were collected with Dachnowsky hand-corer equipment from undisturbed peat



Figure 54. A view of Tschokljovo marsh (Photo D. Kozuharov).

layers in the southwestern part of the marsh. The first core is 4.45 m long and the lithology of the sediments is: 0-90 cm marl with peat, 90-300 cm peat with plant remains, 300-350 cm peaty gyttja, 350-400 cm clay with gyttja, 400-405 cm peat and 405-445 cm clay. The second core is 2.4 m long and the sediment is peat (Tonkov, 1988). The radiocarbon age of 9 samples of bulk sediment was determined and the results are shown on Table 16. They indicate that the age of the sediments of Core 1 is c. 9000 cal. yrs. BP and of Core 2 c. 3600 cal. yrs. BP (Tonkov, Bozilova, 1992).

Pollen analysis

Pollen analysis was conducted at 5-10 cm interval and two percentage pollen diagrams are constructed (Figs. 55 and 56). The uppermost 70 cm of Core 1 contain no pollen. Both pollen diagrams are synchronized and for Core-1 five local pollen assemblage zones (LPAZ) are recognized (TM-1 to TM-5) while for Core-2 they are three (TM-3 to TM-5) (Fig. 57). Brief descriptions are as follows:

Table 16. Radiocarbon dates from Tschokljovo marsh.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Core 1				
Lu-2169	90-105	1250±50	1290-1060 (1175)	peat
Lu-1991	230-240	2380±50	2700-2320 (2510)	peat
Lu-1990A	274-279	3130±50	3450-3210 (3330)	peat
Lu-2168	353-358	4760±80	5650-5310 (5480)	clay with gyttja
Lu-1989	400-405	6300±65	7420-7020 (7220)	peat
Lu-2167	437-442	8000±110	9250-8580 (8915)	clay
Core 2				
LuS-1994A	72-80	1860±50	1930-1630 (1780)	peat
LuS-1993	140-144	2380±50	2700-2320 (2510)	peat
LuS-1992	149-152	2430±50	2710-2350 (2530)	peat

TSCHOKLJOVO MARSH (Konyavska Mt., 870 m)

Percentage pollen diagram (Core 1)

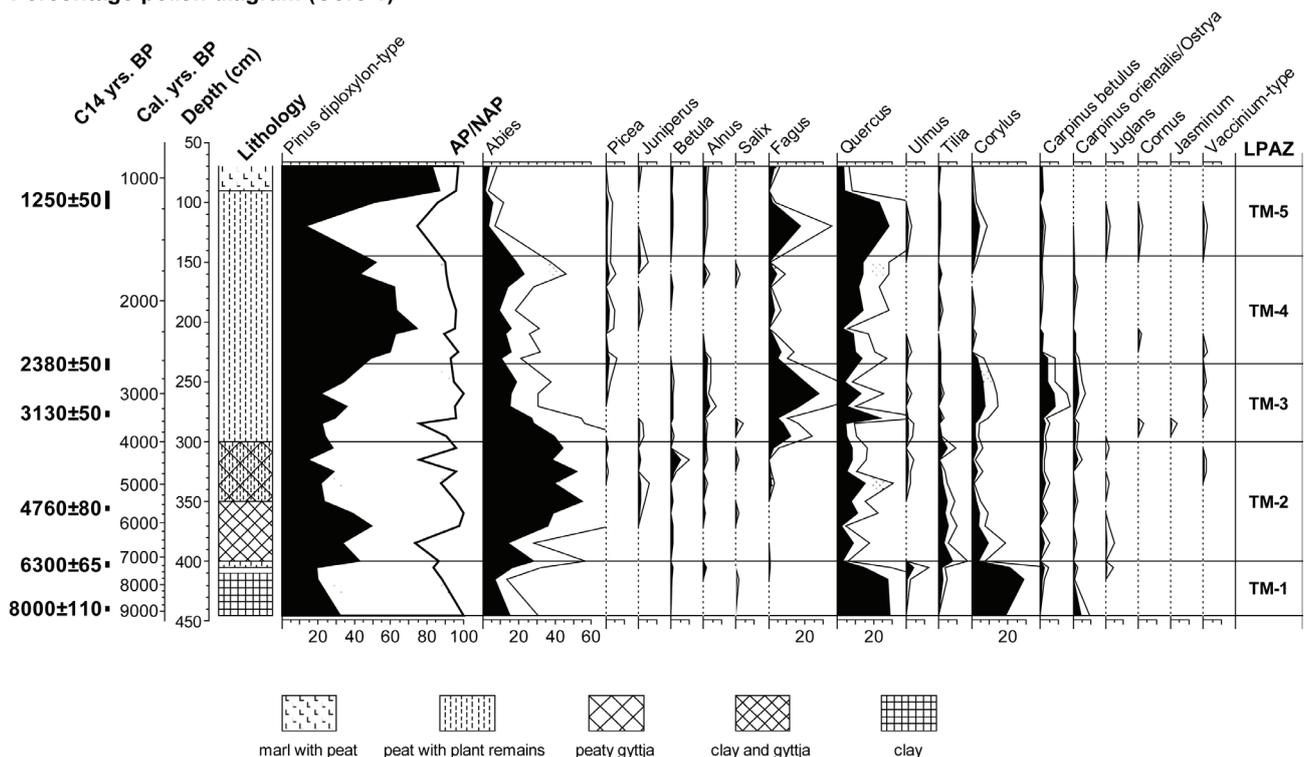
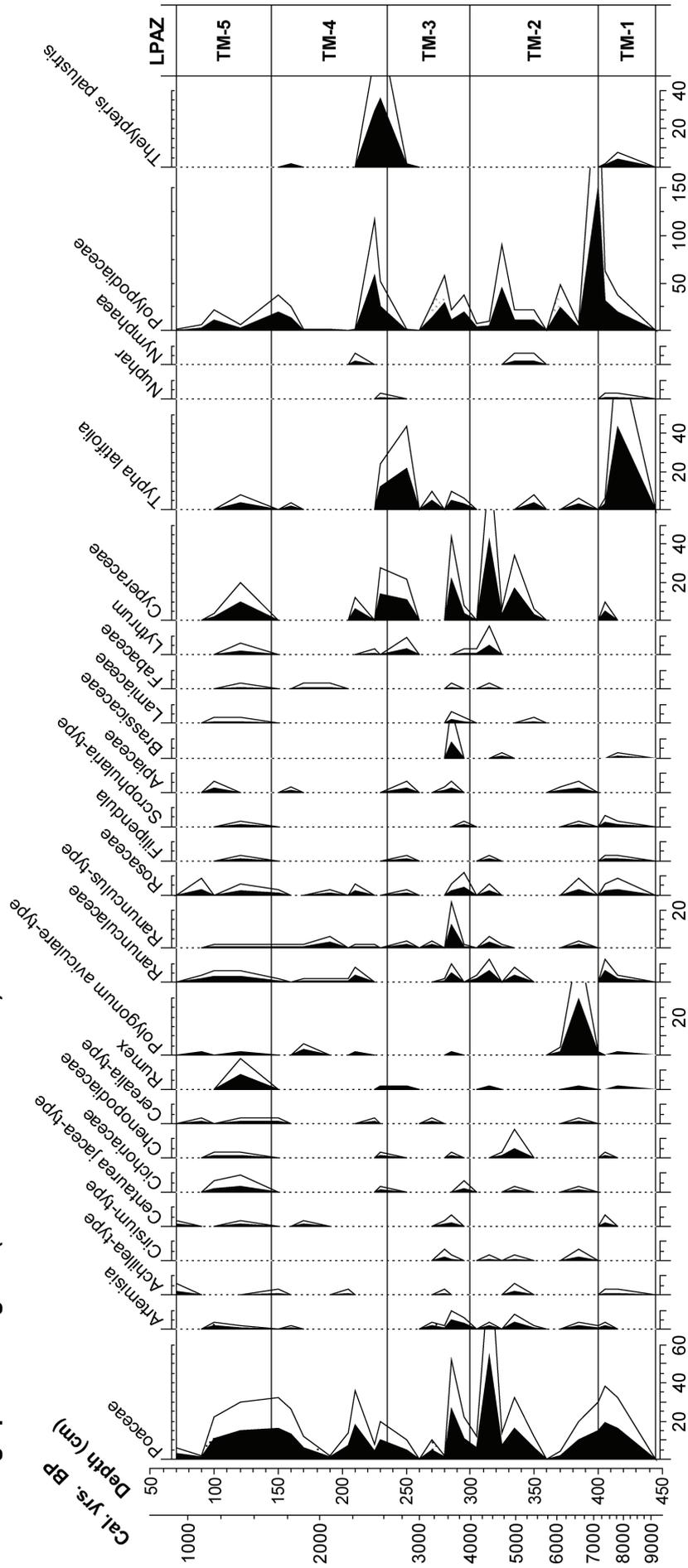


Figure 55. Percentage pollen diagram of Tschokljovo marsh (Core 1).

TSCHOKLJOVO MARSH (Konyavska Mt., 870 m)
 Percentage pollen diagram (Core 1 - continuation)



Modified after Tonkov, Bozilova (1992)

Figure 55. Continued.

TSCHOKLJOVO MARSH (Konyavska, Mt., 870 m)

Percentage pollen diagram (Core 2)

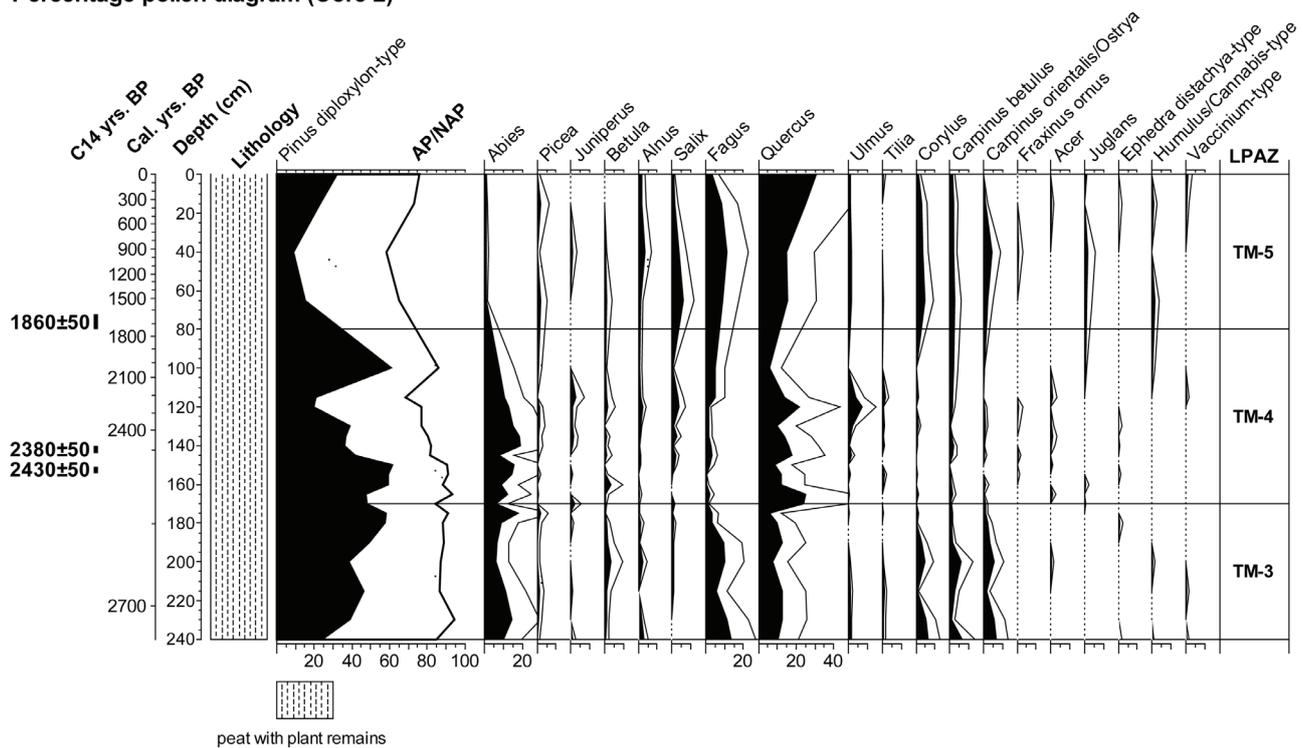


Figure 56. Percentage pollen diagram of Tschokljovo marsh (Core 2).

Core-1

LPAZ TM-1 (445-400 cm, *Quercus-Corylus-Pinus diploxylon-Abies*) (~9000-6200 cal. yrs. BP)

High pollen values are established for *Corylus* 28% and *Quercus* 26%. At the transition to the next zone *Pinus diploxylon*-type and *Abies* reach 43% and 28%, respectively. Pollen of *Tilia* 8%, *Ulmus* 4% and *Carpinus betulus* is also found. The herb pollen taxa are represented by Poaceae 6-8%, Ranunculaceae 2-3%, Rosaceae, *Achillea*-type. The local component includes pollen of *Typha latifolia* 45% and *Nuphar*, spores of Polypodiaceae 150% and *Thelypteris palustris*.

LPAZ TM-2 (400-300 cm, *Abies-Pinus diploxylon*) (6200-3600 cal. yrs. BP)

Pollen of *Abies* reaches maximal values of 52-54%, accompanied by *Pinus diploxylon*-type 20-50%, *Quercus* 15%, *Tilia*, *Corylus*, *Betula* and *Carpinus betulus*. Pollen of Poaceae attains a peak of 50% and the variety of herb pollen taxa is considerable. The pollen curve of Cyperaceae is present up to 40%.

LPAZ TM-3 (300-235 cm, *Pinus diploxylon-Fagus-Abies*) (3600-2400 cal. yrs. BP)

The pollen curve of *Fagus* appears and rises to 26%. Other deciduous tree taxa such as *Quercus* 22%, *Carpinus betulus* 8%, *Corylus* 5%, *Alnus* are also present. Pollen of *Abies* declines to 19% while *Pinus diploxylon*-type rises to 50%. The herb pollen taxa are represented by Poaceae 25-8%, Ranunculaceae, Brassicaceae, Apiaceae, etc. Spores of Polypodiaceae reach 28%, together with a sharp increase for spores of *Thelypteris palustris* with 30% at the transition to the next zone. Hydrophytes and hygrophytes such as *Nuphar*, Cyperaceae and *Typha latifolia* are also present.

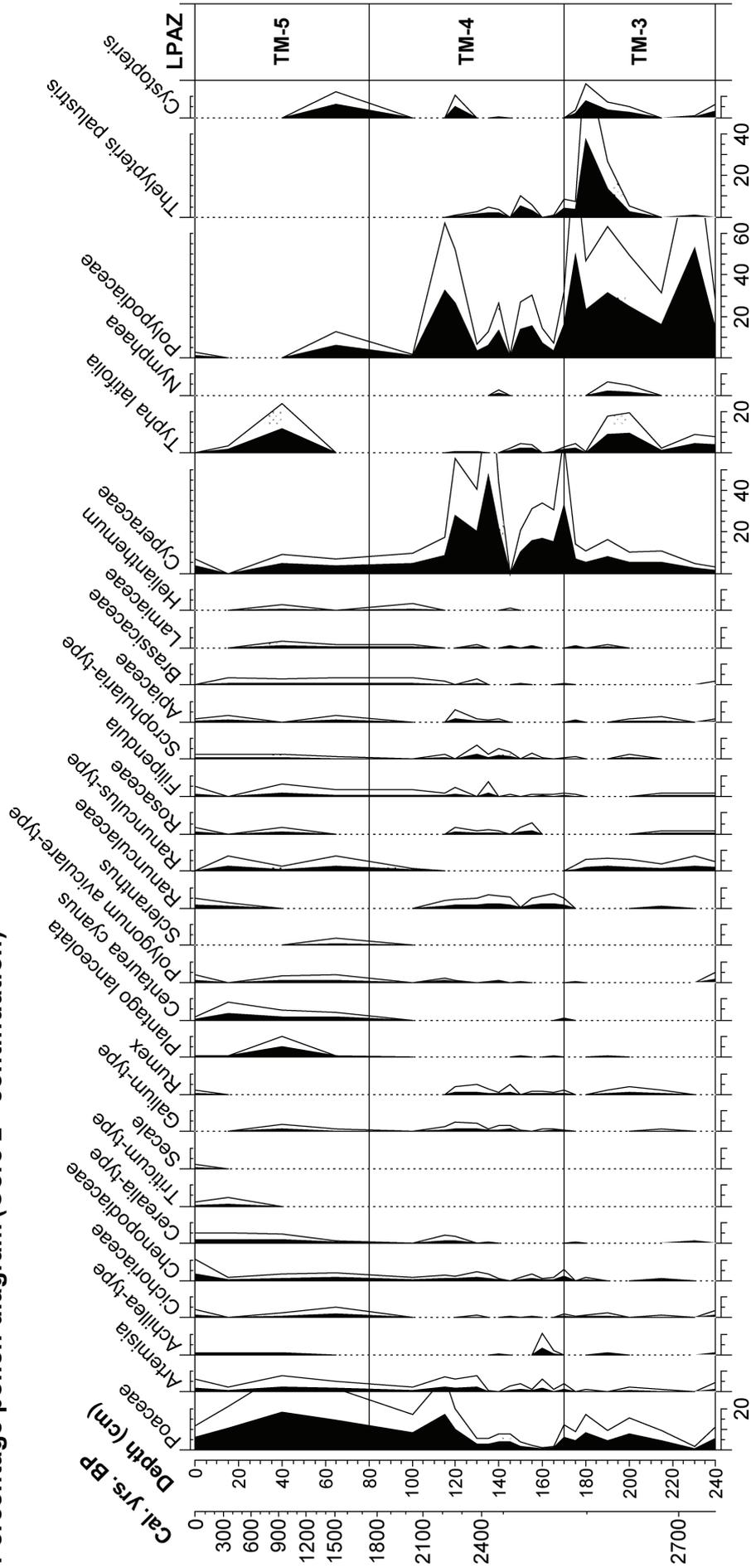
LPAZ TM-4 (235-145 cm, *Pinus diploxylon-Abies-Quercus*) (2400-1600 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type reaches 70-80%. Pollen of *Abies* fluctuates between 13% and 23%, while *Quercus* and *Fagus* are present with 14% and 4%, respectively. Pollen of *Cerealia*-type and *Polygonum aviculare*-type is also determined.

LPAZ TM-5 (145-70 cm, *Quercus-Fagus-Pinus diploxylon*) (1600-1000 cal. yrs. BP)

The pollen curves of *Quercus* and *Fagus* rise to 27% and 17%, respectively. Pollen of *Abies* declines to 3-4%, while *Pinus diploxylon*-type exceeds 80%.

TSCHOKLJOVO MARSH (Konyavska, Mt., 870 m)
 Percentage pollen diagram (Core 2 - continuation)



Modified after Tonkov, Bozilova (1992)

Figure 56. Continued.

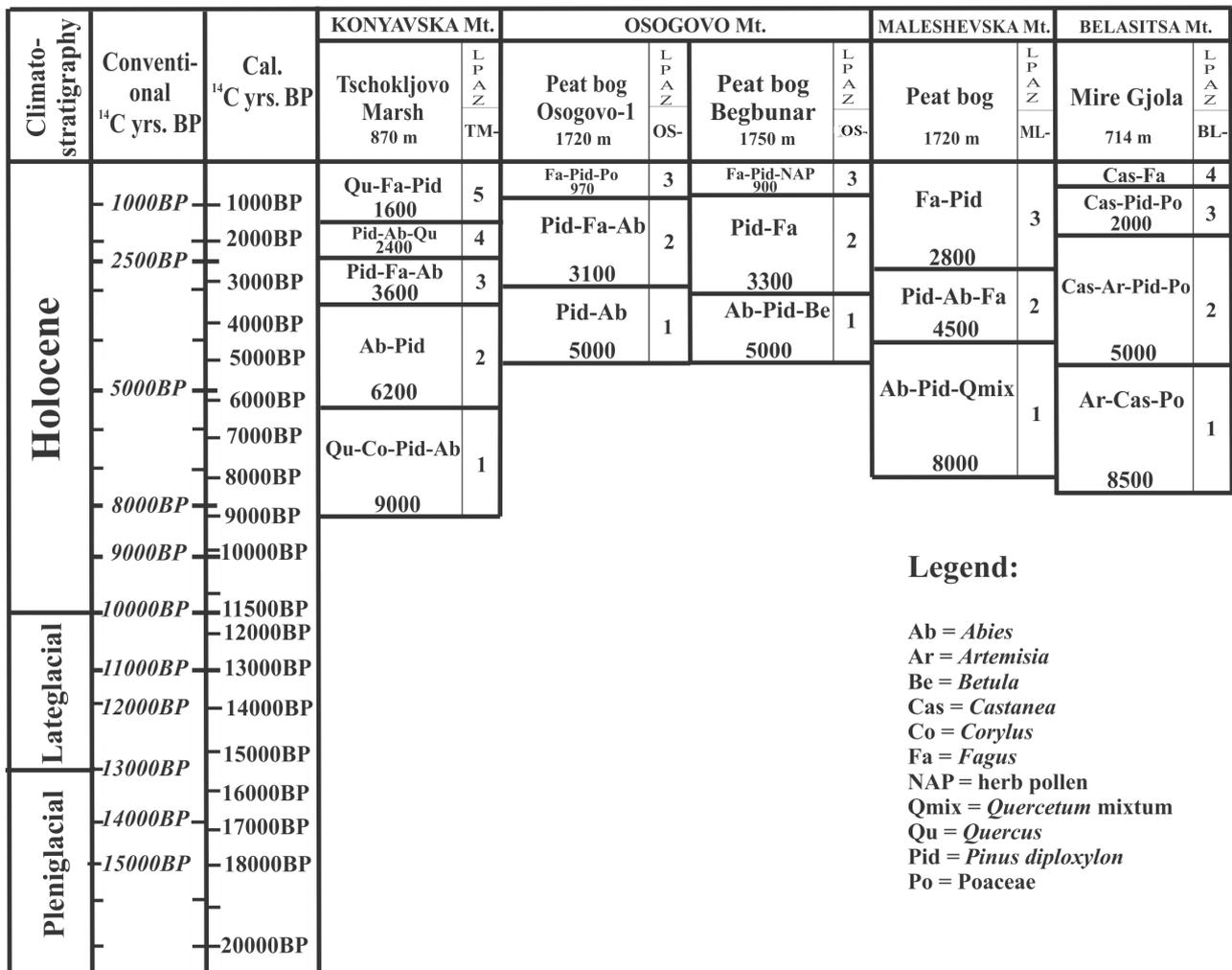


Figure 57. Comparison of the palynostratigraphy and chronology for sites located west of the Struma river.

The herb pollen taxa are represented by *Poaceae* 10-15%, *Rumex* 4%, *Ranunculus*-type 3%, *Cichoriaceae*, *Cerealia*-type, etc. Spores of *Polypodiaceae* and pollen of *Cyperaceae* are also recorded.

Core-2

LPAZ TM-3 (240-170 cm, *Pinus diploxylon*-*Fagus*-*Abies*) (3600-2400 cal. yrs. BP)

Tree pollen dominates represented by *Pinus diploxylon*-type 24-60%, *Abies* 6-18%, *Fagus* 13%, *Quercus* 10%, *Carpinus betulus*, *Corylus*. The variety of herb pollen taxa is high, represented by *Poaceae*, *Ranunculus*-type, *Apiaceae*, *Filipendula*, *Rumex*, etc. The pollen curves of *Cyperaceae* and *Typha latifolia* rise to 33% and 9%, respectively, accompanied by spores of *Polypodiaceae* up to 50% and spores of *Thelypteris palustris* 37%.

LPAZ TM-4 (170-80 cm, *Pinus diploxylon*-*Abies*-*Quercus*) (2400-1600 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type displays a maximum of 60% and then declines to 20%. Pollen of *Abies* reaches 10-20%, *Quercus* 20-25%, *Ulmus* 7% and *Salix* 4%. A great number of herb pollen taxa are determined, among them *Poaceae*, *Chenopodiaceae*, *Ranunculaceae*, *Artemisia*, *Filipendula*, etc. High values for *Polypodiaceae* spores 32% and pollen of *Cyperaceae* up to 40% are characteristic, together with pollen from hygrophytes and hydrophytes.

LPAZ TM-5 (80-0 cm, *Quercus*-*Fagus*-*Pinus diploxylon*) (1600 cal. yrs. BP-till present)

The pollen curves of *Quercus* 30% and *Fagus* 11% increase, together with *Corylus* 5%, *Carpinus*, *Salix*, *Alnus*, etc. Pollen of *Poaceae* 18%, *Plantago lanceolata* 5%, *Cerealia*-type, *Polygonum aviculare*-type, *Secale* and *Triticum*-type is registered. The local component is represented by *Typha lat-*

ifolia 12%, Cyperaceae 5-6%, spores of Polypodiaceae and *Cystopteris*, etc.

Plant macrofossil analysis

The material for analysis was taken from Core-1 at 10 cm interval parallel to the samples for pollen analysis. Altogether 40 samples, each of 20 cm³, were processed following a standard procedure with subsequent sieving through meshes with 0.25, 0.5, 1, 2 and 4 mm holes. The macrofossil diagram is constructed on the basis of the absolute number of fruits and seeds found, while the presence of other plant remains (fragments of stems and roots, sporangia, pieces of wood) is indicated with dots (Fig. 58) (Chakalova et al., 1990). Four local plant macrofossil assemblage zones (LMAZ) are recognized (mTM-1 to mTM-4). Brief descriptions are as follows:

LMAZ mTM-1 (445-295 cm) (~9000-3800 cal. yrs. BP)

Plant macrofossils are almost absent. Single fragments of roots and epidermis are found. Pieces of *Abies* and *Betula* wood are determined at 415 cm and 330 cm, respectively.

LMAZ mTM-2 (295-260 cm) (3800-3000 cal. yrs. BP)

Fruits of *Batrachium* gr. are determined and single finds of *Potamogeton* sp., *Carex rostrata*, *Polygonum* sp., fragments of roots and epidermis as well.

LMAZ mTM-3 (260-145 cm) (3000-1700 cal. yrs. BP)

This zone is the richest in plant macrofossils. Fruits of various *Carex* and *Scirpus* species dominate which is an indication of marshy places in the periphery of the basin. Fruits and seeds from various herb species such as *Potentilla palustris*, *Menyanthes trifoliata*, *Lycopus*, etc. are determined. The share of *Sphagnum* and Bryopsida moss remains, and *Equisetum* stems increases.

LMAZ mTM-4 (145-50 cm) (1700 cal. yrs. BP-till present)

Single finds of fruits from *Carex rostrata*, *Carex* gr., *Polygonum* sp. and *Typha* sp. are recorded, together with seeds from *Symphytum* sp., *Euphorbia* sp. and *Chenopodium* sp. In the uppermost 50 cm plant macrofossils are absent.

Vegetation history in the Konyavska Mountain

The palynological and plant macrofossil data provide possibility for the reconstruction of the vegetation cover during the last 9000 years in one of the lower calcareous mountains in Southwestern Bulgaria. The oldest pollen spectra (pollen zone TM-1, Fig. 55) indicate that the mountain slopes were covered by mixed oak forests and on open places *Corylus* appeared as a pioneering element. In the composition of these forests other trees participated such as *Tilia*, *Ulmus*, *Carpinus betulus*, *Carpinus orientalis* and *Ostrya carpinifolia*. Stands of *Pinus* and *Abies*, mixed in some places with *Betula*, were also growing. On the basis of pollen morphology is not possible to distinguish which pine species has prevailed, i.e. *Pinus nigra* or *Pinus sylvestris*. It is supposed that on calcareous terrains and at lower elevations black pine was predominantly distributed.

This forest composition has existed for nearly 1800-2000 years when the conifers gradually started to enlarge their areas replacing in many places the deciduous forests. The main reason for this change was probably an increase in air and soil humidity and c. 6400 cal. yrs. BP *Abies* started to gain a dominant role. Single pollen grains of *Fagus* were found in the sediments but beech has finally established in this area 2000 years later. The scarce data about the herb vegetation indicates that it was composed mainly of Poaceae, Ranunculaceae, Rosaceae, *Artemisia* species.

The next stage in the vegetation development is characterized by the dominance of *Abies* forests for a period of 3000 years. Fir has formed monodominant communities and has reached downslope near to the shores of the marsh. The participation of *Pinus*, bearing in mind its over-representation in the pollen rain, was restricted, and in some areas mixed *Abies-Pinus* communities existed. The oak forests retained their distribution and *Tilia* was abundant in them. An interesting feature is the continuous presence of *Juglans* pollen which presumes most likely its native distribution in this area, rather than cultivation by the local people (pollen zone TM-2, Fig. 55).

The subsequent change in the vegetation cover is associated with the spread of *Fagus* and this process was initiated after 3500 cal. yrs. BP. Beech has invaded the coniferous belt and the first maximum in its distribution is recorded c. 3000 cal. yrs. BP. A characteristic feature for this period is also the most significant presence of *Carpinus betulus*, *Carpinus orientalis*, *Ostrya carpinifolia*, and a slight enlargement of *Corylus* on more sunny open places. The herb communities were enriched with species from Poaceae, Rosaceae, Fabaceae, Cichoriaceae, *Achillea*, etc. Most of them participated also in the marshy vegetation and were distributed in the peripheral drier parts.

The information about the development of the vegetation in the last 2500 years could be traced in more details from both pollen diagrams (pollen zones TM-4 and TM-5, Figs. 55 and 56). The changes in the vegetation were caused not only by natural factors but also by the increasing human activity. This assumption is confirmed by the regular finds of pollen grains from *Cerealia*-type, *Triticum*-type, *Secale* and anthropophytes such as *Rumex*, *Plantago lanceolata*, *Centaurea cyanus* and *Polygonum aviculare*-type. The extensive exploitation of the forests has resulted in their wide-scale destruction. The area around the marsh is rich in archaeological monuments from Thracian and Roman times such as remains from buildings, water-pipes, ceramics, etc. (Dechev, 1933).

The final enlargement of the beech and oak forests, and partly of hornbeam and hazel, is recorded after c. 1700 cal. yrs. BP. The composition of the uppermost pollen assemblages reflects an intensive deforestation which has affected both the deciduous and coniferous forests. Since that time the present-day appearance of the vegetation cover in the Konyavska Mountain was shaped being influenced to a considerable extent by the anthropogenic activities.

The results from pollen analysis, determination of plant macrofossils and sediment description provide plentiful information about the hydrological regime of Tschokljovo marsh and the origin and transformations of the local vegetation.

In between 9000 and 5500 cal. yrs. BP the sediment type reflects the existence of a lake with a

relatively high water level. The material deposited was grey clay with traces of lake gyttja. The most common hygrophyte was *Typha latifolia* which has overgrown the shores of the lake and c. 7000 cal. yrs. BP the first spores of *Thelypteris palustris* were established, one of the characteristic species of the flora for this water basin.

The sedimentation of peaty gyttja overlain by sedge peat has started since 5500 cal. yrs. BP which could serve as an indication for a lowering of the water level and the establishment of optimal conditions for the spread of water and marshy plants. This situation is confirmed by the nearly continuous pollen curve of Cyperaceae and the find of *Nymphaea*, *Nuphar*, *Typha latifolia* and *Alisma* pollen. Fruits from typical hydrophytes such as *Batrachium* gr. and *Potamogeton* sp. prevailed.

The lowland peat bog vegetation type was widely distributed between 2800 and 1700 cal. yrs. BP represented by *Carex*, *Filipendula* and *Potentilla* species. A typical feature was the local maximum of *Thelypteris palustris* c. 2400 cal. yrs. BP when this species has spread in the reed communities (pollen zone TM-4, Fig. 55). The distribution of this vegetation type is confirmed by the rich macrofossil record represented by fruits from *Carex* gr., *Scirpus* gr., *Juncus* sp., *Carex rostrata*, *Potentilla palustris*, fragments of *Equisetum* stems, and moss remains (Fig. 58). As the peat layer has become more stable the peripheral areas of the marsh were overgrown by shrubs of *Salix* and *Alnus*.

The sediments which accumulated after 1700 cal. yrs. BP appear heterogeneous in composition, changing from almost pure *Phragmites* undecomposed peat to fen-carr peat mixed with mineral particles. Sedge communities composed of various *Carex*, *Scirpus*, *Juncus* and *Heleocharis* species were widely distributed. Fruits of *Carex* gr., *Carex rostrata* and *Typha* sp. are sporadically found, and also seeds/fruits from plants with wider ecological requirements such as *Polygonum* sp., *Symphytum* sp., *Chenopodium* sp., etc. The presence of *Alisma*, *Lythrum*, *Potamogeton* pollen, spores from *Sphagnum* and Polypodiaceae indicate that 1000 years ago the main vegetation types were already present in the Tschokljovo marsh.

5. OSOGOVO MOUNTAIN

Physico-geographical characteristics and modern vegetation

Osogovo Mountain (peak Ruen, 2251 m) is the highest border massif of the Osogovo-Belasitsa mountain range, which is situated in Southwestern Bulgaria and in the Republic of Northern Macedonia (Fig. 1). The northern and northeastern slopes on Bulgarian territory are going down steep to the periphery of Kamenishka and Kyustendil valleys, and to the south the saddle Black Rock is the linkage to Vlahina Mountain. The massif is composed mainly of Paleozoic metamorphic and intrusive rocks. On the surface in the middle of the mountain reveals a core of the southern Bulgarian granite. Sandstones (Triassic, Tertiary and others) are widespread in the eastern parts. From a geomorphological point of view five denudation levels were formed during the Neogene and the transition to the Quaternary. Small valley glaciers existed in the highest parts of the mountain during the Quaternary glaciations stretching down to c. 1700 m (Velchev, 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), above them brown-forest (Cambisols), and the ridge is occupied by montane-meadow (Umbrisols) (Ninov, 1997).

According to the last geobotanical zoning, Osogovo Mountain is included as a separate region in the Western Bulgarian Border Mountain District of the Illyrian (Balkan) Province (Bondev, 2002). The mountain is usually viewed together with the other western border mountains (Vlahina, Maleshevska and Ograzhden) but its vegetation differs in many aspects because of the northern location and higher altitude. Comprehensive

information on the modern vegetation of Osogovo Mountain can be found in the Vegetation Map of Bulgaria (Bondev, 1991) and in the review of Velchev, Tonkov (1986). Following these basic literature sources the vegetation comprises several vertical belts.

The oak forest belt up to 1000 m on the southeastern slopes is dominated by *Quercus pubescens*, *Quercus cerris* and *Quercus dalechampii* with some *Carpinus orientalis*, *Ostrya carpinifolia* and *Juniperus oxycedrus*. Plant communities of *Pinus nigra* and *Fagus sylvatica* are also found. The beech belt (1000–1900 m) is the most well-developed vegetation belt, composed mainly of monodominant communities of *Fagus sylvatica*. At some areas in the beech belt patches of *Abies alba* and *Pinus 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* grow close, or just above, the timber-line. Remnants of mixed coniferous communities composed of *Picea abies* and *Abies 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*, *Vaccinium myrtillus*, *Bruckenthalia spiculifolia*, *Chamaecytisus absinthioides*, *Nardus stricta*, 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 (Tonkov, 2003; Lazarova et al., 2015).

Study sites

In the treeless, mostly flat central part of the mountain, between 1600 and 1800 m just above the beech forests, small peat bogs occur in depressions formed as a result of denudation processes (Velchev et al., 1994). The thickness of the peat layers and the underlying sediments hardly exceeds 1 m. Three peat bogs located near-by springs were selected for study (Fig. 2).

Peat bog Osogovo-1 (site 19)

The peat bog is situated at 1720 m in a depression and occupies a small area of c. 50 m² on a northeastern slope. Stands of *Pinus sylvestris* and *Juniperus communis* grow nearby and patches of *Picea abies* were planted (Tonkov, 2003a).

Coring, lithology and radiocarbon dating

The core 1.7 m long was collected with Dachnowsky hand-corer equipment. The sediment is composed of Cyperaceae peat. The radiocarbon age of 3 samples of bulk sediment was determined and the results are shown on Table 17. The estimates from the radiocarbon dating indicate that the age of the bottom part of the core is c. 5000 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 10 cm interval and a percentage pollen diagram is constructed (Fig. 59). On the pollen diagram three local pollen assemblage zones (LPAZ) are delimited (OS-1 to OS-3) (Fig. 57) which are also recognized in the other two peat bogs investigated. Brief descriptions are as follows:

LPAZ OS-1 (170-115 cm, *Pinus diploxylon-Abies*) (~5000-3100 cal. yrs. BP)

Pollen of *Pinus diploxylon*-type dominates with 65-45%, accompanied by *Abies* with 8-10%. Other tree taxa such as *Juniperus*, *Alnus*, *Quercus*, *Tilia*, *Corylus* and *Carpinus* are found each with low values of 2-4%. The herb component is represented by Poaceae with 5% and a number of taxa such as Cichoriaceae, *Achillea*-type, *Cirsium*-type, *Dianthus*-type, *Lychnis*-type, etc. A characteristic feature for the entire diagram are the high values of *Scleranthus* up to 15-20%.

LPAZ OS-2 (115-55 cm, *Pinus diploxylon-Fagus-Abies*) (3100-970 cal. yrs. BP)

The dominance of *Pinus diploxylon*-type continues with 45-50%. A local maximum of *Abies* pollen 12% is followed by a decline to 3-4%. A peculiar feature is the quick rise of *Fagus* pollen up to 30%. The pollen curves of *Plantago lanceolata*, *Rumex* and Chenopodiaceae are established in this zone.

LPAZ OS-3 (55-0 cm, *Fagus-Pinus diploxylon-Poaceae*) (970 cal. yrs. BP-till present)

Pollen of *Fagus* attains a maximum of 50%. The contribution of *Pinus diploxylon*-type declines to 15% while pollen grains of *Abies* are scarcely found. Deciduous tree pollen increases, due also to *Quercus* 6-8%, *Carpinus orientalis/Ostrya* 3-4%, *Corylus* and *Betula*. Pollen of *Juniperus* shows higher frequencies in the uppermost samples. The presence of Poaceae 15% is accompanied by pollen of *Artemisia*, Brassicaceae, Apiaceae, *Secale*, etc.

Peat bog Osogovo-2 (site 20)

This small peat bog is located at 1620 m on a southwestern slope close to peat bog Osogovo-1 in a completely deforested area, nearby the touristic hut Trite Buki. Stands of beech are seen in the neighborhood (Tonkov, 1994).

Coring, lithology and radiocarbon dating

The core 0.95 m long was collected with Dachnowsky hand-corer equipment. The sediment is composed of Cyperaceae peat. The accumulation of peat has started c. 1200 cal. yrs. BP as confirmed by the single radiocarbon date (Table 17).

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 60). On the pollen diagram two local pollen assemblage zones (LPAZ) are recognized (OS-2 and OS-3). Brief descriptions are as follows:

LPAZ OS-2 (95-63 cm, *Pinus diploxylon-Fagus-Abies*)

Pollen of *Pinus diploxylon*-type dominates with over 60%, accompanied by *Abies* 19%, *Fagus* 10-20% and *Quercus* 3%. Deciduous tree taxa such as *Carpinus betulus*, *Carpinus orientalis/Ostrya*, *Corylus*, *Ulmus* and *Tilia* are sporadically found. Among the herbs Poaceae reaches 10% while single finds of pollen of Apiaceae, *Achillea*-type, *Dianthus*-type, *Cirsium*-type, *Scabiosa*, etc. are registered.

LPAZ OS-3 (63-0 cm, *Fagus-Pinus diploxylon-Poaceae*)

The pollen curve of *Fagus* rises steeply up to 70% and a decline for *Pinus diploxylon*-type to 14% is observed. The uppermost pollen spectra reveal a

Peat bog OSOGOVO-2 (Osogovo Mt., 1620 m)
Percentage pollen diagram

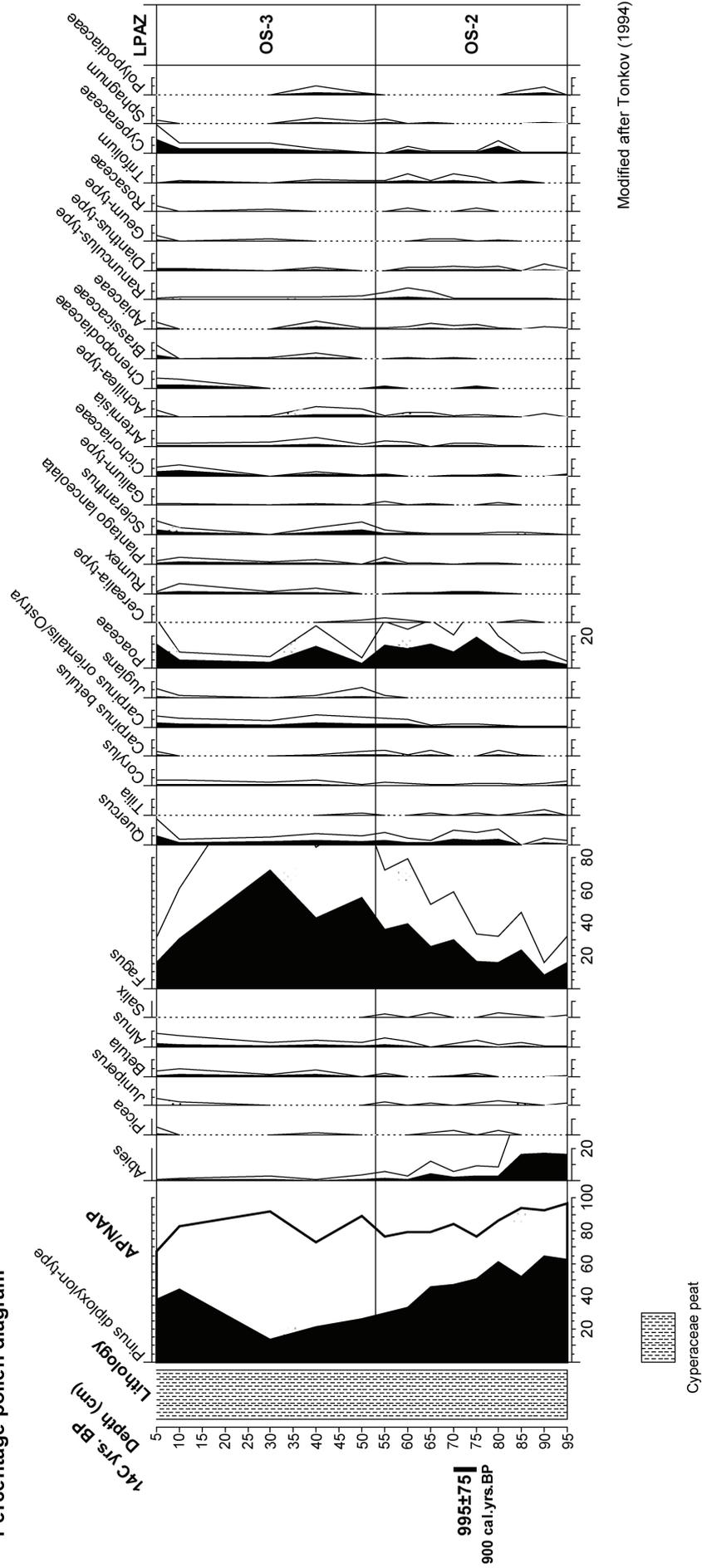


Figure 60. Percentage pollen diagram of Peat bog Osogovo-2.

reverse situation with a quick decline of *Fagus* and some restoration for *Pinus diploxylon*-type with 40%. Pollen of *Quercus*, *Alnus*, *Betula*, *Carpinus orientalis*/*Ostrya* is present each with 3-4%. The second maximum of Poaceae 15% is recorded.

Peat bog Begbunar (site 21)

The third peat bog is located at 1750 m (42°08'51.62"N, 22°32'45.05"E) near a spring on a northwestern slope which continues into a steep, deep ravine where isolated stands of beech grow. Not far to the north are visible scattered groups of *Pinus sylvestris* and *Juniperus sibirica* (Lazarova et al., 2009, 2015)

Coring, lithology and radiocarbon dating

A core 1.05 m long was collected with Dachnowsky hand-corer equipment from a less densely vegetated area of the bog surface. The lithology of the sediments is: 0-75 cm Cyperaceae-*Sphagnum* peat, 75-105 cm Cyperaceae peat with sand. The radiocarbon age of *Carex* fruits and charcoal, extracted from 3 bulk sediment samples, was determined and the results are shown on Table 17. The age of the bottom part of the core is assigned to c. 5000 cal. yrs. BP.

Table 17. Radiocarbon dates from peat bogs in the Osogovo Mountain.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Osogovo-1				
Lu-3420	45-55	790±60	800-640 (720)	peat
Lu-3421	82-98	2220±70	2350-2040 (2200)	peat
Lu-3422	120-130	3350±70	3730-3440 (3580)	peat
Osogovo-2				
Hv-12550	65-80	995±75	1060-740 (900)	peat
Begbunar				
LuS-6714	20-25	245±70	490-11 (250)	4 mg charcoal
LuS-6713	70-74	3190±50	3560-3330 (3450)	5 mg charcoal
LuS-6712	84-89	3755±60	4360-3920 (4140)	6 mg <i>Carex</i> fruits



Figure 61. A view of Peat bog Begbunar (Photo S. Tonkov)

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 62). On the pollen diagram three local pollen assemblage zones (LPAZ) are delimited (OS-1 to OS-3) (Fig. 57). Brief descriptions are as follows:

LPAZ OS-1 (105-72 cm, *Abies*-*Pinus diploxylon*-*Betula*) (~5000-3300 cal. yrs. BP)

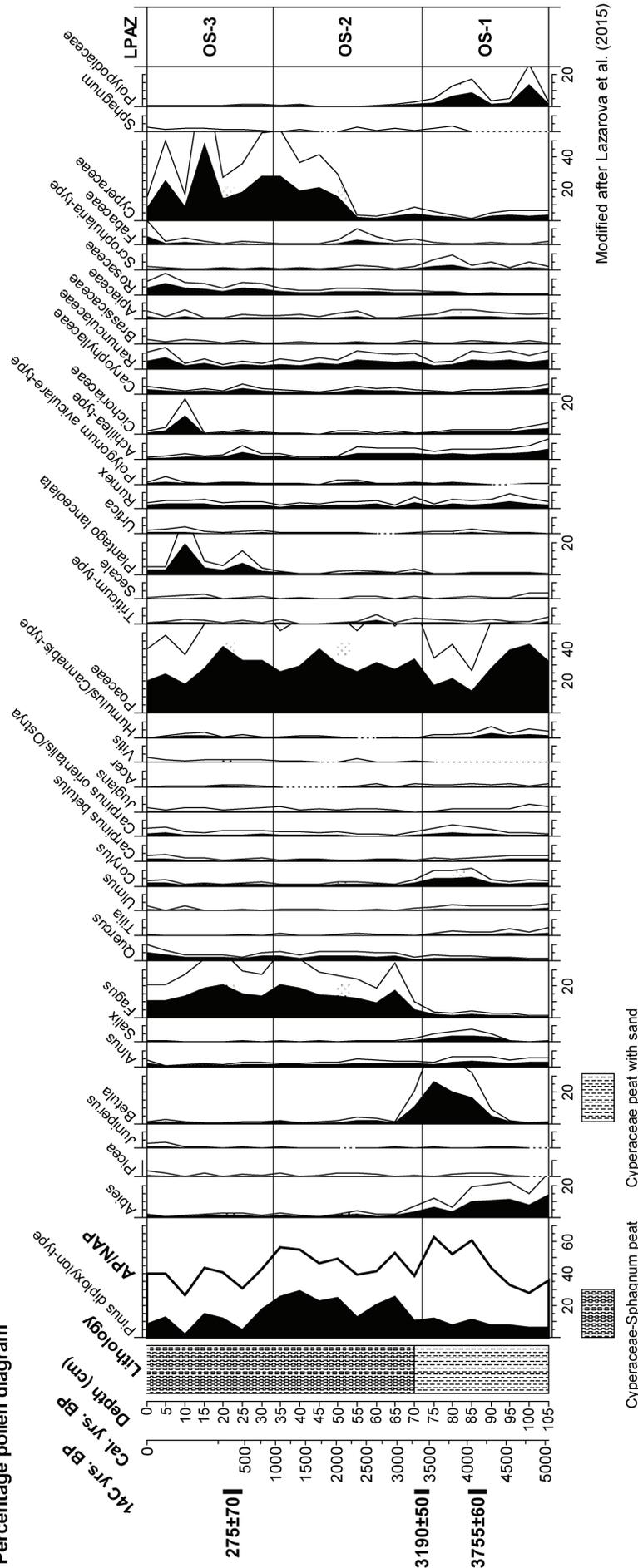
Pollen of *Abies* 13-3% prevails, followed by *Pinus diploxylon*-type 6-12% and *Betula* with a peak of 26% at the transition to the next zone. Deciduous tree pollen is represented also by *Corylus* up to 6%, *Quercus*, *Tilia*, *Ulmus* each with 1-2%, *Alnus* and *Salix*. Minor quantities of pollen are recorded for *Carpinus orientalis*/*Ostrya*, *Carpinus betulus*, *Fagus*, *Fraxinus* and *Acer*. Pollen of *Juglans* is present throughout the entire core. The herb pollen taxa are represented by Poaceae 13-43%, Ranunculaceae up to 6%, *Achillea*-type up to 6%, *Rumex* 5%, Cichoriaceae up to 4%, etc. The constant presence of Polypodiaceae spores is between 2% and 11%.

LPAZ OS-2 (72-33 cm, *Pinus diploxylon*-*Fagus*) (3300-900 cal. yrs. BP)

The abundance of *Pinus diploxylon*-type pollen is between 15% and 29%, accompanied by a gradual rise of *Fagus* pollen curve up to 20%. Pollen of *Abies* almost disappears in this zone. High pollen frequencies up to 40% are established for Poaceae. Pollen of Rosaceae, Fabaceae, Ranunculaceae, *Achillea*-type reaches 3-4% each. The pollen curve of Cyperaceae rises to 22%.

Peat bog BEGBUNAR (Osogovo Mt., 1750 m)

Percentage pollen diagram



Modified after Lazarova et al. (2015)

Figure 62. Percentage pollen diagram of Peat bog Begbunar.

LPAZ OS-3 (33–0 cm, *Fagus-Pinus diploxylon-NAP*) (900 cal. yrs. BP-till present)

Pollen of *Fagus* attains a maximum of 21%, while *Pinus diploxylon*-type declines to 15%. In the uppermost pollen spectra *Quercus*, *Carpinus orientalis/Ostrya* and *Carpinus betulus* rise to 5%, 2% and 1.5%, respectively. Characteristic for this zone are the maximal values for Poaceae 42%, *Plantago lanceolata* 19%, Cichoriaceae 2%, Rosaceae and Ranunculaceae with 7% each. Cyperaceae pollen is 20% with a maximum of 32%.

Plant macrofossil analysis

Complimentary to pollen analysis plant macrofossils and charred wood fragments (> 2 mm) were studied. Sub-samples for macrofossil analysis with a sediment volume of 50 ml were taken at every 5 cm. The material was sieved through meshes of 0.4 and 0.16 mm holes. The results of the analysis are presented as absolute numbers of determinable items (needles, seeds, nutlets, etc.) on a macrofossil diagram (Fig. 63). The remains of vegetative parts like stems, leaves and others are not quantified but their presence is indicated with dots. Two local macrofossil assemblage zones (LMAZ) are distinguished (BM-1 and BM-2). Brief descriptions are as follows:

LMAZ BM-1 (95–55 cm) (~5000–2300 cal. yrs. BP)

In the lower part of the core the prevailing material is charred wood from *Acer* sp., *Fraxinus*, *Alnus*, *Prunoideae/Maloideae*. Also charred wood particles from *Fagus*, *Pinus* sp. and from undeterminable conifers are found. Charred leaf fragments of *Pinus* sp. are present too. The interval 70–55 cm shows an abundance of fruits/seeds and vegetative parts from several semi-shrubs (*Bruckenthalia spiculifolia*, *Vaccinium myrtillus*, *Genista carinalis*) and herbs (*Hypericum*, *Carex* and *Juncus* species).

LMAZ BM-2 (55–0 cm) (2300 cal. yrs. BP-till present)

There are only occasional finds of undeterminable charred wood (0.2–2 mm). Most abundant are nutlets from *Vaccinium myrtillus*, fruits from *Carex echinata*, *Genista carinalis* and *Scirpus sylvaticus*. Nutlets and seeds from *Potentilla* and *Hypericum* species are also determined. Vegetative parts from

Drepanocladus sp. are present in addition to those from Poaceae, Cyperaceae and *Sphagnum*.

Vegetation history in the Osogovo Mountain

The paleoecological information obtained from the analyzed cores, in conjunction with the radiocarbon dates, reveals the vegetation development in the central part of the Osogovo Mountain during the last 5000 years. The oldest pollen spectra (pollen zone OS-1, Fig. 59, Fig. 62) 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 is difficult to be estimated bearing in mind that pollen of *Pinus diploxylon*-type is well known for its high pollen production and effective dispersal. The pollen grains produced by *Pinus mugo* are also included in the above pollen type but cannot be separated by morphological features. The probable past distribution of *Pinus mugo* in the highest parts of the Osogovo Mountain could be suggested but definite confirmation requires finds of macrofossils. Regarding *Abies alba*, the pollen frequencies appear indicative of a considerable participation of fir in the coniferous forests c. 5000–4000 years ago. In places with high air humidity and soil moisture, such as deep ravines and river valleys, grew small populations of *Fagus sylvatica*, while *Alnus* and *Salix* thrived along streams and brooks. The broadleaved tree vegetation, 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. yrs. BP) (pollen zone OS-1, Fig. 62) indicates that openings of the forest took place, which have preceded the beginning of the invasion of beech. The palynological reconstruction of the vegetation in the study area is supported by the finds of macrofossils such as needles and charcoal from *Pinus* sp. and undeterminable small charcoal fragments from conifers. The charcoal fragments from deciduous trees (*Acer* sp., *Fraxinus*, *Maloideae*) suggest that they

Peat bog BEGBUNAR (Osogovo Mt., 1750 m)

Plant macrofossil diagram

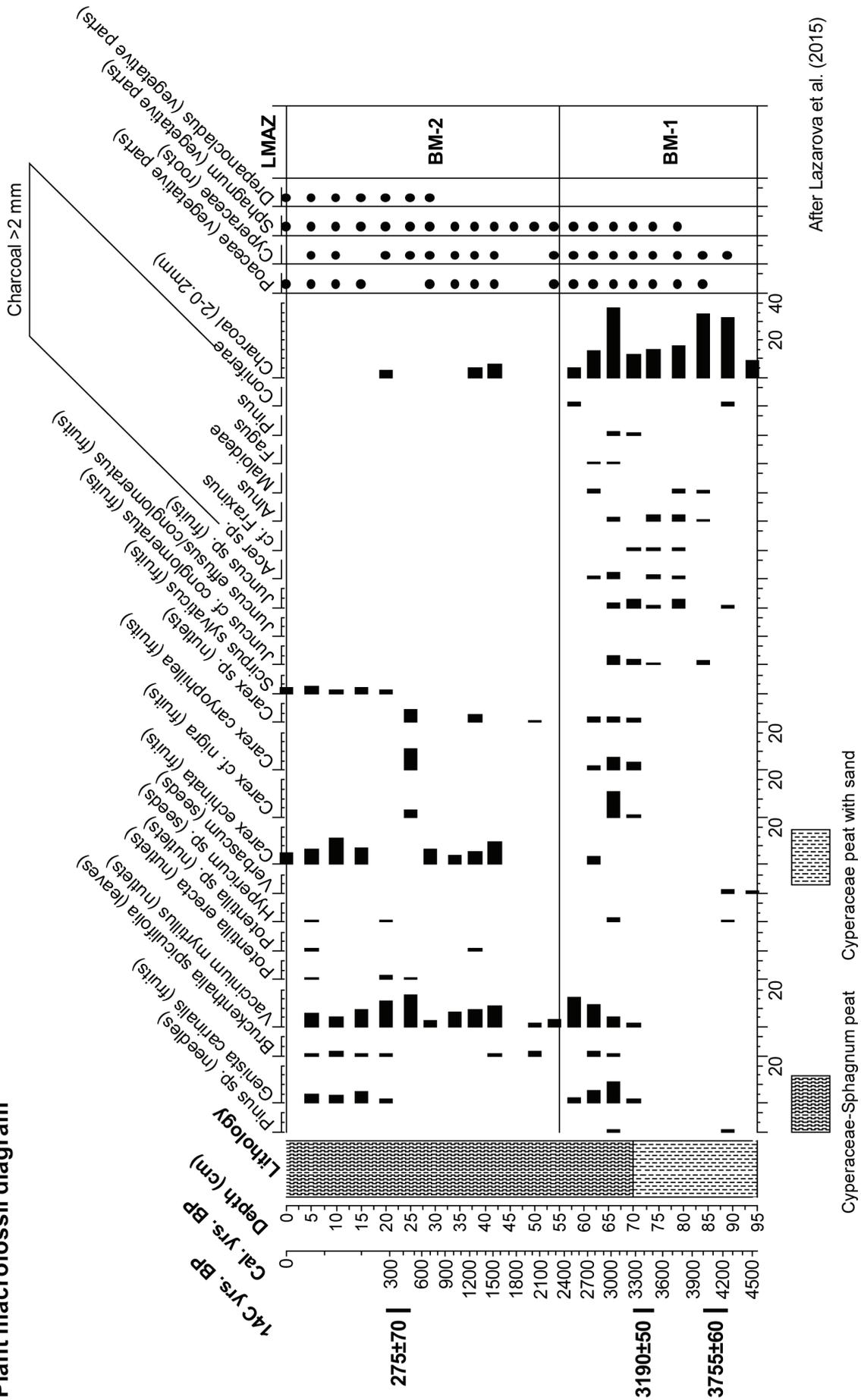


Figure 63. Plant macrofossil diagram of Peat bog Begbunar.

had climbed higher compared to the present-day situation. The charcoal particles of different size point also to local and regional fires (zone BM-1, Fig. 63).

The surface area of the Peat bog Begbunar was covered by various *Juncus*, *Carex* and *Sphagnum* species. Following the second peak of the macrocharcoal fragments c. 3200–3000 cal. yrs. 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 nearby surroundings. This picture of the vegetation cover on the high central parts of the mountain for the time interval 5000–3500 cal. yrs. BP is identical with the results from the Peat bog Osogovo-1.

Indications of human activity are noticed already c. 5000 cal. yrs. BP when pollen of *Secale* and *Triticum*-type was deposited, alongside with the presence of pollen from *Rumex* and *Plantago lanceolata* (pollen zone OS-1, Fig. 62). On the other hand, in the sediments of Peat bog Osogovo-1 the appearance of *Secale* pollen starts much later c. 1300 cal. yrs. BP (Fig. 59). This observation probably reflects local/regional specific features of human activity. For example, high quantities of *Scleranthus* pollen, indicative of stockbreeding, are recorded in the above core with a first maximum assigned to the onset of the Late Bronze Age. Around 2700 cal. yrs. BP a peak in the presence of the anthropogenic indicators is registered, quite probably associated with the local Thracian tribes which moved higher up in the mountains surrounding the Struma river valley (Bozhkova, Delev, 2002).

The next stage in the development of the vegetation cover in the Osogovo Mountain lasted between 3300 and 900 cal. yrs. BP (pollen zone OS-2, Figs. 59 and 60). Important changes in the forest composition took place as in the course of a thousand years populations of *Fagus sylvatica* gradually overcame the conifers, mostly *Abies alba* on many areas, thus shaping a belt of monodominant or mixed communities. The reasons for this replacement were likely of a complex character, including a change towards a more humid and cooler climate with lower average temperatures,

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, Sykes, 2014). For example, the examination of the relationship between pollen percentage values and charcoal data from southern Scandinavia has shown that charcoal values were generally higher immediately prior to local beech establishment (Bradshaw, 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. yrs. BP. 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. yrs. BP as visible in all pollen diagrams. The final advance of *Fagus* has occurred a couple of centuries ago and was quite probably primarily controlled by climatic change.

The rather uniform content of the macrofossil record after c. 2200 cal. yrs. BP (zone BM-2, Fig. 63) and the nearly complete lack of charcoal fragments suggest that vast areas were already deforested and the openings were colonized by various semi-shrubs and herbs. The marshy areas of the peat bogs continued to be overgrown by *Carex* and *Sphagnum* species.

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 has become widespread, as evidenced by the continuous pollen curve of *Juglans* (Fig. 62). After 720 cal. yrs. BP, and particularly since 400 cal. yrs. BP, 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* pollen. The destruction of the woods resulted also in the enlargement of the areas for summer pasture land and the present-day appearance of the vegetation cover.

During the last centuries the general trend of the vegetation development in the Osogovo Mountain witnessed a progressive large-scale degradation of the woodlands. The destruction of the remnants of the pine forests 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 lowering of the timber-line at many places. The peat bogs investigated remained in the treeless zone above the beech forests. The open areas were occupied by diverse herb communities composed of Poaceae, Ranunculaceae, Rosaceae, Fabaceae, Caryophyllaceae and Apiaceae species. Until the last decades intensive cattle-breeding was practiced, as proven by the presence of a large number of anthropogenic pollen indicators such as Cichoriaceae, *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 hornbeam and mixed oak communities are visible at lower altitudes.

In summary, 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* has 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. yrs. BP and was of complex character, promoted by factors related to both climate change and anthropogenic disturbance. The remnants of the coniferous forests and the monodominant or mixed communities of *Fagus sylvatica* were subjected to destruction during the last centuries. Evidence for a pronounced human impact in the study area, including deforestation, stock-breeding and agriculture activities, is available since the Late Bronze Age.

6. MALESHEVSKA MOUNTAIN

Physico-geographical characteristics and modern vegetation

Maleshevska Mountain (peak Iljov vrah, 1802 m) is part of the Osogovo-Belasitsa mountain range. The ridge of the mountain is a highly curved arc, projecting to the south, along the state border with the Republic of Northern Macedonia. Most of its eastern part remains within Bulgaria and covers an area of c. 497 km². In general, the mountain resembles an isosceles triangle with its tip facing west. To the east, its slopes descend steeply to the Kresna Gorge of the Struma river and the northern part of the Sandanski-Petrich Basin, which separates it from the Pirin Mountain. To the west it borders the southeast, south and southwest of the Maleshevo historical and geographical area. To the north through the saddle Chetalo (1619 m) it connects with the Vlachina Mountain and the valley of the Sushichka river, a right tributary of the Struma river. To the south the valley of the Lebnitsa river, a right tributary of the Struma river separates it from the Ograzhden Mountain. Gradually to the south the ridge of the mountain decreases (Todorov et al., 2016) (Fig. 1).

The mountain has a complex geological structure. The lithology of the area is related to the distribution of some major types of metamorphic, magma and sedimentary rocks. The metamorphic rocks are of pre-Cambrian age, represented by biotite and bivalve gneisses and migmatites, accounting for about 60% of the territory. Granites are found in the northeastern parts and in the valley of the Lebnitsa river, spots of volcanic rocks in the highest denudation surfaces and in the lowest places. Paleogene, Neogene and Quaternary sediments are also encountered (Zagorchev, 2001).

The mountain falls in the continental-mediterranean climate region. The average annual temperature in the foothills is 14°C, and at an altitude of 1700-1800 m it is 5°-6°C. The average annual precipitation is also vertically and

horizontally differentiated, in the southern and lower parts of the mountain it is 500–600 mm with a maximum in November, at a height of 600–1000 m it is 700–800 mm with a maximum in October, and above 1000 m it is 1000 mm with a maximum in May (Velev, 2010).

The southwestern, southern and eastern slopes of the mountain belong to the catchment area of the Struma river and are drained by its right tributaries. The northwestern slopes facing the Maleshevo region belong to the Vardar river basin. The rivers in the mountain have rain-snow feeding with winter-spring high water and summer-autumn low water (Todorov et al., 2016).

The most widespread are the leached cinnamon forest soils (Chromic Luvisols) up to 700 m and brown mountain forest soils (Distric Cambisols) up to 1600–1700 m. The former are characteristic of the oak belt and the latter of the beech belt and the remnants of the coniferous forests. Mountain meadow soils (Humic Umbrosols) are developed above the upper timber-line. The erosion is ubiquitous, especially in the lower parts of the mountain (Ninov, 1997).

According to the last geobotanical zoning, Maleshevska Mountain is included as a separate region in the Western Bulgarian Border Mountain District of the Illyrian (Balkan) Province (Bondev, 2002). The combination of geographical location, climatic, soil and hydrological conditions has influenced the character of the modern vegetation, expressed in the presence of rare and southern elements, as well as a clear distribution in three vertical belts. The first belt of the xerothermic oak forests is well separated on the southeast and eastern slopes up to 500–600 m. It is composed of the communities of *Quercus pubescens*, *Quercus frainetto*, *Carpinus orientalis*, *Paliurus spina-christii*, etc. In this belt, over the village of Kamenitsa, there are communities of the evergreen oak *Quercus coccifera*. Other mediterranean elements are also found, such as *Juniperus excelsa*, *Phyllirea latifolia* and *Jasminum fruticans*. The riparian associations of *Platanus orientalis* are also characteristic. In the belt of the mesophilous and xeromesophilous oak and hornbeam forests (600–900 m) the basic communities are those of

Quercus dalechampii and *Ostrya carpinifolia*. They include also *Carpinus betulus*, *Fraxinus ornus* and *Acer pseudoplatanus*. Groups of *Pinus nigra* are also found. The beech forest belt is very well developed and relatively compact above 900–1000 m. These forests are usually monodominant but in their composition participate also *Abies alba*, *Abies borisii-regis*, *Betula pendula*, *Populus tremula*, *Pinus nigra* and *Pinus sylvestris*. The flattened ridges are characterized by the spread of high-mountain species and fragments of communities of *Vaccinium myrtillus*, *Vaccinium uliginosum*, *Chamaecytisus austriacus*, *Bruckenthalia spiculifolia*, etc. (Velchev, Tonkov, 1986)

Study site

Peat bog (site 22)

The peat bog investigated is located in a treeless area at an altitude of 1720 m near a spring on a gentle east slope, above the timber-line shaped by the beech forests. It occupies a small area of about 50 m² (Fig. 2). The locality was used in former times as mountain pasture land. The bog vegetation is composed of *Agrostis tenuis*, *Deschampsia caespitosa*, *Carex echinata*, *Eriophorum latifolium*, *Bistorta major*, *Potentilla erecta*, *Armeria rumelica*, *Veratrum lobelianum*, *Scleranthus perennis*, *Bruckenthalia spiculifolia*, etc. (Tonkov, Bozilova, 1992a).

Coring, lithology and radiocarbon dating

A sediment core 2.05 m long was recovered with Dachnowsky hand-corer equipment. The lithology of the sediments is: 0–180 cm Cyperaceae peat, 180–205 cm peat with sand. The radiocarbon age of 3 samples of bulk sediment was determined and

Table 18. Radiocarbon dates from peat bog in the Maleshevska Mountain.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Material dated
Hv-11347	26-29	2650±105	2380-3010 (2695)	peat
Hv-11349	85-89	3205±185	2950-3900 (3425)	peat
Hv-11487	171-180	6535±105	7250-7600 (7425)	peat

the results are shown on Table 18. The age of the bottom part of the core is estimated at c. 8000 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 64). On the pollen diagram three local pollen assemblage zones (LPAZ) are delimited (ML-1 to ML-3) (Fig. 57). Brief descriptions are as follows:

LPAZ ML-1 (205-115 cm, *Abies-Pinus diploxylon-Quercetum mixtum*) (~8000-4500 cal. yrs. BP)

High pollen values are recorded for *Abies* 35-50% and *Pinus diploxylon*-type 37%. Well represented is also pollen of *Quercus* 24%, *Carpinus betulus* 7%, *Alnus* up to 5%, *Corylus*, *Tilia*, *Ulmus*, *Carpinus orientalis/Ostrya* and *Humulus/Cannabis*-type. Single pollen grains of *Rhamnus/Paliurus*-type, *Jasminum* and *Hedera* are determined. The variety of herb pollen taxa is considerable, represented by Poaceae 13-15%, Apiaceae up to 8%, Cichoriaceae 2%, Chenopodiaceae, *Ranunculus*-type, *Artemisia*, Cyperaceae 9%, etc.

LPAZ ML-2 (115-42 cm, *Pinus diploxylon-Abies-Fagus*) (4500-2800 cal. yrs. BP)

The pollen curve of *Abies* declines to 3% and rises again to a second maximum of 24%. Pollen of *Pinus diploxylon*-type is present with 50%. The most characteristic feature is the appearance of the continuous pollen curve of *Fagus* with up to 5%. The rest of the deciduous tree taxa, with the exception of *Quercus* 12%, are present with values below 2%. It is worth mentioning the first records of *Juglans*, *Castanea*, *Phyllirea* and *Vitis* pollen. The pollen curve of Poaceae varies between 10% and 23%, followed by *Scleranthus* and *Cirsium*-type with 7% and 5%, respectively. Pollen of *Polygonum aviculare*-type, *Plantago lanceolata*, *Urtica*, etc. is also found.

LPAZ ML-3 (42-0 cm, *Fagus-Pinus diploxylon*) (2800 cal. yrs. BP-till present)

Pollen of *Pinus diploxylon*-type is present with 55-25%. The pollen curve of *Abies* reaches its last maximum of 11% and declines. The most characteristic feature is the rise of *Fagus* pollen curve up to 30-33%. Pollen of *Quercus* participates with 10-5%, together with *Carpinus betulus*, *Carpinus*

orientalis/Ostrya, *Corylus*, *Alnus*. Pollen grains of *Juglans* and *Castanea* are determined in all samples. The frequencies of the herb pollen taxa slightly increase, represented by Poaceae 12%, *Scleranthus* 11%, Cichoriaceae 8%, *Artemisia* 6%, *Plantago lanceolata* 3%, *Cirsium*-type, *Polygonum aviculare*-type, *Rumex*, *Filipendula*, Cyperaceae 7%, etc.

Vegetation history in the Maleshevska Mountain

The formation of the peat bog has started about 8000 years ago when forests of *Abies* with admixture of pines (*Pinus sylvestris*, *Pinus nigra*) have dominated the landscape above 1000-1200 m, thus shaping also the timber-line. The wide distribution of the conifers was favored by an increase in precipitation and air/soil humidity during the Holocene climatic optimum, proved also by the find of pollen of *Hedera* and *Humulus/Cannabis*. The peat bog was included in the upper part of the coniferous belt and on more open places developed stands of *Juniperus*. Groups of *Alnus* were found along the mountain streams and brooks. Small populations of *Fagus* and *Betula* were also present. Below the coniferous belt were distributed mixed oak forests (*Quercetum mixtum*) with abundant *Tilia*, *Ulmus*, *Carpinus betulus* and *Corylus*. The pollen assemblages include irregular, small quantities of anthropogenic taxa such as *Plantago lanceolata*, *Rumex* and *Scleranthus* which indicate that the intensity of the human impact on the natural vegetation was still rather low, at least in the high mountain areas (pollen zone ML-1, Fig. 64). The presence of the above mentioned pollen grains is considered as an indication of ruderal communities along forest paths (Behre, 1981; Bozilova, Tonkov, 1990). The find of *Cerealia*-type pollen might reflect the initial cultivation of cereals in this part of the Struma river valley.

Substantial changes in the composition and distribution of the forest vegetation have occurred after c. 4500 cal. yrs. BP. Particularly notable is the quick decline of the areas occupied by *Abies* and the increase of *Pinus*. It is likely, that a decrease in air humidity and human intervention may have

Peat bog (Maleshevska Mt., 1720 m)

Percentage pollen diagram

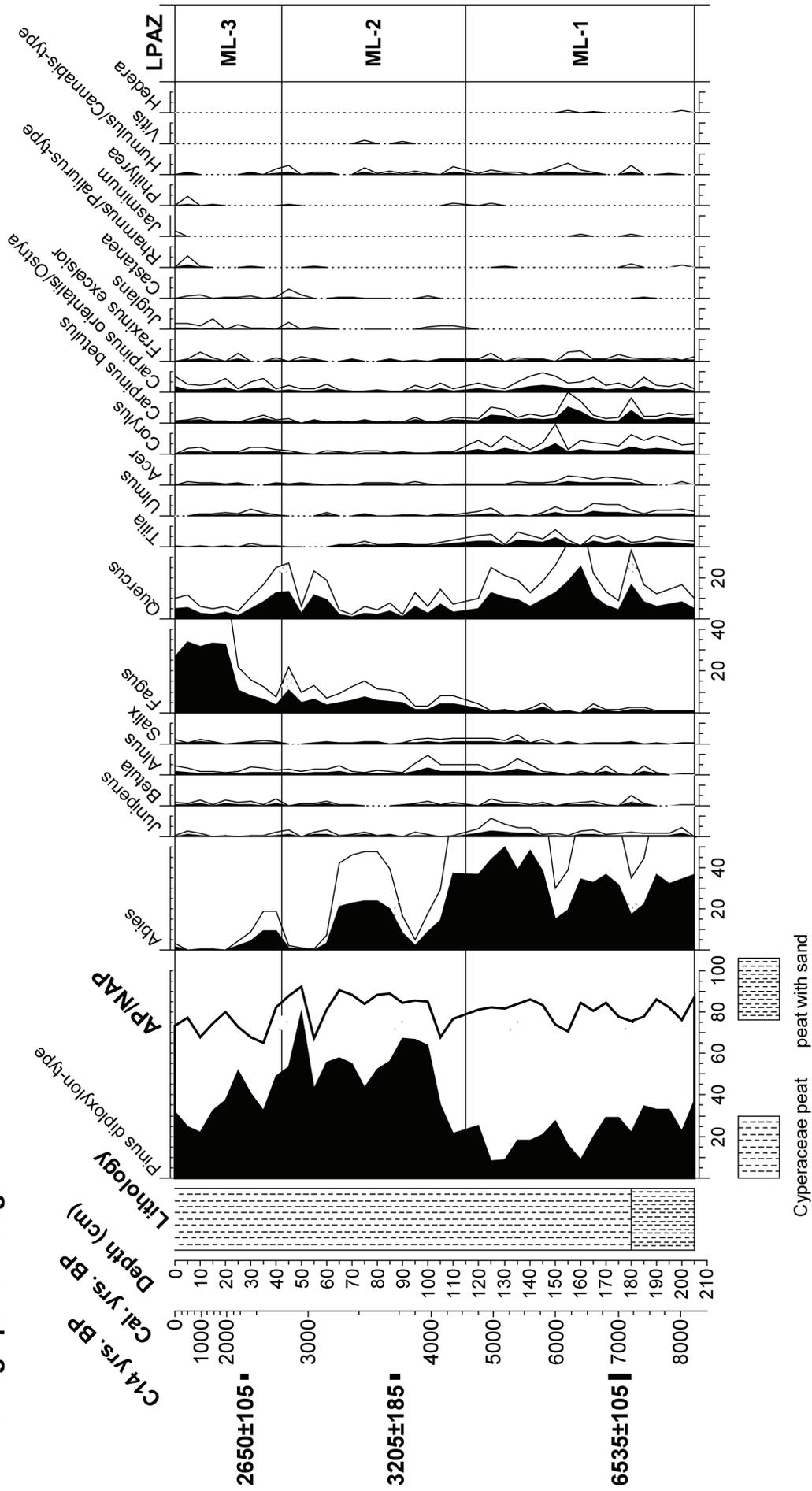
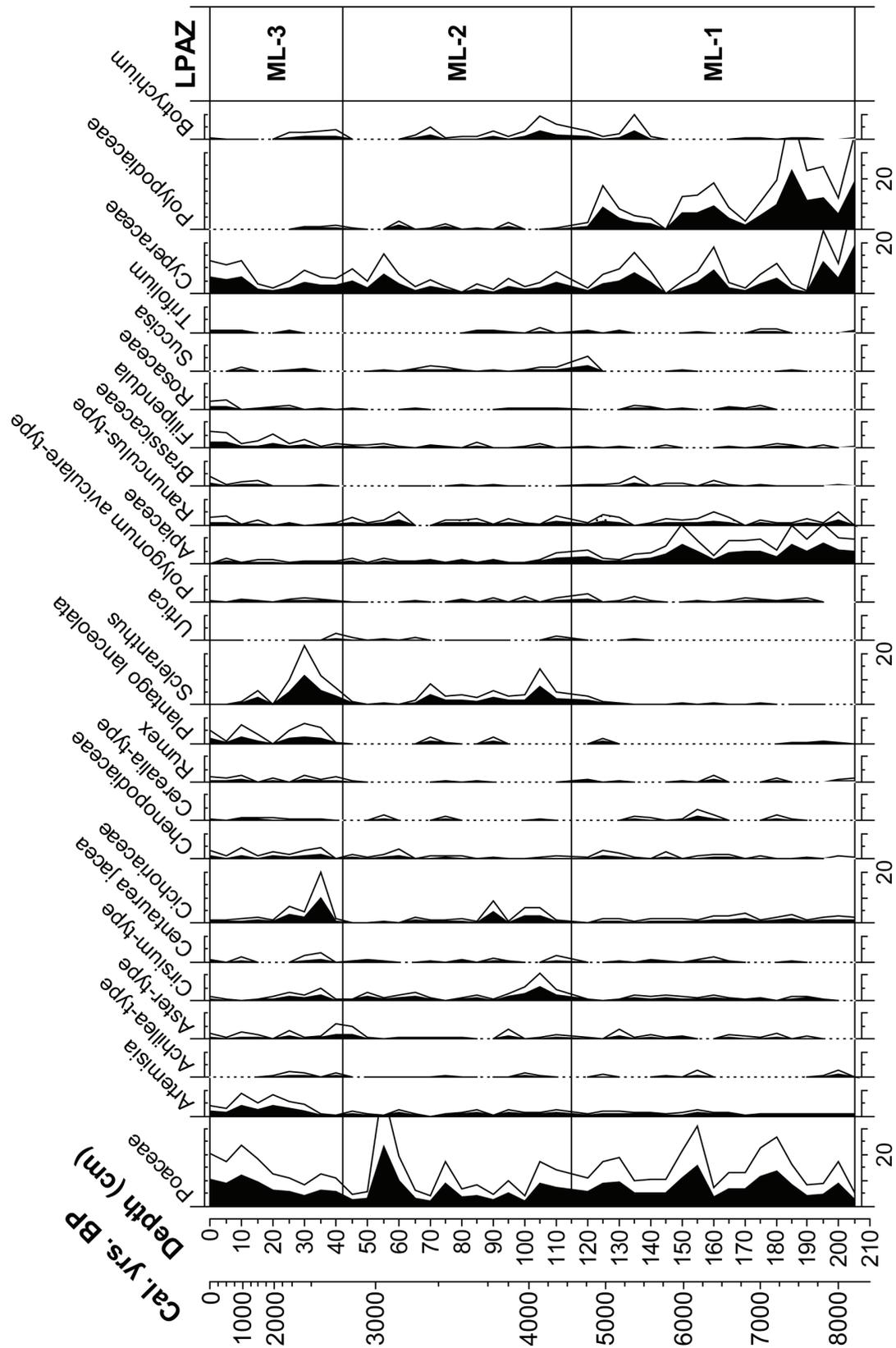


Figure 64. Percentage pollen diagram of Peat bog in the Maleshevska Mountain.

**Peat bog (Maleshevska Mt., 1720 m)
Percentage pollen diagram (continuation)**



Modified after Tonkov, Bozilova (1992a)

Figure 64. Continued.

limited the spread of *Abies* forests. Changes also occurred in the deciduous forests, facing lower participation of *Corylus*, *Ulmus*, *Carpinus betulus*, *Ostrya carpinifolia* and *Carpinus orientalis*. Quite

probably, the upper boundary of the oak belt has also descended, from where a narrow strip of *Fagus* began to form, or the distribution of beech was mosaic in places previously occupied by *Ab-*

ies and *Carpinus betulus*. Mixed coniferous-beech communities have already existed as *Fagus* was invading new areas due to its better growth and renewal opportunities. At the same time evidence of almost continuous presence of *Juglans* and *Castanea* appeared in the pollen record (pollen zone ML-2, Fig. 64).

Around 2800 cal. yrs. BP a heavy destruction of the woody vegetation has occurred, affecting both the deciduous and coniferous forests in the mountain. Undoubtedly, the reason was the anthropogenic factor, confirmed by the increased amount of pollen from plants such as *Scleranthus*, *Cichoriaceae*, *Polygonum aviculare*, *Urtica*. It is assumed that the peat bog was already situated above the upper timber-line.

The last period of vegetation history in the mountain is related to the formation of the modern belt differentiation. As a result of its rapid spread, *Fagus* has become the dominant tree species and has formed a belt between 1000 and 1700 m. The distribution of the beech forests ended the dominance of the conifers and has led to their restriction only in inaccessible places. On one hand, the cooling at the beginning of the Subatlantic proved to be conducive to beech, and on the other, the process of its rapid enlargement was aided by humans. Extensive areas were cleared for livestock breeding and the coniferous wood was preferred material for burning and construction activities. This is proved by the increasing participation of cultivated cereals and antropophytes such as *Plantago lanceolata*, *Rumex*, *Scleranthus* and other herbs. There was a noticeable decrease in the areas occupied by the oak forests, which have been used by the local people on easily accessible slopes. In their place, secondary communities of *Quercus pubescens* and *Carpinus orientalis* settled on eroded terrains (pollen zone ML-3, Fig. 64).

The location of the peat bog was already away from the beech forests, and grasslands spread over vast areas around it. In recent centuries, the local people started to exploit also the forests in the beech belt, which is nowadays in some places already thinned out and filled against erosion processes with artificial plantations of *Pinus sylvestris*.

7. VLAHINA MOUNTAIN

Physico-geographical characteristics and modern vegetation

Vlahina Mountain (peak Ogreyak, 1932 m) is part of the Osogovo-Belasitsa mountain range. It extends from north to south about 50 km and its width varies from 12 km north to 30 km south. A section of the state border between Bulgaria and the Republic of Northern Macedonia crosses the ridge. Most of the mountain area remains on Bulgarian territory. It is bordered on the northwest by the Osogovo Mountain (the Black Rock saddle, 930 m), on the south by the Maleshevska Mountain (the saddle Chetalo, 1619 m), and on the east and west by the valleys of the Struma and Bregalnitsa rivers. (Fig. 1) The ridge of the mountain is flattened, its slopes to the east sloping, and to the west steeper. The mountain is composed mainly of metamorphic rocks (gneisses, amphibolites) but also of metamagmatites, granites, limestones, marls, etc. (Zagorchev, 2001).

The mountain falls in the continental-mediterranean climate region. The average annual temperature is 11°C, the average temperature amplitude is 21°C, the average annual rainfall is 700 mm with a maximum in the autumn and a minimum in summer (Velev, 2010). Climatically, the mountain is characterized by approximately equal amounts of winter rainfall and summer rainfall, which tends to equalize the mediterranean with the continental climatic influence (Tishkov, 1976).

The predominant soils in the lower parts are leached cinnamon forest (Chromic Luvisols), followed by brown mountain forest soils (Distric Cambisols) and above the timber-line are distributed mountain meadow soils (Humic Umbrosols). The spread of shallow soils (Umbric Leptosols) is highly significant, and deluvial soils (Colluviosols) occur in some sections. As a result of active erosion processes regosols (Regosols) are also quite widespread (Ninov, 1997; Todorov et al., 2014).

According to the last geobotanical zoning Vlahina Mountain is included as a separate region

in the Western Bulgarian Border Mountain District of the Illyrian (Balkan) Province (Bondev, 2002) but due to the narrow morphographic connection to the south with the Maleshevska Mountain and the slight difference in their altitudes, the same vegetation belts are observed (Velchev, Tonkov, 1986; Bondev, 2002). The vegetation of each of the mountains has certain features that should be taken into account. For example, in the belt of the xerothermic oak forests, well distinct on the eastern and northeastern slopes of the Vlahina Mountain, there are no characteristic mediterranean species like *Quercus coccifera*. The communities of *Carpinus betulus* in the northern parts of the mountain are relatively compact. The beech forests also include *Betula pendula*, *Populus tremula*, *Abies alba*, *Pinus sylvestris*. Particularly characteristic are the mixed communities of beech with *Pinus nigra* preserved above the village of Gabra and below peak Momina Skala at 1200 m. Compared to the Maleshevska Mountain, the ridges are characterized by widespread distribution of fragments from the communities of *Chamaecytisus austriacus*, *Juniperus communis*, *Vaccinium myrtillus*, as well as of a number of high mountain species (Kitanov et al., 1986).

Study sites

Peat bog Kadiytza (site 23)

The peat bog is located at 1700 m near a small stream in a vast deforested area, above the beech forests, south of peak Kadiytza, at an area of about 150 m² (Fig. 2). The scarce tree vegetation is represented by separate groups or single trees of *Pinus sylvestris* and *Juniperus communis*. The bog vegetation is composed of *Carex echinata*, *Eriophorum latifolium*, *Bistorta major*, *Potentilla erecta*, *Geum montanum*, *Ranunculus montanus*, *Filipendula ulmaria*, *Veratrum album*, etc. (Tonkov, 1992).

Coring and lithology

The thickness of the peat layers varies between 40 and 80 cm, and at some places it reaches 100–120 cm. The core is 1.1 m long and was recovered with Dachnowsky hand-corer equipment. The

sediments consist of Cyperaceae peat mixed with vegetative plant remains. The attempts to obtain radiocarbon dates were not successful.

Pollen analysis

Pollen analysis was performed at 5 cm interval and a percentage pollen diagram is constructed (Fig. 65). On the pollen diagram two local pollen assemblage zones (LPAZ) are delimited (K-1 and K-2) which are correlated with the palynostratigraphy from the peat bog in the Maleshevska Mountain. Brief descriptions are as follows:

LPAZ K-1 (110–37 cm, *Pinus diploxylon-Abies-Fagus*)

Tree pollen dominates with 80%, contributed by *Pinus diploxylon* 62–68%, followed by *Abies* 20%, *Quercus*, *Corylus*, *Alnus* and *Juniperus* each with 2–7%. Pollen of *Juglans* and *Syringa* is also determined. From the herb pollen taxa could be mentioned Poaceae 2–8%, Cichoriaceae 4%, Apiaceae, *Scleranthus*, *Cirsium*-type, etc. The anthropogenic pollen taxa like *Cereal*-type, *Plantago lanceolata*, *Rumex* are present sporadically. The curve of Polyodiaceae reaches 10%.

LPAZ K-2 (37–0 cm, *Fagus-Pinus diploxylon-NAP*)

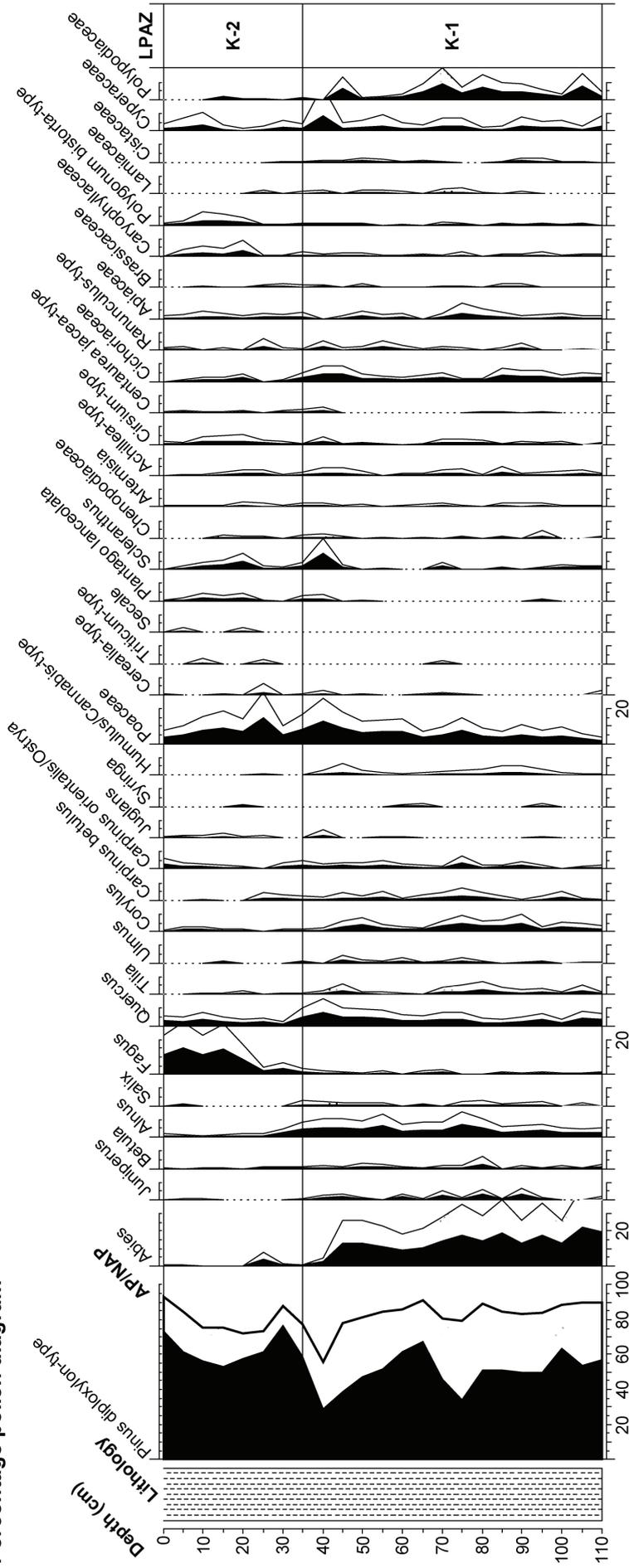
Total herb pollen is present with 25%, contributed by Poaceae 10%, *Scleranthus* 5%, Cichoriaceae 3%, *Plantago lanceolata*, Cichoriaceae, etc. Arboreal pollen taxa participate with low values with the exception of *Pinus diploxylon*-type 60–75%. The pollen curve of *Fagus* reaches 15%. Pollen of *Juglans* is recorded in all samples. Spores of Polyodiaceae are sporadically found.

Swamp Obel (site 24)

This small swamp with a triangular shape is located near the village of Obel (41°58'07.36"N, 22°55'32.21"E) at 950 m on the right side of the road Blagoevgrad-Delchevo and occupies an area of 0.35 ha (Fig. 2, Fig. 66). It is fed by a spring and condensation waters from the surrounding hills. In the direction of the nearby neighborhood Klisura it is surrounded by arable land, and to the east and north it borders with coppice woods of *Quercus pubescens*, *Quercus cerris* and *Carpinus betulus*. In their composition are found also *Fagus*

Peat bog KADIY TSA (Vlahina Mt., 1700 m)

Percentage pollen diagram



Modified after Tonkov (1992)

Figure 65. Percentage pollen diagram of Peat bog Kadiyt sa.



Figure 66. A view of Swamp Obel (Photo S. Tonkov)

sylvatica, *Carpinus orientalis*, *Acer platanoides*, *Acer campestre*. The vegetation of the swamp and around it is represented by *Potamogeton natans*, *Sparganium erectum*, *Iris pseudacorus*, *Alisma plantago-aquatica*, *Heleocharis palustris*, *Mentha aquatica*, *Galium palustre*, *Lythrum salicaria*, *Gratiola officinalis*, *Potentilla reptans*, *Prunella vulgaris*, etc. (Tonkov, 1992).

Coring and lithology

The sediment core is 1.1 m long and was recovered with Dachnowsky hand-corer equipment from the peripheral western part of the swamp at water depth of 0.5 m. The sediment is clay. The attempts to obtain radiocarbon dates were not successful.

Pollen analysis

Pollen analysis was performed at 5-10 cm interval and a percentage pollen diagram is constructed (Fig. 67). On the pollen diagram three local pollen assemblage zones (LPAZ) are delimited (Ob-1 to Ob-3). Brief descriptions are as follows:

LPAZ Ob-1 (110-72 cm, *Pinus diploxylon-Quercus*)

Tree pollen dominates with 75-90%, contributed by *Pinus diploxylon*-type 80-40%, followed by *Quercus* 10-15%, *Salix* 5% (with a short peak of 21% at level 75 cm), small quantities of pollen from *Juniperus*, *Alnus*, *Fagus*, *Corylus* and traces of *Acer*, *Carpinus betulus*, *Juglans* and *Vitis* pollen. The herb pollen taxa are represented by Poaceae 10%, *Polygonum aviculare*-type 5%, Cichoriaceae, *Achillea*-type and Chenopodiaceae each below 5%, *Scleranthus*, Brassicaceae, etc. The hygrophytes and hydrophytes are represented by Cyperaceae, *Typha/Sparganium*-type, *Typha latifolia* 10%, *Lemna* 8%.

LPAZ Ob-2 (72-42 cm, *Pinus diploxylon-NAP-Quercus*)

This zone is characterized by a high abundance of herb pollen taxa such as Poaceae with a maximum of 35% (level 45 cm), Cichoriaceae 5%, Chenopodiaceae 5%, Brassicaceae, including a number of anthropogenic taxa (*Cerealia*-type, *Triticum*-type, *Centaurea cyanus*, *Plantago lanceolata*, *Urtica*). Tree pollen is represented by *Pinus diploxylon*-type up to 60% with a steep decline at the transition to the next zone, *Quercus* with minimal

Swamp OBEL (Vlahina Mt., 990 m)

Percentage pollen diagram

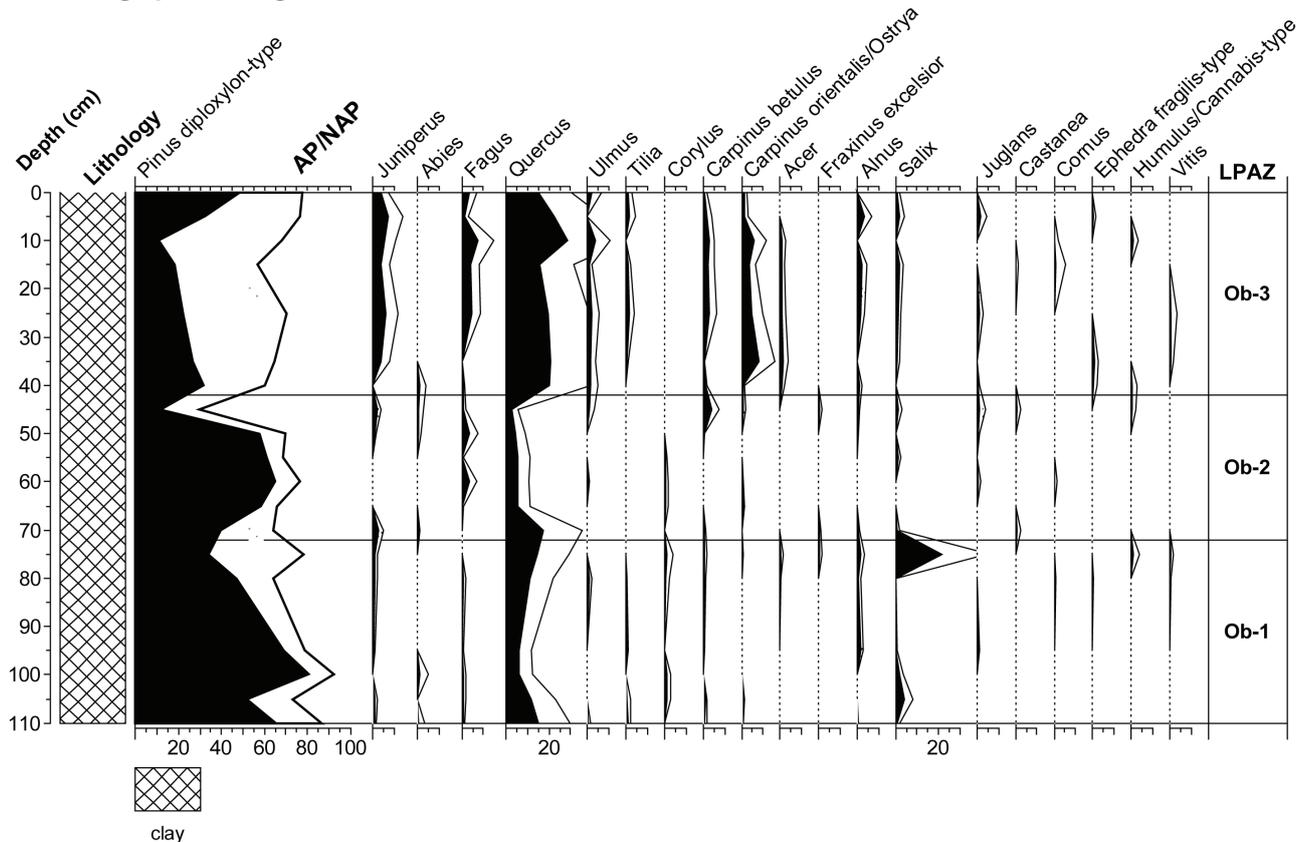


Figure 67. Percentage pollen diagram of Swamp Obel.

values of 5–7%, the appearance of continuous pollen curves of *Juniperus*, *Fagus*, *Ulmus*, *Carpinus betulus*, *Carpinus orientalis/Ostrya*. Finds of *Juglans* pollen are regular. Pollen of *Lemna*, *Typha latifolia*, *Alisma* and *Iris* is also determined.

LPAZ Ob-3 (42–0 cm, *Quercus-Fagus-Carpinus*)

The transition to the last zone is clearly marked by decline of the total tree pollen to 30%. Subsequently, the participation of tree taxa increases again, contributed by *Quercus* up to 27%, *Juniperus* 6%, *Carpinus orientalis/Ostrya* 7%, *Carpinus betulus* 4%, *Ulmus*, *Alnus* and *Salix* each with 4%. In the uppermost samples pollen of *Fagus* reaches 7% and *Pinus diploxylon*-type 20–25%. Among the herb pollen taxa a steady presence for pollen of Poaceae 7–10%, Chenopodiaceae 5%, Cichoriaceae 5%, *Achillea*-type 3% is recorded. Notable is the continuous participation of pollen of *Triticum*-type, *Polygonum aviculare*-type, *Rumex* and *Scleranthus*. The hygrophytes and hydrophytes

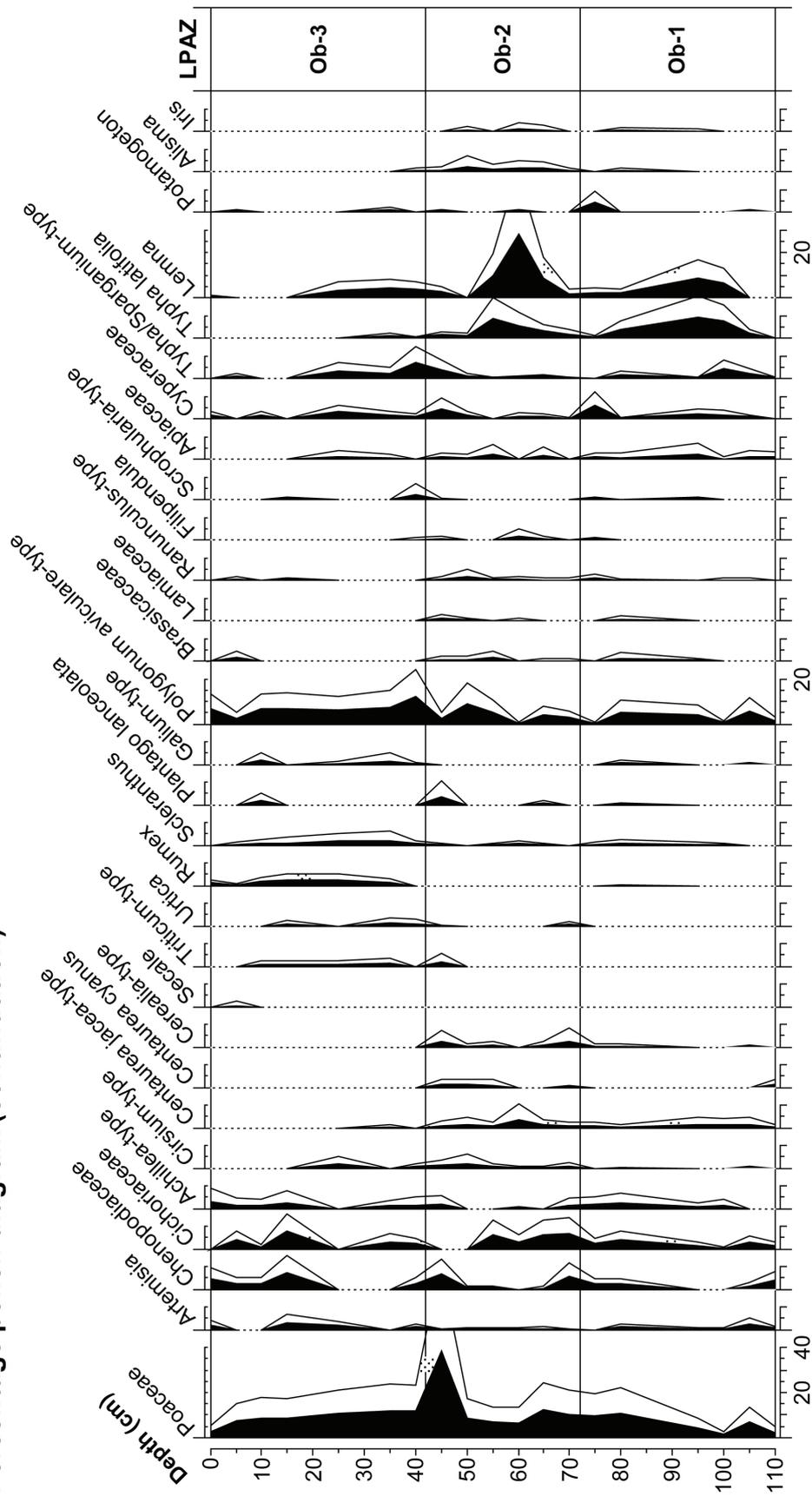
are represented by pollen of Cyperaceae, *Typha/Sparganium*-type, *Lemna* and *Potamogeton*.

Vegetation history in the Vlahina Mountain

The age of the bottom part of the core from Peat bog Kadiytza is provisionally estimated at c. 4700 cal. yrs. BP (pollen zone K-1, Fig. 65) when compared with the core from the Maleshevska Mountain (pollen zone ML-2, Fig. 64). The time when the sedimentation in the Swamp Obel has started is difficult to determine but the palynostratigraphy suggests that most probably the core spans the last c. 2000–1500 years.

Several thousands years ago in the southern high part of the Vlahina Mountain coniferous forests of *Pinus* and *Abies* were distributed. Large areas were occupied by monodominant or mixed communities of *Abies* in which the herb layer was composed of shade-tolerant species including

Swamp OBEL (Vlahina Mt., 990 m)
Percentage pollen diagram (continuation)



Modified after Tonkov (1992)

Figure 67. Continued.

ferns. In the oak forests below the coniferous belt were found *Tilia*, *Corylus*, *Carpinus orientalis* and *Ostrya carpiniifolia*. Small groups or populations

of *Fagus* and *Carpinus betulus* were distributed in places between the oak and the coniferous forest belts. The relatively high percentage of

Alnus pollen could be explained by the presence of groups near streams. The herb communities occupied small areas and were composed mainly of Poaceae, Apiaceae, Cichoriaceae, Lamiaceae, Asteraceae and Ranunculaceae species.

Around 2800 cal. yrs. BP a substantial change in the forest cover has occurred, characterized by the nearly complete disappearance of *Abies* and the enlargement of the areas occupied by *Pinus*. The expansion of *Fagus* was preceded by a short-term increase of herbs (pollen zone K-2, Fig. 65).

The next period of vegetation development in the Vlahina Mountain marked the widespread distribution of beech forests in place of the conifers. As a result, only separate groups of pines (*Pinus sylvestris* and *Pinus nigra*) were preserved inside the beech forest belt or above it.

At lower altitudes the destructions in the oak forest belt have resulted in the rise of the total herb pollen and the significant presence and increase of the anthropogenic pollen taxa such as *Triticum*-type, *Cerealia*-type, *Secale*, *Plantago lanceolata*, *Rumex*, *Polygonum aviculare*, Cichoriaceae, Chenopodiaceae. The pollen diagram from Swamp Obel manifests a period of human occupation in the area (pollen zone Ob-2, Fig. 67), characterized by cultivation of crops, walnut and sweet chestnut, animal husbandry and exploitation of the forest resources for diverse uses. Later on, the arable land around the swamp was abandoned and gradually colonized by various herbs and junipers, while beech has enlarged its areas. Also, a partial restoration of the oak forests with lime, elm and hornbeam has taken place.

In recent centuries, as a result of the permanent settlement in these lands and the diverse human activities, the natural vegetation in all belts was destroyed and replaced in many places by secondary shrub or herb plant communities.

It should be noted that the palynological studies in the Maleshevska and Vlahina mountains are the most convincing evidence for the widespread of coniferous forests in the distant past west of the Struma river. The dynamic processes in this montane region were not prolonged and the modern vegetation belt differentiation was formed also under the influence of human activity.

8. BELASITSA MOUNTAIN

Physico-geographical characteristics and modern vegetation

Belasitsa Mountain (peak Radomir, 2029 m) is the southernmost part of the Osogovo-Belasitsa mountain range located in the southwestern corner of the country, south of the Strumeshnitsa river valley. The territory of the mountain is divided among three countries: Bulgaria, Greece and the Republic of Northern Macedonia. It extends from the Rupel gorge in the east to the Kosturinska saddle in the west about 60 km in length. On the territory of Bulgaria are located about 30% of its area, the northern slopes, and the length of this section is 33 km with an average width of 4–5 km (Fig. 1). The mountain was formed as a separate orographic unit, a linear horst, as a result of block-fractured tectonic movements during the Tertiary. The adjacent fields sank deep and the mountain rose as a block, extended east-west between two parallel faults. It is made up of amphibolites, shists, granites, gneisses, etc. The erosion along the northern faulty slope of the mountain has attracted abundant sediment at the foot of the slope where extensive sediment cones have accumulated, arranged in a continuous plume from Petrich to Strumitsa. The highest parts of the sedimentary cones are made up of large rock blocks mixed with coarse gravel and sand. Smaller materials are located below, and the finer particles build the lowest parts of the cones, from which many springs come (Galabov et al., 1977; Nikolov, Yordanova, 2002).

The climate in the region is continental-mediterranean and is characterized by mild winters but with frequent and sometimes heavy rainfall, and hot dry summers. The average annual temperature is 13.9°C and decreases to 3°C with increasing altitude. The average January temperatures change from 1°C in the low parts to -6°C in the highlands, and the average July temperatures from 21°C to 11°C, respectively. The average annual precipitation is 676 mm and depending on the altitude it varies from 600–700 mm at the foot of the mountain to 900 mm in the

high parts. Their distribution is characterized by autumn-winter maximum and summer minimum (Koleva, Peneva, 1990; Velev, 2010).

The leached cinnamon forest soils (Chromic Cambisols) occur on the lower slopes and above 800 m up to the ridge they change to brown forest soils (Cambisols) with a thin humus horizon (Ninov, 1997).

According to the last geobotanical zoning Belasitsa Mountain is included as a separate district of the Macedonian-Thracian Province (Bondev, 2002). The forested area of the Bulgarian part of the mountain is c. 10000 ha. The prevailing territory of this area is covered by native broadleaf forests (74.5 %) while the rest of it is forest plantations (25.5%). The most widespread tree species are *Fagus sylvatica* (48.3% from the total forested area) and *Castanea sativa* (13.1%), followed by *Pinus sylvestris* (6.8%) and *Pinus nigra* (5.9%) (Velichkov et al., 2010). The present vegetation on Bulgarian territory is distributed in several vertical belts. The lowermost xerothermic oak belt (up to 300–400 m) is fragmented, composed of *Quercus pubescens*, *Quercus frainetto*, *Juniperus oxycedrus*, *Paliurus spina-christi*. Along small riverlets and brooks are found communities of *Platanus orientalis*. The belt of mesophilous and xeromesophilous oak and hornbeam forests (300/400–800/900 m) is characterized by the dominance of communities of *Castanea sativa*. In their composition are growing also *Fraxinus ornus*, *Platanus orientalis*, *Ostrya carpinifolia*, *Colutea arborescens*, *Coronilla emerus*, etc. The beech forest belt (800/900–1700 m) is very well developed, formed mainly by monodominant communities of *Fagus sylvatica*. On small areas are growing *Abies borisii-regis* and *Betula pendula*. *Taxus baccata* and *Ilex aquifolium* are also found. Nowadays beech shapes the upper timber-line as a coniferous belt is lacking. Above the beech forests follows a belt of shrubby and herb vegetation composed of *Juniperus communis*, *Vaccinium myrtillus*, *Bruckenthalia spiculifolia*, *Chamaecytisus absinthioides*, *Nardus stricta*, *Festuca vallida*, etc. In the lower part of this belt are growing isolated trees of *Pinus sylvestris*. Overall, the vegetation is highly influenced by the anthropogenic activity, particularly the oak and hornbeam forests, and the

communities of sweet chestnut as well (Velchev, Tonkov, 1986; Bondev, 1991).

The southern slopes on Greek territory are deforested to a great extent. Up to 1000 m are found *Quercus coccifera*, *Phyllirea latifolia*, *Pistacia terebinthus*, *Quercus dalechampii*, *Quercus pubescens*, *Carpinus orientalis*, and in the northeastern parts *Castanea sativa*. In the eastern part of the beech forests, between 1150 and 1300 m, are growing groups of *Abies borisii-regis* (Stojanov, 1921; Athanasiadis et al., 2000, 2003).

Study sites

Mire Gyola (site 25)

This small mire, named Gyola, is located at 714 m (41°21'17.12"N, 23°07'31.31" E) in the center of the Bulgarian part of the mountain, southwards from the village of Kolarovo (Fig. 2). The mire occupies 0.1 ha within a forest of *Castanea sativa* with some admixture of *Fagus sylvatica*, *Ostrya carpinifolia*, *Coryllus avellana*, *Carpinus orientalis*, *Juglans regia*, *Alnus glutinosa*, *Quercus dalechampii* and *Fraxinus ornus*. Planted stands of *Pinus sylvestris* and *Pinus nigra* are also found nearby. The shores of the mire are overgrown by *Carex* sp., *Alisma plantago-aquatica*, *Equisetum arvense*, *Lysimachia vulgaris*, *Pteridium aquilinum*, *Dryopteris filix-mas*, *Aegopodium podagraria*, *Plantago major*, *Poa nemoralis*, *Brachypodium sylvaticum*, etc. (Tonkov et al., 2012; Tonkov, Possnert, 2014) (Fig. 68).

Coring, lithology and radiocarbon dating

A sediment core 2.1 m long was obtained from the peripheral part of the mire at water depth of 30 cm with Dachnowsky hand-corer equipment. The lithology of the sediments is: 0–80 cm yellow-brown clay with sand, 80–140 cm grey clay with sand, 140–210 cm yellow-brown clay with sand. The radiocarbon age of 4 samples of bulk sediment was determined and the results are shown on Table 19. The age of the bottom part of the core is estimated at c. 8500 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 5–10 cm interval and a percentage pollen diagram is constructed

Table 19. Radiocarbon dates from Mire Gyola and Peat bog Belasitsa-1.

Lab. code	Depth (cm)	¹⁴ C age (BP)	¹⁴ C age cal. BP, ±2σ (mid-point)	Calibration (yrs. BC/AD)	Material dated
Mire Gyola					
Ua-43943	30-35	507±30	630-500 (565)	1320-1450 AD (1385)	clay with sand
Ua-41527	120-126	1474±30	1410-1300 (1355)	560-650 AD (605)	clay with sand
Ua-43944	148-153	3277±30	3580-3410 (3495)	1610-1420 BC (1515)	clay with sand
Ua-41249	176-190	7099±44	8010-7840 (7925)	6060-5890 BC (5975)	clay with sand
Belasitsa-1					
INRNE-112	50-70	1850±50	1900-1620 (1760)	50-330 AD (190)	peat with sand

(Fig. 69). On the pollen diagram four local pollen assemblage zones (LPAZ) are delimited (BL-1 to BL-4) (Fig. 57). Brief descriptions are as follows:

LPAZ BL-1 (210-172 cm, *Artemisia*-*Castanea*-*Poaceae*) (~8500-5000 cal. yrs. BP)

The dominant pollen type is *Artemisia* with 45-70%, followed by *Castanea* 15%, *Poaceae* 12%, *Alnus* 7% and *Quercus robur*-type 4%. Pollen of *Juglans* is present in all samples. Low percentages are recorded for *Fagus*, *Quercus cerris*-type, *Pinus diploxylon*-type, *Carpinus orientalis*/*Ostrya* and various herbs.

LPAZ BL-2 (172-130 cm, *Castanea*-*Artemisia*-*Pinus diploxylon*-*Poaceae*) (5000-2000 cal. yrs. BP)

The pollen curve of *Castanea* rises to 50%, while *Artemisia* declines to 10%. Other pollen taxa which could be mentioned are *Pinus diploxylon*-type 10%, *Poaceae* 15%, *Alnus* 7%, *Cichoriaceae*, *Chenopodiaceae*, *Polygonum aviculare*-type and *Dianthus*-type each below 5%.

LPAZ BL-3 (130-42 cm, *Castanea*-*Pinus diploxylon*-*Poaceae*) (2000-650 cal. yrs. BP)

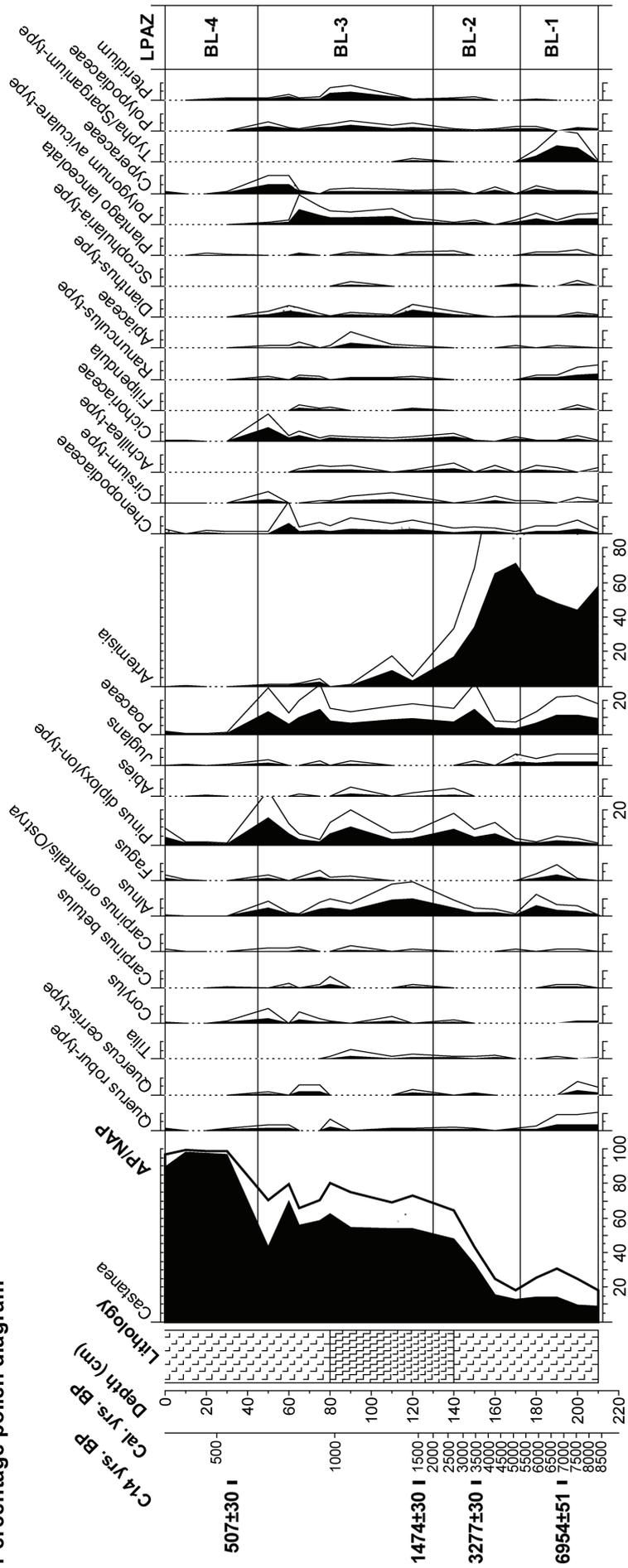
Pollen of *Castanea* continues to dominate with 50-60%, accompanied by *Pinus diploxylon*-type 10-15%, *Alnus* 10-5%, minor quantities of *Fagus*, *Abies*, *Corylus*, *Carpinus* and *Juglans* pollen. The herb pollen taxa are represented by *Poaceae* 15%, *Artemisia* 8%, *Polygonum aviculare*-type 7%, *Cichoriaceae* 6%, *Apiaceae*, *Plantago lanceolata*,



Figure 68. A view of Mire Gyola (Photo S. Tonkov).

Mire GYOLA (Belasitsa Mt., 714 m)

Percentage pollen diagram



Modified after Tonkov, Possnert (2014)

Figure 69. Percentage pollen diagram of Mire Gyola.

etc. Pollen of Cyperaceae 5%, spores of Polypodiaceae 3% and *Pteridium* 4% are determined.

LPAZ BL-4 (42-0 cm, *Castanea-Fagus*) (650 cal. yrs. BP-till present)

Pollen of *Castanea* dominates with 95% in the uppermost samples, accompanied by other tree and herb pollen taxa with rather low values such as *Fagus*, *Pinus diploxylon*-type, Poaceae, Cichoriaceae, Chenopodiaceae, *Plantago lanceolata*.

Peat bog Belasitsa-1 (site 26)

This small peat bog is located on a north-facing slope, above the timber-line, at 1640 m (41°20'08.82"N, 23°00'15.18"E) nearby a small spring (Fig. 2). The bog vegetation is represented by *Festuca nigrescens*, *Nardus stricta*, *Deschampsia caespitosa*, *Eriophorum latifolium*, *Juncus effusus*, *Ranunculus montanus*, *Cirsium appendiculatum*, *Caltha palustris*, etc. (Panovska et al., 1990).

Coring, lithology and radiocarbon dating

A sediment core 0.9 m long was obtained with Dachnowsky hand-corer equipment. The lithology of the sediments is: 0-10 cm peat, 10-80 cm peat with sand, 80-90 cm sand. The radiocarbon age of one sample of bulk sediment was determined and the result is shown on Table 19. The age of the bottom part of the core is provisionally estimated at c. 2500 cal. yrs. BP.

Pollen analysis

Pollen analysis was performed at 10 cm interval and a percentage pollen diagram is constructed (Fig. 70). On the pollen diagram three local pollen assemblage zones (LPAZ) are delimited (BLa-1 to BLa-3). Brief descriptions are as follows:

LPAZ BLa-1 (90-67 cm, *Fagus-Pinus diploxylon*-Poaceae) (~2500-2000 cal. yrs. BP)

The dominant tree pollen taxa are *Fagus* 10-20% and *Pinus diploxylon*-type 14-18%, accompanied by *Quercus*, *Carpinus orientalis*/*Ostrya*, *Alnus* and *Tilia* each with 2-4%. Pollen of *Castanea* is sporadically found. The herb pollen taxa are represented by Poaceae 12-20%, *Rumex* 10-20%, Cichoriaceae 8%, *Plantago lanceolata* up to 20%, *Scleranthus* 5-7%.

LPAZ BLa-2 (67-25 cm, *Fagus-Castanea*-Poaceae) (~2000-700 cal. yrs. BP)

The pollen curve of *Fagus* retains values of 15-12%, while *Pinus diploxylon*-type is below 10%. The pollen curves of *Juniperus* and *Castanea* appear with 1-3% each. The other tree taxa demonstrate no changes in their pollen frequencies. The presence of *Bruckenthalia* pollen with 10-12% is considered as a local effect. The participation of Poaceae rises to 30-35%. Pollen of *Triticum*-type, *Rumex*, *Plantago lanceolata*, Ranunculaceae, Cichoriaceae, Fabaceae is determined. Pollen of Cyperaceae reaches 20%.

LPAZ BLa-3 (25-0 cm, *Fagus*-Poaceae-*Castanea*) (700 cal. yrs. BP-till present)

The pollen curve of *Fagus* slightly decreases, accompanied by a rise for Poaceae, *Juniperus*, *Achillea*-type, Ranunculaceae, Cyperaceae pollen. No changes are recorded for the participation of *Castanea* pollen.

Vegetation history in the Belasitsa Mountain

The information from the pollen diagram of Mire Gyola is rather valuable as it reveals the dynamics in the vegetation cover on the northern slopes of the mountain at low altitudes for the last 8500 years. Of particular interest is the history of *Castanea sativa* because this is the first long record from Bulgaria which throws light on the ongoing discussion about the spontaneous or anthropogenic origin of sweet chestnut in the country. During the first stage of vegetation development (pollen zone BL-1, Fig. 69) which has started more than 8000 years ago the main tree at the elevation of the study site was sweet chestnut. It was accompanied by *Quercus*, *Carpinus orientalis*, *Ostrya carpinifolia*, *Carpinus betulus*, *Tilia*, some *Juglans*, *Fagus* and *Alnus* on wetter places. This deciduous forest was rather sparse and on drier places with lower soil humidity thrived various herb species from Cichoriaceae, Chenopodiaceae, Brassicaceae, Asteraceae (*Artemisia*, *Cirsium*, *Achillea*). Among them *Artemisia* dominated over large areas. Pines were distributed at higher altitudes compared to other tree species. For this period archaeobotanical data are lacking to indicate if the Neolithic people in the region had introduced

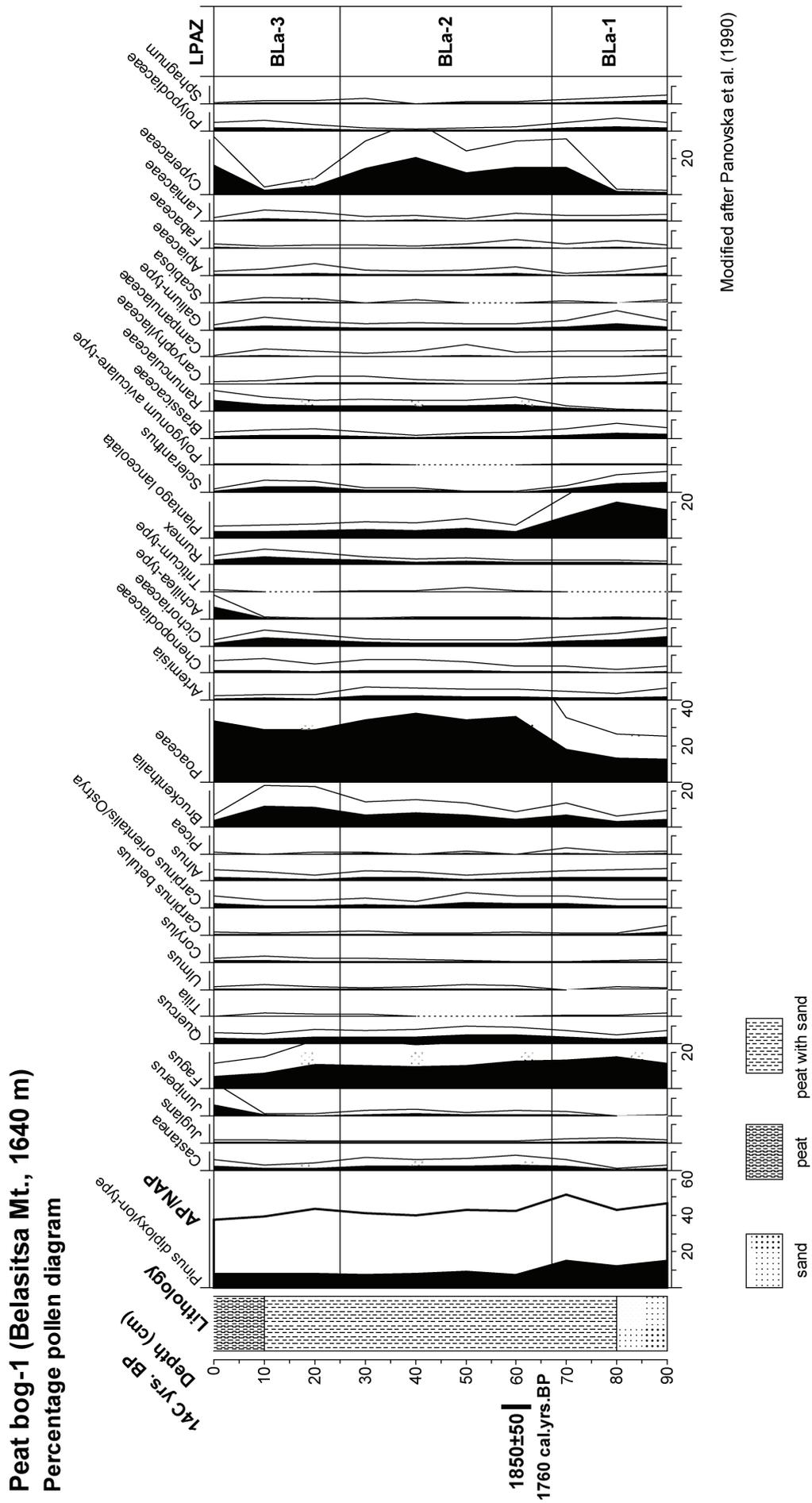


Figure 70. Percentage pollen diagram of Peat bog Belasitsa-1.

sweet chestnut for cultivation. The palynological evidence confirms that by that time *Castanea sativa* was spontaneously growing alone or in mixtures with other deciduous trees on the northern slopes of the mountain.

The review of Krebs et al. (2004) presented an attempt to develop a *Castanea* refugium probability index on the localization of sweet chestnut refugia in Europe and its subsequent migration through the Holocene based on paleobotanical data (an extended palynological approach and macro-remains). One of the main conclusions was the identification of Southeastern and Southwestern Bulgaria as potential medium-probability refugia territories that required further studies. The main argument for Southwestern Bulgaria was the appearance of a minimal amount of pollen (0.5-1%) after 7500 cal. yrs. BP. The new palynological evidence from Mire Gyola effectively supports this hypothesis and quite probably this area has sheltered sweet chestnut in postglacial time.

A later study on this topic, using a palaeo-distribution modelling approach on an European scale for two crucial periods, i.e. Last Glacial Maximum and mid Holocene (Roces-Díaz et al., 2018), has detected for the LGM potential refugia on the three large Mediterranean peninsulas (Balkan, Italian and Iberian), along the Atlantic coast of France and Spain, and along the southern coast of the Black Sea. This distribution was validated by fossil records, and is also in agreement with genetic analyses of the species. The results also suggest a postglacial expansion of *Castanea sativa* in the mid-Holocene, when climatic conditions were more favorable for it than current climatic conditions in Europe. So that, some of the isolated populations in Southern Central Europe and on the Mediterranean peninsulas could represent current refugia from the Holocene expansion. However, the later influence of humans also has to be considered.

A similar conclusion can also be assumed for the distribution of *Juglans*. Walnut is considered as a native tree species to some regions of Bulgaria, like in the northwestern montane part of the country, where this tree grows on rocky, sandy terrains, far away from the villages (Velchev, 1971).

The nearest to Belasitsa Mountain palynological site studied is the peat bog in the Maleshevska Mountain located above the present timber-line. On the relevant pollen diagram the appearance of *Castanea* and *Juglans* is synchronous, c. 4800 cal. yrs. BP (Fig. 64), or 3500 years later compared to the pollen diagram from Mire Gyola, which presumes also anthropogenic influence. This result corresponds well to the existence of Early Bronze age settlements in the valley of the Struma river (Marinova et al., 2012).

The beginning of the next stage of dynamic changes in the forest cover of the Belasitsa Mountain (pollen zone BL-2, Fig. 69), following the radiocarbon chronology, can be defined c. 5000 cal. yrs. BP. First of all, it was characterized by a sharp reduction of the areas occupied by *Artemisia* and some of the other herbs. The participation of *Castanea*, *Pinus*, *Alnus*, and *Tilia* has increased and the presence of *Abies* was also recorded. These changes suggest a rise in air and soil humidity which had a favorable effect on the spread and enlargement of the forest cover. Subsequently, during the time of the Roman rule (pollen zone BL-3, Fig. 69), the cultivation of sweet chestnut was widely practiced as its valuable fruits and timber were used for various purposes. On the pollen diagram the participation of plants considered as indicators for anthropogenic disturbance in the forest cover such as *Chenopodiaceae*, *Polygonum aviculare*, *Cirsium* and *Cichoriaceae* increases.

The palynological information from Peat bog Belasitsa-1 situated above the present timber-line, reveals the vegetation dynamics at higher altitudes in the last c. 2500 years (Fig. 70). Low quantities of *Castanea* pollen, evidently air-transported upslope, are present in the fossil record. After IInd-IIIrd cent. AD the participation of *Castanea* pollen increased, which could be explained by the intensification of the agricultural activity of the local people. By that time, at high altitudes, on the place of the deforested coniferous and partly beech forests, spread groups of *Juniperus* and various herbs (pollen zone BLa-2, Fig. 70). Quite probably, the enlargement of the forest vegetation at 400-800 m on the northern slopes of the mountain, dominated nowadays by the commu-

nities of *Castanea sativa*, has started in historical times. As found for Northern Greece, the spread of *Juglans*, *Castanea* and *Platanus* was associated with human economic activity since 1200 yrs. BC, and especially during the Roman rule in these lands (Bottema, 1980, 2000).

The final stage of the forest development spans the last 5–6 centuries (pollen zone BL-4, Fig. 69). It was characterized by the widespread of *Castanea sativa* and a slight increase for *Fagus* communities. Pines, most probably *Pinus sylvestris*, declined considerably while the presence of *Carpinus orientalis* and *Corylus* indicated periodical openings of the forest canopy. Beyond doubt, this was the time of the strongest anthropogenic impact on the natural forest cover in the mountain.

More detailed palynological and paleoecological information on the changes in the vegetation cover after 650 cal. yrs. BP (XIVth cent. AD) on the southern slopes of Belasitsa Mountain is presented by Athanasidis et al. (2003). Between 650 and 450 cal. yrs. BP the tree vegetation was already severely restricted in its distribution. Above 1400 m fragments of *Pinus* communities were still found, while *Fagus* and *Abies* were represented by separate stands. From 460 to 260 cal. yrs. BP (XVIth–XVIIIth cent. AD) as a result of increasing human intervention, much of the communities of *Pinus* were destroyed, with a subsequent decrease of the upper timber-line. In the course of the above time interval there has been a short-term expansion of the areas occupied by *Fagus*, which can be explained by both human activity and the climatic conditions during the Little Ice Age. A similar late maximum in the spread of *Fagus* was also established for several Greek mountains bordering with the Republic of Northern Macedonia (Gerasimidis, Athanasiadis, 1995). Subsequently, a profound decline in the distribution of the forest vegetation was recorded as anthropogenic interventions took place in all vegetation belts and deforested areas were colonized by herb vegetation. Regarding *Castanea sativa*, which grows nowadays in the northeastern Greek part of the Belasitsa Mountain, this tree started slightly to increase its area as oak forests declined (Athanasiadis et al., 2003).

9. ANTHROPOGENIC IMPACT ON THE NATURAL VEGETATION

The natural vegetation of Bulgaria was significantly influenced by the millennial diverse human activity at many places. One of the important issues in considering the impact of Man on vegetation in the past is related to the establishment of agriculture, the practice of animal husbandry and the acquisition of plant material for various purposes, which has started c. 8000 years ago in Southwestern Bulgaria. To establish the nature of this activity and the degree of anthropopression a basic role is attributed to paleobotanical research, including study of plant remains from archaeological sites, or plant materials used for radiocarbon dating, and especially to pollen analysis to infer the past vegetation cover. Pollen analysis is also one of the powerful tools to reconstruct climate change and thus provides crucial evidence on the impact of climate on human cultures.

The palynological archives provide information on the livelihood of the people during the different historical epochs on regional scale. The comparison of these data with paleoethnobotanical evidence from archaeological sites presents a reliable picture of the land use, but also of the anthropogenic impact on the natural vegetation. Pollen grains from cultivated cereals such as *Cerealia*-type, *Triticum*-type, *Hordeum*-type, *Avena*-type and *Secale* can be considered as „primary anthropogenic indicators“ for agricultural activity. Their appearance in the pollen diagrams is an indication for cereal crop cultivation in the landscape, accordingly, in the qualitative and quantitative composition of the flora in general. Another group of pollen taxa, which reflect a long lasting presence of human impact like ruderalization, animal husbandry, etc. on the landscape and are specific for a given area are considered as “secondary anthropogenic indicators“ (Behre, 1981; Faegri, Iversen, 1989).

The methodological approach for the selection of pollen taxa as anthropogenic indicators from pollen diagrams for Central Europe, the

Mediterranean and Greece, in the assessment of human activity has been discussed in detail (Behre, 1981, 1988; Bottema, 1982; Bottema, Woldring, 1990, Brun 2011). To a large extent, the views of the above authors on „primary“ and „secondary anthropogenic indicators“ can be accepted for pollen diagrams from Bulgaria (Marinova et al 2012). For our study region, a specific group of “secondary indicators” was defined (*Plantago lanceolata*, *Rumex*, *Scleranthus*, *Urtica*, *Polygonum aviculare*, *Juniperus*) (Bozilova, Tonkov, 1990). Quite often, considering the overall anthropogenic signals in the pollen assemblages, also pollen from Poaceae, *Artemisia*, Chenopodiaceae, and Cihoriaceae can be included in this group, indicating opening of the woody vegetation by human activities (Bottema, Woldring, 1990). Even Iversen (1947) pointed out that a sharp change in the arboreal/herb pollen ratio in favor of herb taxa can be considered as an indication of anthropogenic interference with natural vegetation. On the other hand, such a change in this ratio can also be caused by climate change especially in the first half of the Holocene.

Anthropogenic changes in vegetation can also be correlated with the charred particles that occur together with pollen grains in the studied sediments. The increased concentration of charcoal particles is considered evidence of natural or Man-made fires. The absolute number of micro-charcoal particles counted on pollen slides is commonly used by paleoecologists to study the occurrence of past fires and their effects on ecosystems (Tinner, Hu, 2003). The relationship between the number of charred particles and the frequency of fires is complex, but it can be assumed that the latter is in general connected to the maxima of charred particles and fragments of subfossil wood in sediments (Tolonen, 1986).

In interpreting the palynological data of the anthropogenic impact on vegetation, the available archaeological information for the respective study area is essential. The territory of Southwestern Bulgaria is of special interest for studies on this topic as its natural vegetation has been influenced by anthropogenic activity since at least 8000 years ago, starting with the introduction

of Neolithic farming and continuously increasing through millennia of human occupation.

The development of the praehistorical cultures in Southwestern Bulgaria, and particularly along the Struma river valley, is a key question in Balkan praehistory. The direct territorial connection of this region with the northern Aegean coast, and from there with Anatolia, has influenced the specific dynamics of cultural changes through all praehistorical periods (Pernicheva, 1995; Nikolov, 2007). According to archaeological research, the neolithization in Southwestern Bulgaria is an early phenomenon (Todorova et al., 2007) and it delineates the boundary between hunter-gatherer societies and the more developed societies of early farmers and pastoralists. An important aspect of the Neolithic was the cultivation of plants and breeding of animals, which in turn has caused lasting and significant changes in the surrounding vegetation.

The transition from appropriating to productive economy took place outside Europe, on the territory of the „fertile crescent“ - Palestine, Zagros, Mesopotamia (Zohary et al., 2012). At the end of the 8th millennium BC the Neolithic was already fully developed as the beginning of the cultivation of cereals by selection from the wild growing ones in the region has begun between 10500 and 9250 ¹⁴C yrs. BP (Tanno, Willcox, 2006). In the second half of the 7th millennium BC part of the agricultural settlements were established on the Balkan peninsula.

The territory of Southwestern Bulgaria is considered also as one of the primary routes for the neolithization of Southeastern Europe, the Balkan peninsula in particular (Lichardus-Itten et al., 2006), which according to the available archaeological evidence and radiocarbon dates has started around 6200/6100 cal. BC (Görsdorf, Bojadziev, 1996; Bojadziev, 2009). In this sense the Struma river valley has served as a connecting link between Aegean Thrace and Central Europe. Along its length and north along the Iskar river, the main central European communication artery, the Danube river, was reached. At the end of the 7th and the beginning of the 6th millennium BC this was one of the main routes along which agriculture and

animal husbandry from Anatolia has penetrated in Europe (Todorova et al., 2007; Krauß et al., 2018).

The rapid spread of the neolithic culture and agriculture to Southeastern Europe can be viewed as a direct response to the abrupt climate change around 8200 cal. yrs. BP (6200 cal. BC), which led to important, irreversible and rapid changes in the then socio-economic and religious life of the population in significant areas of Western Asia and the Balkans. It should be noted that at that time many important archeological settlements either arose (Northwestern Anatolia, Greece, Bulgaria) or were abandoned (Cyprus). This abrupt climate fluctuation is thought to have caused a drought in the western parts of the Eastern Mediterranean, forcing early farmers to move from Anatolia to Macedonia and the fertile plains of Thessaly, as well as to Southwestern Bulgaria (Weninger et al., 2006, 2009).

The emergence of Early Neolithic settlements in the Struma river valley has occurred, according to the available absolute dates, about 300 years before the Karanovo-I culture in Thrace which is among the oldest in Europe. The Early Neolithic settlements of the Struma river valley were situated in the foothills of the mountains, between 400 and 650 m (Kovačevo, Topolnitsa, Brezhani, Ilindentsi, Bulgarčevo, Mursalevo, Kremenik, Galabnik, etc.) and, quite probably, their location reflected favorable climatic and ecological conditions (Todorova, Vaisov, 1989; Ivanova et al. 2018). They showed in a new light the social structure, livelihood and cult sphere of prehistoric Man not only in the region but also in Southeastern Europe as a whole.

During the second half of the Early Neolithic and during the Late Neolithic, large settlements appeared, located in the Struma river valley itself. At the end of the Late Neolithic and the beginning of the Early Eneolithic the settlements moved to naturally protected places (Grebska-Kulow, Kulow 2007). After this period, the number of the settlements decreased significantly and this trend continued during the Early Bronze Age.

Information about the Early Eneolithic (4750-4600 yrs. BC) is provided by the excavations in Slatino (Chohadziev, 2006) after which the number

of settlements along the Struma river decreased during the Late Eneolithic.

Materials related to the Early Bronze Age (3200-2500 cal. BC) were found along the Blatna river, Radomir region (Alexandrov, 1994) and at the site Kovačevo (Lichardus-Itten et al., 2002). The Late Bronze Age (1400-1200 cal. BC) is documented in several places along the middle and lower courses of the Struma river and archeological sites of special importance are Kamenska Čuka, Krasto and Marikostinovo. By that time, a second maximum was registered in terms of the number of settlements and human activity (Grebska-Kulowa, Kulow, 2007). Of great importance for the reconstruction of the prehistorical settlement history of the Struma region is the significant decrease of settlement activity established (Todorova et al., 2007). Between the Early Bronze Age and the beginning of the Late Bronze Age there is a chronological hiatus of about 600 years from which no particular sites and cultural content have yet been found (Bojadziev, 2007).

Paleoecological reconstructions from the region of Southwestern Bulgaria were used for inferring the human impact on the vegetation and landscape during the last 8 millennia. They are based on data from pollen analyses of lakes and peat bogs, plant macrofossils, archaeobotanical finds and radiocarbon dating (Bozilova, Tonkov, 2007). Against the background of the archaeological situation, attention should be paid to some objective facts in the analysis of the presence of the two groups of anthropogenic indicators in the pollen diagrams. First, almost all investigated palynological sites are located above 1600 m, where the transport of pollen from cultivated cereals is very limited. Second, a significant part of these sites are relatively far from the nearest studied prehistorical settlements. Third, the time span covered and the chronological resolution of the pollen cores is variable, which sometimes makes it impossible to assess the anthropogenic impact from palynological data for earlier archaeological periods.

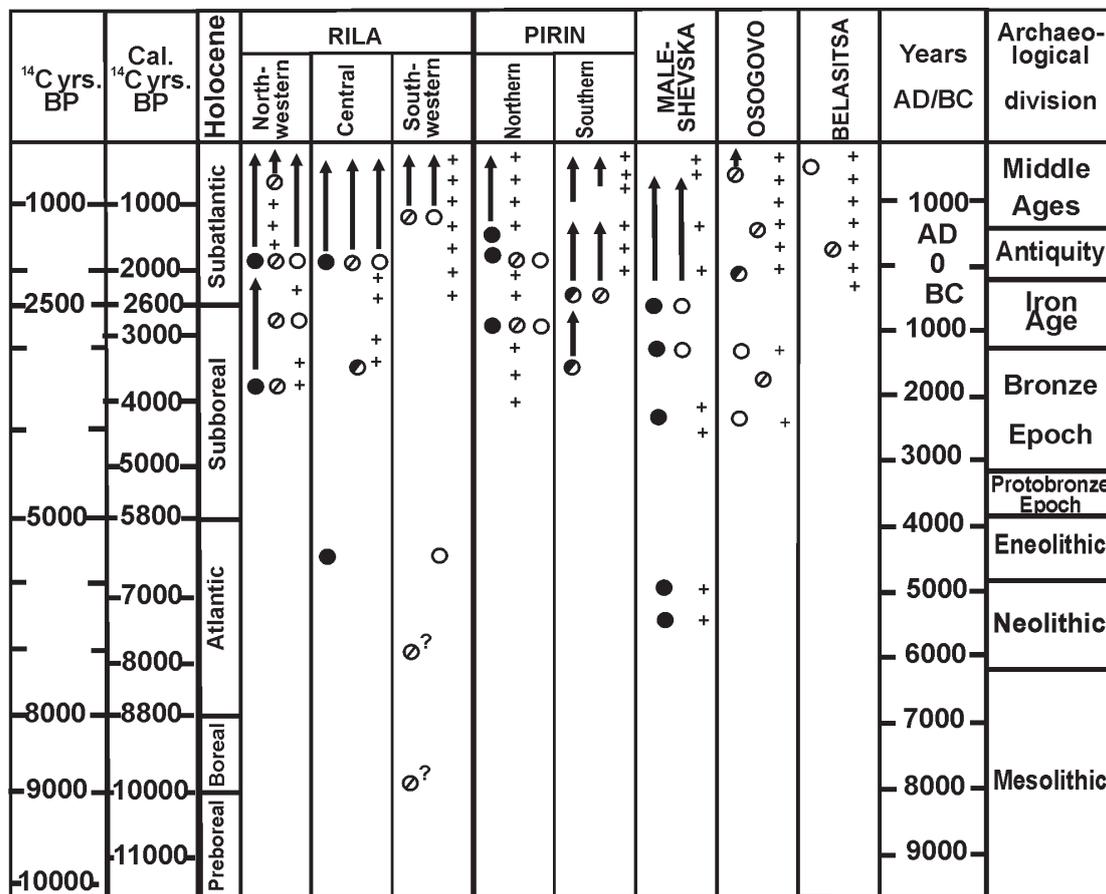
Pollen from primary (*Cerealia*-type, *Triticum*-type, *Hordeum*-type, *Secale*) and secondary (*Plantago lanceolata*, *Rumex*, *Scleranthus*, *Urtica*, *Polygonum aviculare*, *Juniperus*) anthropogenic

indicators, confirming the economic activity of the local population, is present after 8000 cal. BC (10000 cal. yrs. BP) in the diagrams from Southwestern Bulgaria. There are two distinct periods in the presence of these indicators in the region. The first period from 8000/7300 to 4500/3600 cal. BC (10000/9300 to 6500/5600 cal. yrs. BP) is characterized by their sporadic participation in the vegetation. During the second period, which started after 2300/2000 cal. BC (4300/4000 cal. yrs. BP), the presence of anthropogenic pollen indicators is constant and significant (Fig. 71) (Marinova et al., 2012).

During the first period single pollen grains from *Secale* were determined in the core from

Lake Suho Ezero (Fig. 33) which can be considered to belong to the wild perennial species *Secale montanum* (Kozhuharov ed., 1992). The pollen grains of *Cerealia*-type and *Triticum*-type c. 4500-3700 cal. BC (6500-5700 cal. yrs. BP) probably reflect agricultural activity during the Eneolithic and the Early Bronze Age (Figs. 9 and 33).

The radical change in the quantitative share of the anthropogenic pollen indicators has started in the second period after a gap of 1600-2000 years. The palynological evidence suggests both agriculture at the foothills of the mountains and the use of mountain meadows for seasonal grazing during the Late Bronze Age. The intensification of the anthropogenic activity coincides with the



SYMBOLS:

- Primary anthropogenic pollen indicators:
 ● *Cerealia*-type ○ *Hordeum*-type
 ○ *Triticum*-type ○ *Secale*-type

- Secondary anthropogenic pollen indicators:
 + (*Plantago lanceolata*, *Rumex*, *Scleranthus*,
Urtica, *Polygonum aviculare*, *Juniperus*)

↑ continuous presence

Figure 71. Summary scheme for the presence of the anthropogenic indicators in the pollen diagrams from Southwestern Bulgaria (modified after Marinova et al., 2012).

permanent establishment of *Fagus* and *Picea* in the Rila and Northern Pirin mountains, which supports the assumption that Man has helped the spread of these tree species by felling and fires (Feurdean et al., 2019).

In most of the sites during the second period a continuous occurrence and increase is observed for both groups of anthropogenic pollen indicators and microcharcoals as well. The data from pollen diagrams from different parts of the Rila Mountain revealed the steady presence of *Cerealia*-type pollen after c. 4000 cal. yrs. BP (2000 cal. BC), of *Secale*, *Triticum*-type and *Hordeum*-type pollen after 3000/2200 cal. yrs. BP (1000-200 cal. BC), alongside with a continuous presence of *Plantago lanceolata* pollen after c. 4500/4000 cal. yrs. BP (2500-2000 cal. BC). Numerous fragments of charcoal found just before 3770 cal. yrs. BP and c. 2800 cal. yrs. BP in the sediments of Lakes Ostrezki (Figs. 28 and 29) point that some of the forest fires were caused by the local population to clear areas for high-mountain seasonal grazing. The next increase in the presence of the anthropogenic pollen indicators began at the end of the Iron Age after 2600 cal. yrs. BP (600 cal. BC), when their participation in the pollen diagrams is almost continuous with some site-specific features. The lower number of macrofossils of *Pinus sylvestris* and *Pinus peuce* recorded after c. 2200 cal. yrs. BP can be explained by the opening of the woody vegetation and the lowering of the upper timberline. The abundance of herb pollen taxa, some of them pasture and ruderal plants, as well as fragments of charred wood, in the sediments of Lake Panichishte shows that areas around the lake were burned and used for seasonal grazing since the Roman rule (Figs. 15 and 16).

From more recent historical times as a convincing example of diverse human activity can be mentioned the pollen diagram of Lake Suho Ezero-RM, above the Rila Monastery, in which a general increase of the anthropogenic indicators is observed, such as *Plantago lanceolata*, *Rumex*, *Scleranthus*, along with the presence of pollen from cultivated cereals (*Cerealia*-type, *Triticum*-type, *Secale*) (Fig. 31). Historical data on the economic activity in the Rilska river valley (cattle breeding,

seasonal grazing, agriculture, forest use, etc.) after the foundation of the monastery in the 10th century AD (Koeva, 1989) is successfully correlated with the palynological information.

The beginning of the expansion of *Picea abies* in the Northern Pirin Mountain coincides with the appearance of pollen from cultivated cereals (*Cerealia*-type, *Triticum*-type, *Secale*) and *Scleranthus* c. 1000/500 cal. BC (3000/2500 cal. yrs. BP) (Figs. 43, 46 and 47). In the area of Peat bog Popovi Livadi, Southern Pirin Mountain, a period of increased anthropogenic impact on the surrounding vegetation is registered between 530 cal. BC and 700 cal. AD (2530-1300 cal. yrs. BP) when the coniferous and deciduous forests were destroyed on large areas, along with the practice of intensive mountain pasture (Fig. 52).

In the diagrams from Osogovo Mountain the first indication of human presence is recorded between 3000 and 1500 cal. BC (5000-3500 cal. yrs. BP) when the anthropogenic influence on the vegetation is represented by finds of *Triticum*-type, *Secale*, *Plantago lanceolata*, *Urtica*, *Rumex* pollen (Fig. 62). The high values of *Scleranthus* pollen found throughout the entire core of peat bog Osogovo-1 (Fig. 59), with a first peak assigned to the onset of the Late Bronze Age, are of local/extra-local origin pointing to stock-breeding practiced in the nearby vicinity. The intensity of human impact increased notably after 1200 cal. BC (3200 cal. yrs. BP, approx. Late Bronze Age) as documented by a rise of the anthropogenic pollen indicators. The final transformations in the natural forest cover after 800 cal. BC (2800 cal. yrs. BP, the onset of the Iron Age) marked the reduction of the coniferous forests and their replacement by beech. These changes in the vegetation cover appear contemporaneous with an increase of the palaeofire activities and subsequent peaks of the anthropogenic indicators that point to diversification of human impact (Marinova et al., 2012). In medieval times, after 1230 cal. AD, 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* (Fig. 59). The increasing deforestation has led to

the enlargement of the areas for summer pasture land and the establishment of the present day open vegetation cover in the highest parts of the mountain.

Indications of human presence are not recorded from the pollen diagrams of Tschokljovo marsh, Konyavska Mountain, between 7000 and 5200 cal. BC (9000–7200 cal. yrs. BP). By that time, the mountain slopes surrounding the marsh were covered by mixed oak forests with *Tilia*, *Corylus*, *Ulmus*, some *Carpinus orientalis*/*Ostrya carpinifolia* and *Carpinus betulus*. On the higher mountain areas stands of *Pinus* and *Abies* occurred. For the the following time interval of c. 3000 years (5200–2000 cal. BC or 7200–4000 cal. yrs. BP) the most interesting feature, however, is the continuous presence of *Juglans* pollen, probably indicating its native distribution in this area rather than cultivation by the local population. Until the start of the Roman rule (pollen zone transition T-4/T-5, Figs. 55 and 56), the palynological indications of human presence and activity occur rather sporadically.

In the pollen diagram from Maleshevska Mountain three distinct periods of human impact can be recognized (Fig. 64). During the earliest period 5500–2760 cal. BC (7500–4760 cal. yrs. BP, Middle/Late Neolithic–Early Bronze Age) when the coniferous forests were widely distributed and below them mixed oak forests developed, the presence of *Cerealia*-type pollen for the last quarter of the 6th millennium BC might reflect increasing settlement activity and cereal cultivation in the Struma river valley. In the course of the next period 2760–800 cal. BC (4760–2800 cal. yrs. BP, Early Bronze Age–Early Iron Age), when a sharp decline in the areas occupied by *Abies* forests is observed, the uninterrupted presence of the anthropogenic pollen indicators (*Cerealia*-type, *Plantago lanceolata*, *Rumex*, *Scleranthus*) clearly points to the practice of agriculture in the foothills of the mountain and extended sheep/goat and cattle-breeding in the lower mountain areas. The last period which started c. 800 cal. BC (2800 cal. yrs. BP) is characterized by a strong anthropogenic influence on the vegetation. At lower elevations

the oak forests were disturbed and replaced by secondary communities dominated by *Carpinus orientalis* and *Quercus pubescens*, while at higher elevations beech forests replaced the conifers (Marinova et al., 2012). The significant increase and presence of anthropogenic pollen indicators such as *Triticum*-type, *Secale*, *Cerealia*-type, *Plantago lanceolata*, *Rumex*, Cichoriaceae, *Urtica*, *Scleranthus*, as well as the decrease of almost all tree species, recorded in the pollen diagrams from Maleshevska and Vlahina mountains, appear as a consequence of the permanent settlement in these lands.

For the northern slopes of Belasitsa Mountain the most significant change in the vegetation cover caused by anthropogenic intervention started in historical times, after c. 2000 cal. yrs. BP, with the widespread cultivation of *Castanea sativa* for its valuable fruits and timber, synchronously with that of *Platanus* and *Juglans*. Pollen grains from cultivated cereals (*Triticum*-type, *Secale*) and the presence of secondary anthropogenic pollen indicators (*Plantago lanceolata*, *Scleranthus*, Cichoriaceae) are associated with human economic activities, especially during the Roman rule.

The palynological information from the above studied sites in Southwestern Bulgaria is convincing in terms of the practice of cattle breeding, mountain agriculture and enlargement of grazing areas through felling or fires, which have led to lowering of the upper timber-line. On the other hand, the paleoecological records considered provide little information on medieval land use either because of low resolution or absence of radiocarbon age control for this period.

The palynological data for the anthropogenic impact on the vegetation cover during the Neolithic, Eneolithic and Bronze Age are confirmed also by the paleoethnobotanical finds from pre-historical settlements in Southwestern Bulgaria (Marinova, 2006; Marinova et al., 2002, 2012, 2016, 2017; Popova, 2003, 2009; Popova, Marinova, 2007; Marinova, Thiebault, 2008; Marinova, Valamoti, 2014; Marinova, Ntinou, 2018, etc.) (Fig. 72 and Table 20).

The Neolithic agriculture was well developed and relied mainly on *Triticum monococcum*

(einkorn) and *Triticum dicoccum* (emmer). The wide distribution of *Triticum monococcum* was due to its adaptability to different environmental conditions. *Triticum dicoccum* was also present in large quantities but was rarely predominant in the study region. Individual seeds whose morphological features correspond to those of *Triticum aestivum/durum* were also found. In addition to wheat, barley was also grown in smaller quantities, mainly *Hordeum vulgare* var. *vulgare*, but also *Hordeum vulgare* var. *nudum*. The single finds of *Panicum milliaceum* (millet) in the settlement Drenkovo (Kreuz et al., 2005) raise the question of its possible cultivation, but in the view of recent large scale studies involving numerous radiocar-

bon dates suggest that such single finds in Neolithic layers have intrusive character (Filipović et al., 2020).

Along with cereals, there were various accompanying weed species such as *Bromus* sp., *Polygonum aviculare*, *Setaria viridis*, *Phleum phleoides*, *Galium* sp., *Verbena officinalis*, *Centaurea* sp., etc. Legumes were second in importance, mainly *Lens culinaris*, *Lathyrus sativus* and *Vicia ervilia*. Of interest are the finds of *Cicer arietinum*. The plant is part of the Near Eastern crop assemblage (Tanno, Willcox, 2006a) but almost unknown so far according to paleobotanical data outside Levant and Anatolia. Its presence in these settlements proves that it came together with the whole Anatolian

Table 20. Paleoethnobotanical materials from prehistorical settlements in Southwestern Bulgaria (Neolithic-Bronze epochs).

SETTLEMENT	PERIOD	CHRONOLOGY (cal. BC)	WOOD	CULTIVATED PLANTS	REFERENCE
Kovačevo	Early Neolithic	6159-5630	<i>Quercus</i> , <i>Cornus</i> , <i>Alnus</i> , <i>Pinus nigra/sylvestris</i> , <i>Pomoideae</i> , <i>Carpinus</i> , <i>Corylus avellana</i>	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Lens culinaris</i> , <i>Lathyrus sativus/cicera</i> , <i>Vicia ervilia</i> , <i>Pisum sativum</i>	Marinova (2006)
Galabnik	Early Neolithic	6100-5700	<i>Quercus</i> , <i>Rosaceae</i> , <i>Pinaceae</i> , <i>Acer</i> , <i>Fagus</i> , <i>Carpinus</i> , <i>Pinus</i> sp., <i>Cornus mas</i> , <i>Buxus</i> , etc.	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Lens culinaris</i> , <i>Cicer arietinum</i>	Marinova et al. (2002)
Kremenik	Early and Middle Neolithic	5720-5620	<i>Quercus</i> , <i>Fraxinus</i> , <i>Cornus</i> , <i>Alnus</i> , <i>Corylus</i> , <i>Fagus</i> , <i>Euonymus</i> , <i>Pinus</i> sp., <i>Prunus</i>	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Lens culinaris</i> , <i>Pisum sativum</i> , <i>Vicia</i> sp., <i>Vicia ervilia</i>	Marinova et al. (2002)
Vaksevo	End of the Early Neolithic	5870-5730	<i>Quercus</i>	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i>	Popova (2001)
Balgarčevo	End of the Early Neolithic	5640-5430	<i>Quercus</i> sp., <i>Pinus</i> sp., <i>Cornus</i> , <i>Juniperus</i> , <i>Salix</i> , <i>Populus</i> , <i>Fraxinus</i> , <i>Ulmus</i> , <i>Prunoideae</i>	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Triticum aestivum/durum</i> , <i>Hordeum vulgare</i> , <i>Pisum sativum</i> , <i>Lens culinaris</i> , <i>Vicia ervilia</i> , <i>Cicer arietinum</i> , <i>Linum usitatissimum</i>	Marinova (2017)
Drenkovo	Late Neolithic	No ¹⁴ C dates		<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Lens culinaris</i> , <i>Lathyrus sativus/cicer</i>	Kreuz et al. (2005)
Mursalevo	Early and Late Neolithic	No ¹⁴ C dates		<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Lens culinaris</i> , <i>Lathyrus sativus/cicera</i> , <i>Vicia ervilia</i> , <i>Pisum sativum</i> , <i>Linum usitatissimum</i>	Marinova et al. (2016)
Topolnitsa	Early Eneolithic		<i>Quercus</i> , <i>Rosaceae</i> , <i>Pinus</i> sp.	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Lens culinaris</i> , <i>Vicia ervilia</i>	Valamoti (2007) Popova (2009)
Slatino	Early Eneolithic	4650-4500		<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Vicia ervilia</i> , <i>Lens culinaris</i>	Marinova et al. (2002)
Kamenska Čuka	Late Bronze	2471-2292	<i>Quercus</i> , <i>Pinus sylvestris</i> , <i>Abies</i> , <i>Juniperus</i> , <i>Ulmus</i> , <i>Fraxinus</i> , <i>Rosa</i>	<i>Triticum monococcum</i> , <i>Triticum dicoccum</i> , <i>Hordeum vulgare</i> , <i>Panicum milliaceum</i> , <i>Lens culinaris</i> , <i>Vicia ervilia</i>	Popova (1998)

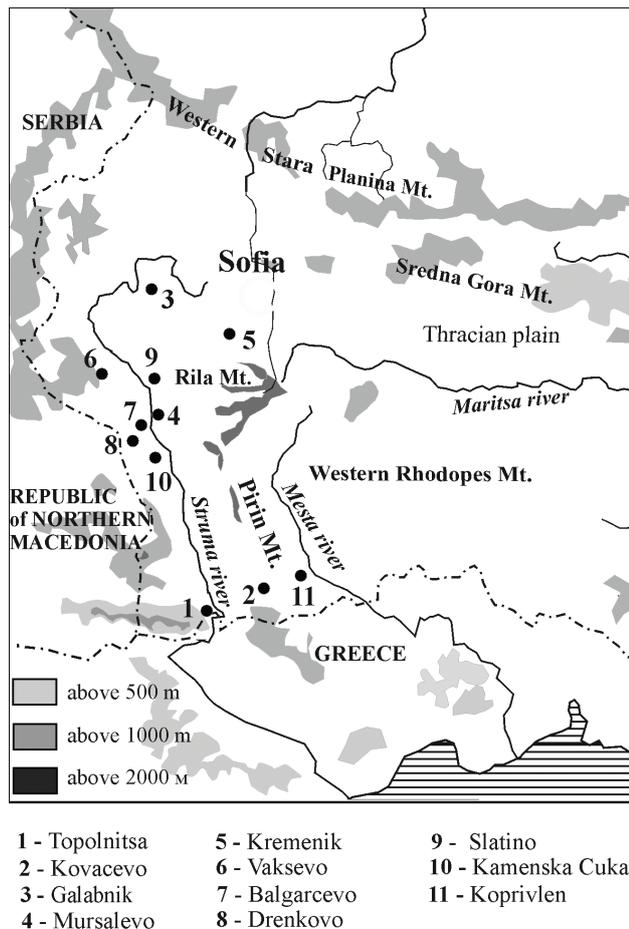


Figure 72. Map of the prehistorical settlements in Southwestern Bulgaria (Neolithic-Bronze epochs) with paleoethnobotanical remains studied (modified after Marinova et al., 2012)

complex of cultivated plants on the territory of the country (Marinova, Popova, 2008).

For the subsequent Eneolithic period the archaeobotanical evidence suggests certain continuity of the crop spectra with some dominance of einkorn and emmer. However, it seems that in the spectrum of leguminous crops most important was the drought resistant *Vicia ervilia* as visible from the site Galabnik (Marinova et al., 2002). Of interest is also to mention that at this site a storage find of *Chenopodium* seeds was recovered pointing to use also of wild plant resources (famine food?) probably from wetlands in the surroundings.

Of particular interest for paleobotanical research is the finding of charred or mineralized wood in archaeological sites, which is usually associated with its use for various purposes – primary firewood but also building material, tools, etc. It

was almost always collected from the surrounding area and thus provides valuable information about the woody flora.

Since most of the prehistorical settlements in Southwestern Bulgaria were located at relatively low altitudes (300-800 m), the analysis of wood from their cultural layers complements the knowledge of the vegetation at the foothills of the mountains. These studies provide direct information on the use of wood in the settlements and clarify the importance of the lower mountain belt as a valuable source of plant material for various purposes, including leaf fodder.

In the materials from the Neolithic settlements such as Galabnik (Marinova et al., 2002), Kovačevo (Marinova, Thiebault, 2008), Topolnitsa (Popova, 2009), Balgarčevo (Marinova, 2017), Ilindentsi (Marinova, Ntinou, 2018) wood of *Quercus* predominates, which is a confirmation of the widespread distribution of oak forests in the lower mountain belt during the climatic optimum of the Holocene. There are also numerous fragments of wood from Rosaceae (Pomoideae, Prunoideae), followed by those of *Cornus mas*, *Corylus*, *Acer*, *Ulmus*, *Fraxinus*, *Pinus* sp. This is a general tendency of the Neolithic woodland use observed for the broader study region (Marinova, Ntinou, 2018).

The find of wood from *Fagus* in Galabnik, Pernik region, is especially important, as according to palynological data the presence of beech in the vegetation of Southwestern Bulgaria c. 8000-7500 cal. yrs. BP (6000-5500 cal. BC) was sporadic. Fragments of wood from *Salix*, *Populus* and *Alnus* prove that these species were an integral part of the riparian plant communities and were used by humans. The origin of the wood from *Buxus* in the Neolithic layers remains unclear (Marinova et al., 2002).

Abundant archaeozoological and scarce botanical materials were found in the cultural layers of final Early Neolithic to Early Bronze Age of the prehistorical settlement Vaxevo located at 600 m 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 *Hordeum vulgare* and *Triticum monococcum*. 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).

The wood from the Late Bronze age in the settlements Kamenska Čuka (Popova, 1998) and Koprivlen (Popova, Marinova, 2007) has almost the same composition and the finds from *Abies*, *Pinus sylvestris*, *Juniperus* deserve attention, thus confirming the palynological data on the distribution of coniferous forests of *Abies* and *Pinus* in the western border mountains during the mid-Holocene.

With the introduction of iron and the growing demand for timber, many local tribes moved to mountainous areas. This movement is established in the pollen diagrams from the Osogovo-Belasisa mountain range c. 3000 cal. yrs. BP (1000 cal. BC), when the oak forests were disturbed and the coniferous woods were gradually replaced by beech forests.

The changes in the landscape during the Roman rule and the Medieval period reflect regional environmental features and were forced by the diversification of the anthropogenic activity. The paleoethnobotanical materials from the Iron Age, the Antiquity and the Middle Ages for Southwestern Bulgaria are very scarce against the background of the abundant archaeological information. In this aspect of interest are the crop (*Triticum aestivum/durum*, *Triticum monococcum*, *Triticum dicoccum*, *Hordeum vulgare*, *Panicum milliaceum*, *Secale cereale*, *Avena sativa*, *Lens culinaris*, *Pisum sativum*, *Vicia ervilia*, *Vitis vinifera*) and wood charcoal (*Abies*, *Pinus sylvestris*, *Quercus* sp., *Fagus*, *Corylus*, *Fraxinus*) assemblages found in the settlement Koprivlen dated predominantly to the Late Iron Age (Popova, 2003).

10. CONCLUSIONS

The paleobotanical and paleoecological research on the postglacial history of vegetation in Southwestern Bulgaria with the application of several research methods allows the presentation of some general issues and conclusions. They are based on the trends and patterns in the development of vegetation, climate changes and anthropogenic impact in the study area, as well as on some specific regional features. These scientific data expand the information about this region as an integral part of the country and the Balkan peninsula in terms of past environmental changes.

The reconstruction of the vegetation cover in Southwestern Bulgaria during the last c. 18000 years reveals some general characteristics influenced also by the global climate changes after the Last Glacial Maximum (23000–19000 cal. yrs. BP). Indications for climate warming were established simultaneously in ice cores from Greenland and Antarctica as early as about 23000 cal. yrs. BP and this trend has intensified after 19000 cal. yrs. BP (Blunier, Brook, 2001) in synchrony with the increase in solar insolation in the northern hemisphere and the onset of melting of ice sheets with subsequent sea level rise (Yokohama et al., 2000). The isotope signal from Greenland shows a clear warming trend around 14700 cal. yrs. BP (Labeyrie et al., 2003) which correlates with a significant retreat and shrinking of the area of the mountain glaciers in the Alps (Husen, 1989).

The assumption for the beginning of climate change at the termination of the Late Pleniglacial (24000–14600 cal. yrs BP) in Southwestern Bulgaria is confirmed by the pollen diagrams from the Northwestern Rila Mountain, the area of the Seven Rila lakes. The gradual enlargement of groups of *Pinus*, as well as the appearance of *Juniperus*, *Betula* and *Alnus* within large areas occupied by herb vegetation, serve as evidence of climate improvement at the onset of the lateglacial interstadial Bölling/Alleröd. The same trend is observed in the pollen diagrams from Lake Ribno Banderishko and other glacial lakes in the Northern Pirin Mountain. Moreover, the paleobotanical data compared with

the deposition of silty clay in the lakes suggest a much earlier retreat of the cirque glaciers above 2300–2400 m similar to the deglaciation in the Western Pyrenees (Jalut et al., 1992). However, the climate at the end of the Pleniglacial and during the Lateglacial has remained cold and dry, with temperatures of 5–7°C lower than today.

A comparison with several pollen records from the northern part of the Balkans in Romania which also span the terminal part of the Pleniglacial (18000–14700 cal. yrs. BP) suggests that the landscapes in the Carpathian region were likely covered by open forest mixed with steppe-tundra vegetation. The main tree taxa were of boreal (*Picea abies*, *Pinus*, *Juniperus*) and cool temperate type (*Alnus*, *Betula*, *Salix*). Scattered pollen percentages of temperate deciduous trees (*Ulmus*, *Quercus*, *Fraxinus*, *Corylus avellana*) were also recorded. The steppe-tundra assemblages consisted of herbs growing in open landscape under dry conditions, and tundra elements composed of arctic herbs and shrubs that occurred where the conditions were too cold for trees to grow (Feurdean, Tantau, 2017).

In the highest parts of the Carpathians, Rila and Northern Pirin mountains near the glaciers there was probably alpine tundra. Below it, the areas were occupied by open herb vegetation dominated by *Artemisia* and *Chenopodiaceae*, along with various species of *Poaceae*, *Asteraceae*, *Apiaceae*, shrubs of *Ephedra* and *Juniperus* (Jalut et al., 2005). The microrefugia for different thermophilous tree species such as *Quercus*, *Corylus*, *Ulmus*, *Tilia*, *Carpinus betulus* were located in suitable habitats at altitudes below 1000 m with sufficient moisture, relatively well-developed soils and protected southern exposures (Bennet et al., 1991; Willis et al., 2000).

By that time, the presence of pollen from *Quercus*, *Carpinus orientalis/Ostrya*, *Carpinus betulus*, *Ulmus*, *Tilia*, *Corylus*, *Pinus peuce*, *Fagus*, *Abies* in records from the mountains of Northwestern Greece and Southern Bulgaria (Western Rhodopes) indicates the existence of glacial refugia at mid-low altitudes (Bottema, 1974; Tzedakis, 2004; Tonkov et al., 2014).

According to the regional radiocarbon chronology the plant paleosuccession in Southwestern Bulgaria for the last 18000–15000 years comprises

several well-defined stages. The first stage refers to the termination of the Pleniglacial and the Lateglacial, and the rest are related to the Holocene. During the Lateglacial (15000–11600 cal. yrs. BP) in the Rila and the Northern Pirin mountains open herb vegetation of “mountain-steppe” character dominated by *Artemisia-Chenopodiaceae-Poaceae* and various cold-resistant and heliophilous species from *Achillea*, *Centaurea*, *Rumex*, *Thalictrum*, *Galium*, *Dianthus*, *Brassicaceae*, etc. was widely distributed at mid-high altitudes. This vegetation pattern included also stands of pines (*Pinus mugo*, *Pinus sylvestris*, *Pinus peuce*) and shrubland of *Juniperus-Ephedra*, which partly expanded during the lateglacial interstadial complex Bölling/Alleröd (15000–12800 cal. yrs. BP). Isolated groups/populations of coniferous (*Abies*, *Picea abies*) and deciduous (*Quercus*, *Fagus*, *Tilia*, *Carpinus*, etc.) trees have survived the harsh glacial conditions in sheltered habitats with favorable microclimatic and ecological conditions for their growth.

The last pronounced deterioration of the climate during the Lateglacial and return to glacial conditions, i.e. the Younger Dryas stadial, after 12800 cal. yrs. BP has lasted for 1100–1300 years. It was characterized by a re-advance of the „mountain-steppe“ vegetation with dominants *Artemisia*, *Chenopodiaceae* and *Poaceae*, as well as with retreat of moisture demanding trees to lower altitudes. It should be noted that the first macroremains of *Pinus peuce* and *Betula* appeared in the fossil assemblages from the Rila and the Northern Pirin mountains at altitudes above 1800 m.

The onset of the Holocene was characterized by a quick increase of the average annual temperatures with 5–6°C in the course of several decades (von Grafenstein et al., 1998). In the high mountains of Southwestern Bulgaria the rapid amelioration of the climate has led to a significant reduction and retreat of the herb „mountain-steppe“ vegetation. The initial afforestation on the mountain slopes lasted from 11600 to 8000/7900 cal. yrs. BP and within this stage two phases could be distinguished. During the first one (11600–10200/9900 cal. yrs. BP) pioneer communities of *Betula* became widespread between 1900 and 2200 m on a still poor, skeletal soil cover. These communities were rather sparse

and mixed with stands of *Pinus mugo*, *Pinus sylvestris*, *Pinus peuce* and *Juniperus*, confirmed also by the plant macroremains determined. The pollen data reveal the distribution at lower altitudes of mixed oak forests with significant participation of *Tilia*, *Ulmus*, *Fraxinus* and *Acer*. These trees, together with *Corylus*, have reached their maximal development during the second phase after 10200/9900 cal. yrs. BP. In the Early Holocene this vegetation pattern has persisted for a long period of nearly 4000 years in the the Rila and the Northern Pirin mountains.

The most significant transformation in the vegetation composition in Southwestern Bulgaria is associated with the Holocene climatic optimum, when the general trend of warming reached its culmination. This time interval generally covers the period 8000–5000 cal. yrs. BP. The results of physical and chemical analyses of ice cores from Greenland (GRIP, GISP2 and NGRIP) revealed that the temperatures were 2–3°C higher than today, as well as the subsequent trend towards cooling after 5000 cal. yrs. BP was gradual (Stuiver et al., 1995; Johnsen et al., 1997; NGRIP Members, 2004). The climatic optimum was preceded by a short-term sharp deterioration of the climate c. 8200 cal. yrs. BP (8.2 ky event) or 7400 ¹⁴C yrs. BP, which was the most pronounced cooling during the Holocene in the northern hemisphere with a duration of 160 years according to data from ice cores in Greenland (Alley, Ágústsdóttir, 2005). The manifestation of this climatic oscillation on the European continent, including the Balkans, was not one-way. As a direct consequence of it the data from pollen and plant macrofossil analyses in Southwestern Bulgaria after 8000 cal. yrs. BP reflect wide distribution of conifers displacing the birch and oak forests.

Also, the spread of the Neolithic culture and agriculture in Southwestern Bulgaria from Anatolia can be considered as a response to the climatic event 8.2 ky, as in this region of the Balkans the ecological conditions have proved favorable for the socio-economic life of the Neolithic settlers (Weninger et al., 2006).

During the climatic optimum (8100/7900–5400/5200 cal. yrs. BP) a coniferous belt was shaped in the Rila and the Northern Pirin mountains

composed of *Pinus sylvestris*, *Pinus peuce* and *Abies* in the conditions of general climate change towards cooler summers, milder winters and increased air and soil humidity. The upper timber-line has climbed higher than today, which was evidenced by the plant macrofossils found. Above the coniferous forest belt on rocky places and on poorer soils *Betula* has retained its pioneering role and the groups of *Pinus mugo* have become more compact. The palynological and macrofossil data from the Osogovo-Belasitsa mountain range and the Konyavska Mountain also reveal that after 8000/7000 cal. yrs. BP a vast coniferous belt was shaped dominated by *Abies*, *Pinus sylvestris*, *Pinus nigra*, and below it developed mixed oak forests.

In the first half of the Late Holocene (5400/5200–3000 cal. yrs. BP) the most important changes in the vegetation cover of the high mountains Rila and Pirin are related to the final establishment of *Fagus sylvatica* and *Picea abies*, alongside with the maximal distribution of *Pinus peuce*, *Pinus sylvestris*, *Pinus mugo*, and the commencement of *Abies* decline. In the lower western border mountains *Fagus sylvatica* has gradually started to gain importance at the expense of the coniferous woods, thus shaping monodominant or mixed communities with *Abies* and *Carpinus betulus* predominantly on northern slopes in the transitional zone between the deciduous and coniferous vegetation belts.

During the second half of the Late Holocene after 3000/2800 cal. yrs. BP, in the conditions of more humid and cooler climate, the modern vertical distribution of vegetation in Southwestern Bulgaria was established, characterized by the pulsating invasion of *Picea abies* in the coniferous belts of the Rila and Pirin mountains, reaching its first expansion maximum c. 2800 cal. yrs. BP. In many places *Picea abies* has formed the upper timber-line together with *Pinus peuce* and *Pinus sylvestris*. A significant retreat and reduction is established for the communities of *Abies* and their distribution was limited in the lower part of the coniferous belt between 1400 and 1600 m.

The destructive changes in the natural vegetation of the Rila and Pirin mountains were intensified in historical time, when the areas occupied by *Pinus sylvestris*, *Picea abies*, *Pinus peuce* and *Abies*

were seriously affected. In many places the upper timber-line has been artificially lowered with the opening of new terrains, subsequently occupied by a variety of herbs and used for pasture land. The disturbances in the vegetation are confirmed by the significant presence of the anthropogenic pollen indicators and the reduced number of macrofossils from *Pinus* sp., *Picea abies* and *Juniperus*.

In the Osogovo-Belasitsa mountain range the wide distribution of *Fagus sylvatica* has commenced on the place of the coniferous woods, which appeared synchronously in time with the enlargement of *Picea abies* in the Rila and Pirin mountains. The expansion of beech was assisted by the human economic activities such as felling of the conifers for timber and other uses, and for acquiring of new areas for seasonal grazing on the slopes and the rounded ridges. In the last 1000 years the deforestation in the Osogovo Mountain has led to the progressive reduction of the remnants of the coniferous communities. In Belasitsa Mountain the most significant change in the vegetation cover on the northern slopes has occurred immediately before 1760 cal. yrs. BP when the communities of *Fagus sylvatica* were seriously destroyed and the upper timber-line was lowered. The palynological evidence for the last centuries shows a decline of the areas occupied by the beech forests and an increase in the presence of *Carpinus orientalis*, *Ostrya carpinifolia*, and partly of *Quercus* and *Corylus* at lower altitudes.

The impact of the climate cooling during the Little Ice Age (1550-1850 AD) on the vegetation cover in Southwestern Bulgaria is manifested by the last pulsation of the spruce forests in the Rila and Pirin mountains, when they have enlarged in the altitudinal range 1600-1400 m, mainly on slopes with northern and derivative exposure. According to the palynological evidence, the last expansion of beech in the Osogovo-Belasitsa mountain range about 300 years ago was favored by this climate change and the local disturbances in the forest ecosystems.

The changes in the natural vegetation cover in the study area were also assisted by the increasing human activities since the Late Bronze Age such as crop cultivation, animal husbandry, tree felling and fires in order to enlarge the pasture land.

REFERENCES

- Alexandrov, S. 1994. The Prehistoric Site of Radomir-Vahovo: Some Problems of the Early Bronze Age in South-Western Bulgaria (Northern Connections). In: Roman, P., M. Alexianu, M. (eds.), *Rélations Thraco-Illyro-Helléniques. Actes du XIVE Symposium National de Thracologie (à participation internationale) Baile Herculane*. Bucurest, pp. 117-129.
- Alley, R. B. 2000. The Younger Dryas cold interval as viewed from central Greenland. *Quaternary Science Reviews* 19, 213-226.
- Alley, R. B., Ágústsdóttir, A. M. 2005. The 8 k event: cause and consequences of a major Holocene abrupt climate change. *Quaternary Science Reviews* 24, 1123-1149.
- Ammann, B., Eicher, U., Gaillard, M.-J., Wohlfarth, B., Haeblerli, W., Lister, G., Lotter, A. F., Maisch, M., Niessen, F., Schlüchter, C., Wohlfarth, B. 1994. The Würmian Late Glacial in lowland Switzerland. *Journal of Quaternary Science* 9, 119-125.
- Ammann, B., van der Knaap, W. O., Lang, G., Gaillard, M.-J., Kaltenrieder, P., Rösch, M., Finsinger, W., Wright, H. E., Tinner, W. 2014. The potential of stomata analysis in conifers to estimate presence of conifer trees: examples from the Alps. *Vegetation History and Archaeobotany* 23, 249-264.
- Atanassova, J., Stefanova, I. 2003. Late-glacial vegetational history of Lake Kremensko-5 in the Northern Pirin Mountains, southwestern Bulgaria. *Vegetation History and Archaeobotany* 12, 1-6.
- Atanassova, J., Stefanova, I. 2005. Late-Holocene vegetation changes in the Northern Pirin Mountains (Southwestern Bulgaria). Palynological data from Lake Suho Breznishko and Lake Okadensko. *Geologica Carpathica* 56 (5), 447-453.
- Athanasiadis, N., Tonkov, S., Atanassova, J., Bozilova, E. 2000. Palynological study of Holocene sediments from Lake Doirani in Northern Greece. *Journal of Paleolimnology* 24 (3), 331-342.
- Athanasiadis, N., Gerasimidis, G., Panajotidis, S. 2003. A palynological study in the Beles Mountains, Northern Greece. In: Tonkov, S. (ed.), *Aspects of Palynology and Palaeoecology*. Pensoft Publishers. Sofia-Moscow, pp. 185-198.

- Baltakov, G. 2002. Rudimentary, embryonic and drifted types of mountain glaciers from the eastern part of the Balkan peninsula. *Problems of Geography* 1-2, 81-87. (in Bulgarian)
- Beaulieu, J.-L., Clerc, J., Richard, H., Ruffaldi, P. 1994. History of vegetation in the French Alps and the Jura over the last 15000 years. *Dissertationes Botanicae* 234, 1-23.
- Behre, K.-E. 1981. The interpretation of anthropogenic indicators in pollen diagrams. *Pollen et Spores* 23 (2), 225-245.
- Behre, K.-E. 1988. The role of Man in European vegetation history. In: Huntley, B., Webb, T. III. (eds.), *Vegetation history. Handbook of vegetation science*. Kluwer. Dordrecht, pp. 633-672.
- Beijerinck, W. 1947. *Atlas of seeds and fruits*. H. Veeman & Zonnen. Wageningen.
- Bennett, K. D., Willis, K. J. 1995. The role of ecological factors in controlling vegetation dynamics on long temporal scale. *Giornale Botanico Italiano* 129 (1), 243-254.
- Bennett, K., Tzedakis, P., Willis, K. 1991. Quaternary refugia of north European trees. *Journal of Biogeography* 18, 103-115.
- Beug, H.-J. 1961. *Leitfaden der Pollenbestimmung. Lieferung 1*. Gustav Fischer. Stuttgart.
- Beug, H.-J. 2004. *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*. Verlag Dr. Friedrich Pfeil. München.
- Birks, H. H., Birks, H. J. B. 2000. Future uses of pollen analysis must include plant macrofossils. *Journal of Biogeography* 27, 31-35.
- Birks, H. J. B., Birks, H. H. 1980. *Quaternary Palaeoecology*. Edward Arnold. London.
- Björck, S., Walker, M. J. C., Cwynar, L. C., Johnsen, S., Knudsen, K.-L., Lowe, J. J., Wohlfarth, B., Members INTIMATE. 1998. An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland ice-core record: a proposal by the INTIMATE group. *Journal of Quaternary Science* 13, 283-292.
- Bjorkman, L., Feurdean, A., Wohlfarth, B. 2003. Late-Glacial and Holocene forest dynamics at Steregoiu in the Gutaiuiu Mountains, Northwest Romania. *Review of Palaeobotany and Palynology* 124, 79-111.
- Blunier, T., Brook, E. 2001. Timing of Millennial-Scale Climate Change in Antarctica and Greenland During the Last Glacial Period. *Science* 251, 109-112.
- Blyakharchuk, T., Stefanova, I., Ammann, B., Wright, H. E. 2001. Paleoenvironment Reconstructions for Mountains in the Eurasian Mid-Continent. *PAGES News* 9 (3), 11-13.
- Bojadziev, J. 2007. Absolute Chronology of the Neolithic and Eneolithic Cultures in the Valley of Struma. In: Todorova, H., Stefanovic, M., Ivanov, G. (eds.), *In the Steps of James Harvey Gaul. The Struma/Strymon River Valley in Prehistory. vol. 2*. Gerda Henkel Stiftung. Sofia, pp. 309-316.
- Bojadziev, J. 2009. Early Neolithic cultures on the territory of Bulgaria. In: Gatsov, I., Bojadziev, J. (eds.), *The First Neolithic Sites in Central/South-East European transect vol. I: Early Neolithic Sites on the territory of Bulgaria*. BAR International Series 2048, pp. 7-44.
- Bonchev, E., Karagjuleva, J., Kostadinov, V. et al. 1960. Fundamentals of the tectonics of the Kraishte and its adjacent lands. *Works on the geology of Bulgaria, series stratigraphy and tectonics* 1, 7-92. (in Bulgarian)
- Bondev, I. 1991. *The Vegetation of Bulgaria*. Map 1:600000 with explanatory text. St. Kliment Ohridski University Press. Sofia. (in Bulgarian)
- Bondev, I. 2002. Geobotanical regioning. In: Kopravlev, I. (ed.), *Geography of Bulgaria*. Publishing House ForCom. Sofia, pp. 336-351. (in Bulgarian)
- Bottema, S. 1974. *Late Quaternary Vegetation History of Northern Greece*. Theses. Groningen.
- Bottema, S. 1980. On the history of walnut (*Juglans regia* L.) in Southeastern Europe. *Acta Botanica Neerlandica* 29 (5/6), 343-349.
- Bottema, S. 1982. Palynological investigations in Greece with special reference to pollen as an indicator of human activity. *Palaeohistoria* 24, 257-289.
- Bottema, S. 2000. The Holocene history of walnut, sweet-chestnut, manna-ash and plane tree in the Eastern Mediterranean. *PALLAS* 52, 35-59.
- Bottema, S., Woldring, H. 1990. Anthropogenic indicators in the pollen record of the East-

- ern Mediterranean. In: Bottema, S., van Zeist, W., Entjes-Nieborg, G. (eds.), *Man's Role in the Shaping of the Eastern Mediterranean Landscape*. Balkema. Rotterdam, pp. 231-264.
- Bozhkova, A., Delev, P. 2002. *Koprivlen vol. 1: Rescue archaeological investigations along the Gotse Delchev-Drama Road 1998-1999*. NOUS Publishers. Sofia.
- Bozilova, E. 1972. Lateglacial and postglacial vegetation history of Rila Mountain. PhD Theses. Sofia University St. Kliment Ohridski. Sofia. (in Bulgarian)
- Bozilova, E. 1975. Changes of vegetation belts in Rila Mountain during Late and Postglacial time. *Bulletin Geologiczny* 19, 93-99.
- Bozilova, E. 1975a. Correlation of the vegetational development and climate changes during Late and Postglacial time in Rila and Pirin mountains compared to other areas. In: Jordanov, D. (ed.), *Problems of the Balkan Flora and Vegetation*. Bulgarian Academy of Sciences. Sofia, pp. 64-71.
- Bozilova, E. 1975b. Pollen-analytical investigations in Northeastern Pirin Mountain. *Annual Sofia University, Faculty of Biology* 69 (2), 20-25.
- Bozilova, E. 1976. Vegetation development in Rila Mountain in lateglacial and postglacial times on the basis of spore-pollen analyses. *Forest Science* 13 (5), 10-20. (in Bulgarian)
- Bozilova, E. 1977. Pollen-analytical Investigations in Eastern Rila mountain. *Annual Sofia University, Faculty of Biology* 68 (2), 53-60.
- Bozilova, E. 1977a. The late Holocene history of vegetation in Northwestern Pirin Mountain I. *Fitologija* 7, 18-24.
- Bozilova, E. 1981. Vegetation changes in the Rila Mountain for the last 12000 years. *Annual Sofia University, Faculty of Biology* 71 (2), 37-44. (in Bulgarian)
- Bozilova, E. 1986. Paleoeological conditions and vegetation changes in eastern and southwestern Bulgaria in the last 15000 years. DSc Theses. Sofia University St. Kliment Ohridski. Sofia. (in Bulgarian)
- Bozilova, E., Filipova, M., Filipovitch, L., Tonkov, S. 1996. 21. Bulgaria. In: Berglund, B. et al. (eds.), *Palaeoecological Events During the Last 15000 Years. Regional Syntheses of Palaeoecological Studies of Lakes and Mires in Europe*. John Wiley & Sons. Chichester, pp. 701-728.
- Bozilova, E., Jungner, H., Atanassova, J., Tonkov, S. 2004. A contribution to the Late Holocene vegetation history of the Northern Pirin Mountains, southwestern Bulgaria: palynological study and radiocarbon dating of Lake Muratovo. *Acta Palaeobotanica* 44 (2), 239-247.
- Bozilova, E., Smit, A. 1979. Palynology of Lake Suho Ezero from South Rila Mountain (Bulgaria). *Fitologija* 11, 54-67.
- Bozilova, E., Tonkov, S. 1983. Glacial refugia and migration routes of *Picea abies* (L.) Karst. and *Abies alba* Mill. on the territory of Bulgaria in the last 15000 years. In: Velchev, V. (ed.), *Third National Botanical Conference*. Bulgarian Academy of Sciences. Sofia, pp. 684-690. (in Bulgarian)
- Bozilova, E., Tonkov, S. 1985. Migration routes of some deciduous trees in Bulgaria during Lateglacial and Postglacial times. *Annual Sofia University, Faculty of Biology* 75 (2), 95-102.
- Bozilova, E., Tonkov, S. 1985a. Vegetational development in the mountainous areas of SW Bulgaria. I. Palynological investigations and reconstruction of past vegetation. *Ecologia Mediterranea* XI, 33-37.
- Bozilova, E., Tonkov, S. 1990. The impact of Man on the natural vegetation in Bulgaria from the Neolithic to the Middle Ages. In: Bottema, S., Entjes-Nieborg, G., van Zeist, W. (eds.), *Man's Role in the Shaping of the Eastern Mediterranean Landscape*. Balkema. Rotterdam, pp. 327-332.
- Bozilova, E., Tonkov, S. 2000. Pollen from Lake Sedmo Rilsko reveals southeast European postglacial vegetation in the highest mountain area of the Balkans. *New Phytologist* 148, 315-325.
- Bozilova, E., Tonkov, S. 2007. Palaeoecological Evidence of the Main Postglacial Vegetation and Climate Changes in Southwestern Bulgaria from the Neolithic to Modern Times. In: Stefanovic, M., Todorova, H. (eds.), *The Struma/Strymon River Valley in Prehistory. In the Steps of James Harvey Gaul 2*. James Harvey Gaul Foundation. Sofia, pp. 531-534.

- Bozilova, E., Tonkov, S. 2011. 14. Lake Sedmo Rilsko (Bulgaria): Lateglacial vegetation history. *Grana* 50 (3), 232-234.
- Bozilova, E., Tonkov, S., Marinova, E., Jungner, H. 2002. Pollen and plant macrofossil analyses of Late Holocene sediments from Lake Panichishte in Northwestern Rila Mountains. *Razprave IV. Razreda SAZU Ljubljana*, XLIII-2, pp. 37-51.
- Bozilova, E., Tonkov, S., Pavlova, D. 1990. Pollen and plant macrofossil analyses of the Lake Suho Ezero in the South Rila mountains. *Annual Sofia University, Faculty of Biology* 80 (2), 48-57.
- Bozilova, E., Tonkov, S., Popova, T. 1994. Forest clearance, land use and human occupation during the Roman colonization in Bulgaria. In: Frenzel, B. (ed.), *Palaeoclimate Research* 10. Gustav Fischer Verlag. Stuttgart, pp. 37-44.
- Bozilova, E., Atanassova, J., Tonkov, S., Stefanova, I. 2002. Late Holocene vegetation history of the northwestern Pirin Mts. II. Palaeoecological investigation of peat bogs in the Begovitsa river valley. *Annual Sofia University, Faculty of Biology* 90 (2), 23-30.
- Bradshaw, R. H. W., Kito, N., Giesecke, T. 2010. Factors influencing the Holocene history of *Fagus*. *Forest Ecology and Management* 259, 2204-2212.
- Bradshaw, R. H. W., Lindbladh, M. 2005. Regional spread and stand-scale establishment of *Fagus sylvatica* and *Picea abies* in Scandinavia. *Ecology* 86, 1679-1686.
- Bradshaw, R. H. W., Sykes, M. T. 2014. *Ecosystem Dynamics. From the Past to the Future*. Wiley Blackwell. Oxford.
- Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51 (1): 337-360.
- Brun, C. 2011. Anthropogenic indicators in pollen diagrams in eastern France: a critical review. *Vegetation History and Archaeobotany* 20, 135-142.
- Chakalova, E., Stoyanova, D., Tonkov, S. 1990. Plant macro-remains from Tschokljovo marsh (Konjavaska Mountain). *Annual Sofia University, Faculty of Biology* 80 (2), 41-47. (in Bulgarian)
- Chakalova, E., Dimitrova, T. 1980. Anatomical study of wood from the peat bog Suhoto Ezero in Rila. *Annual Sofia University, Faculty of Biology* 70 (2), 5-15. (in Bulgarian)
- Cheddadi, R., Yu, G., Guiot, J., Harrison, S., Prentice, I. 1997. The climate of Europe 6000 years ago. *Climate Dynamics* 13, 1-9.
- Chohadziev, S. 2006. Slatino: prehistoric settlements. Faber. Veliko Tarnovo. (in Bulgarian)
- Chohadziev, S., Genadieva, V., Gjurova, M., Popova, Tz., Ninov, L. 2001. Vaxevo - Prehistorical Settlements. Faber. Veliko Tarnovo. (in Bulgarian)
- Dansgaard, W., Johnsen, S. J., Clausen, H. B., et al. 1993. Evidence for general instability of past climate from a 250-kyr ice-core record. *Nature* 364, 218-220.
- Davis, B., Brewer, S., Stevenson, A., Guiot, J. and Data Contributors. 2003. The temperature of Europe during the Holocene reconstructed from pollen data. *Quaternary Science Reviews* 22, 1701-1716.
- Davis, M. B., Brubaker, L. B., Webb, T. III. 1973. Calibration of absolute pollen influx. In: Birks, H. J. B., West, R. G. (eds.), *Quaternary plant ecology*. Blackwell Scientific Publications. Oxford, pp. 9-25.
- de Klerk, P. 2004. Confusing concepts in Lateglacial stratigraphy and geochronology: origin, consequences, conclusions (with special emphasis on the type locality Bøllingsø). *Review of Palaeobotany and Palynology* 129, 265-298.
- Dechev, D. 1933. The sanctuary in the Tschokljovo marsh. *Bulletin of the Bulgarian Archaeological Institute* 7, 383-386. (in Bulgarian)
- Dimitrov, D. 1974. The climatic resources of Bulgaria. Nauka i Izkustvo. Sofia. (in Bulgarian)
- Faegri, K., Iversen, J. 1989. *Textbook of pollen analysis*. 4th edition. John Wiley & Sons. Chichester.
- Farcas, S., de Beaulieu, J.-L., Reille, M., Coldea, G., Diaconeasa, B., Goeury, C., Goslar, T., Yull, T. 1999. First C¹⁴ datings of Late Glacial and Holocene pollen sequences from Romanian Carpathes. *Science de la vie, C. R. Acad. Paris* 322, 799-807.
- Feurdean, A., Tantau, I. 2017. The Evolution of Vegetation from the Last Glacial Maximum Until the Present. In: M. Rădoane, M., Vespremeanu-Stroe, A. (eds.), *Landform Dynamics and Evolution in Romania*. Springer Geography. Switzerland, pp. 67-86.
- Feurdean, A., Tonkov, S., Pfeiffer, M., Panait, A., Warren, D., Vanni ere, B., Marinova, E. 2019. Fire

- frequency and intensity associated with functional traits of dominant forest type in the Balkans during the Holocene. *European Journal of Forest Research* 138 (6), 1049-1066.
- Filipova-Marinova, M. 1995. The Late Quaternary history of the genus *Fagus* L. in Bulgaria. In: Bozilova, E., Tonkov, S. (eds.), *Advances in Holocene Palaeoecology in Bulgaria*. Pensoft Publishers. Sofia-Moscow, pp. 84-95.
- Filipović, D., Meadows, J., Corso M. D., Kirleis, W., Alsleben, A., Akeret, Ö., et al. 2020. New AMS ¹⁴C dates track the arrival and spread of broomcorn millet cultivation and agricultural change in prehistoric Europe. *Scientific Reports* 10:13698. <https://doi.org/10.1038/s41598-020-70495-z>
- Finsinger, W., Tinner, W. 2020. New insights on stomata analysis of European conifers 65 years after the pioneering study of Werner Trautmann (1953). *Vegetation History and Archaeobotany* 29, 393-406.
- Galabov, Zh., Ivanov, I., Penchev, P., Mishev, K., Nedelcheva, V. 1977. Physical geography of Bulgaria. Narodna Prosveta. Sofia. (in Bulgarian)
- Gerasimidis, A., Athanasiadis, N. 1995. Woodland history of northern Greece from the mid Holocene to recent time based on evidence from peat profiles. *Vegetation History and Archaeobotany* 4, 109-116.
- Giesecke, T., Fontana, S. 2008. Revisiting pollen accumulation rates from Swedish lake sediments. *The Holocene* 18 (2), 293-305.
- Giesecke, T., Hickler, T., Kunkel, T., Sykes, M. T., Bradshaw, R. H. W. 2007. Towards an understanding of the Holocene distribution of *Fagus sylvatica* L. *Journal of Biogeography* 34, 118-131.
- Glovnya, M. 1958. Geomorphological researches in Southwestern Rila Mountain. *Annual Sofia University, Faculty of Biology, Geology and Geography* 51 (3), 70-173. (in Bulgarian)
- Glovnya, M. 1962. Investigation on the glacial morphostructure in the Eastern Rila Mountain. *Annual Sofia University, Faculty of Biology, Geology and Geography*, 55 (3), 1-51. (in Bulgarian)
- Glovnya, M. 1969. Glacial and periglacial relief in the southern part of the Central Rila Mountain. *Annual Sofia University, Faculty of Geology and Geography*, 61 (2), 37-69. (in Bulgarian)
- Görsdorf, J., Bojadziev, J. 1997. Zur absoluten Chronologie der bulgarischen Urgeschichte. Berliner C¹⁴ Datierungen von bulgarischen archaologischen Fundplätzen. *Eurasia Antiqua* 2, 105-173.
- Grebska-Kulow, M., Kulow, I. 2007. Prehistorical Sites in the Middle Struma River Valley Between the End of the 7th mill. BC and the Beginning of the 1st mill. BC. In: Todorova, H., Stefanovic, M., Ivanov, G. (eds.), *In the Steps of James Harvey Gaul. The Struma/Strymon River Valley in Prehistory*. vol. 2. Gerda Henkel Stiftung. Sofia, pp. 279-296.
- Grimm, E. 1987. CONISS: A Fortran 77 Program for stratigraphically constraint cluster analysis by the method of incremental squares. *Computer Science* 13, 13-35.
- Grimm, E. 1991-2015. *Tilia* (ver.2.0.41). Springfield. Illinois State Museum. Springfield. USA.
- Grove, J. 1988. *The Little Ice Age*. Routledge. London.
- Grünwald, K., Scheithauer, J. 2011. *Landscape Development and Climate Change in Southwest Bulgaria (Pirin Mountains)*. Springer. Dordrecht.
- Hoek, W. Z. 1997. Late-glacial and early Holocene climatic events and chronology of vegetation development in the Netherlands. *Vegetation History and Archaeobotany* 6, 197-213.
- Hoek, W. Z., Bohncke, S. J. P. 2001. Oxygen-isotope wiggle matching as a tool for synchronising ice-core and terrestrial records over Termination 1. *Quaternary Science Reviews* 20, 1251-1264.
- Hoevers, R. 2017. *Plant macrofossils as proxy for Holocene tree-line changes in Southeastern Europe - a case study of the Rila Mountains, Bulgaria*. MSc. Theses. Center for Archaeological Sciences of the KU Leuven, Belgium.
- Hughes, P., Woodward, G., Gibbard, P. 2006. Quaternary glacial history of the Mediterranean mountains. *Progress in Physical Geography* 30 (3), 334-364.
- Huntley, B., Bartlein, P., Prentice, I. 1989. Climatic control of the distribution and abundance of beech (*Fagus* L.) in Europe and North America. *Journal of Biogeography* 16, 551-560.
- Huntley, B., Birks, H. J. B. 1983. *An atlas of past and present maps for Europe: 0-13000 years ago*. Cambridge University Press. Cambridge.

- Husen, D. 1989. The last interglacial-glacial cycle in the eastern Alps. *Quaternary International* 3/4, 115-121.
- Ivanov, I. 1954. Geomorphological research in the western part of Northwestern Rila Mountain. *Issues of the Institute of Geography. Bulgarian Academy of Sciences* 2, 7-89. (in Bulgarian)
- Ivanov, K. (ed). 1964. The lakes in Bulgaria. Nauka i Izkustvo. Sofia. (in Bulgarian)
- Ivanova, M., De Cupere, B., Ethier, J., Marinova, E. 2018. Pioneer farming in southeast Europe during the early sixth millennium BC: Climate-related adaptations in the exploitation of plants and animals. *PLoS ONE* 13:e0197225.
- Iversen, J. 1947. The influence of prehistoric man on vegetation. *Danmarks Geologiske Undersøgelse* 4, 1-25.
- Jalut, G., Carrion, J., David, F., Gonzalez-Samperiz, P., Sanchez Goni, M. F., Tonkov, S., Willis, K. 2005. The vegetation around the Mediterranean basin during the last glacial maximum and the Holocene climatic optimum. In: Petit-Mair, N., Vrielinck, B. (eds), *The Mediterranean basin: The last two climatic extremes. Explanatory notes of the maps (scale 1/5000000)*. MMSH and ANDRA. Aix en Provence, pp. 37-57.
- Jalut, G., Monserrat, M., Fontugne, M., Delebrias, G., Vilaplana, J., Julia, R. 1992. Glacial to interglacial vegetation changes in northern and southern Pyrenees: deglaciation, vegetation cover and chronology. *Quaternary Science Reviews* 11, 449-480.
- Johnsen, S., Clausen, H., Dansgaard, W., et al. 1997. The $\delta^{18}\text{O}$ record along the Greenland Ice Core project deep ice core and the problem of possible Eemian climatic instability. *Journal of Geophysical Research* 102 (26), 397-410.
- Jordanov, D. (ed). 1963-2012. *Flora Reipublicae Bulgariae*. vol. I-XI. Academic Publishing House Prof. Marin Drinov. Sofia. (in Bulgarian)
- Jordanov, D. 1929. A new small contribution to the flora of Bulgaria. *Notices of the Bulgarian botanical society* 3, 285-291. (in Bulgarian)
- Jordanov, D. 1931. Phytogeographical studies of swamps in Bulgaria in connection with their higher vegetation. *Annual Sofia University, Faculty of Physics and Mathematics* 27 (3), 75-156. (in Bulgarian)
- Jordanov, D. 1947. Materials and critical notes for studying the flora of Bulgaria. *Annual Sofia University, Faculty of Physics and Mathematics* 43 (3), 97-112. (in Bulgarian)
- Katz, N., Katz, S., Kipiani, M. 1977. Atlas and keys of fruits and seeds occurring in the Quaternary deposits of the USSR. Nauka. Moscow. (in Russian)
- Kitanov, B., Koeva, J., Stojanov, D. 1986. Chorological data on the high flora of the mountains in southwestern Bulgaria. *Annual Sofia University, Faculty of Biology* 77 (2), 61-69. (in Bulgarian)
- Koeva, M. 1989. Rila Monastery. Sofia Press. Sofia.
- Koleva, E., Peneva, R. 1990. Climate reference book. Precipitation in Bulgaria. Bulgarian Academy of Sciences. Sofia. (in Bulgarian)
- Konstantinov, H. 1979. Morphostructural development of Konyavska Mountain in Neogene and Quaternary. *Annual Sofia University, Faculty of Geology and Geography* 73 (2), 15-30. (in Bulgarian)
- Kozuharov, S. (ed.). 1992. Guide to higher plants in Bulgaria. Nauka i Izkustvo. Sofia. (in Bulgarian)
- Krauß, R., Marinova, E., De Brue, H., Weninger, B. 2018. The rapid spread of early farming from the Aegean into the Balkans via the Sub-Mediterranean-Aegean Vegetation Zone. *Quaternary International* 496, 24-41.
- Krebs, P., Conedera, M., Pradella, M., Torriani, D., Felber, M., Tinner, W. 2004. Quaternary refugia of the sweet chestnut (*Castanea sativa* Mill.): an extended palynological approach. *Vegetation History and Archaeobotany* 13, 145-160.
- Kreuz, A., Marinova, E., Schäfer, E., Wiethold, J. 2005. A comparison of early Neolithic crop and weed assemblages from the Linearbandkeramik and the Bulgarian Neolithic cultures: differences and similarities. *Vegetation History and Archaeobotany* 14, 237-258.
- Kuhlemann, J., Gachev, E., Gikov, A., Nedkov, S. 2008. Glacial extent in the Rila Mountain (Bulgaria) as part of an environmental reconstruction of the Mediterranean during the Last Glacial Maximum (LGM). *Problems of Geography* 3-4, 87-96.
- Kuhlemann, J., Gachev, E., Gikov, A., Nedkov, S., Krumrei, I., Kubik, P. 2013. Glaciation in the Rila

- mountains (Bulgaria) during the Last Glacial Maximum. *Quaternary International* 293, 51-62.
- Labeyrie, L., Cole, J., Alverson, K., Stocker, T., et al. 2003. The History of Climate Dynamics in the Late Quaternary. In: Alverson, K., et al. (eds.), *Palaeoclimate, Global Change and the Future*. Springer. Berlin, pp. 33-61.
- Lang, G. 1994. *Quartäre Vegetationsgeschichte Europas*. Gustav Fischer Verlag. Jena.
- Latalowa, M., van der Knaap, W.O. 2006. Late Quaternary expansion of Norway spruce *Picea abies* (L.) Karst. in Europe according to pollen data. *Quaternary Science Reviews* 25 (21-22), 2780-2805.
- Lazarova, M., Marinova, E., Tonkov, S., Snowball, I. 2015. A 5000-year pollen and plant macrofossil record from the Osogovo Mountain, Southwestern Bulgaria: Vegetation history and human impact. *Review of Palaeobotany and Palynology* 223, 1-9.
- Lazarova, M., Tonkov, S., Snowball, I., Marinova, E. 2009. 6. Peat-bog Begbunar (Osogovo Mts., SW Bulgaria): Four millennia of vegetation history. *Grana* 48, 147-149.
- Lichardus-Itten, M., Demoule, J-P., Perniceva, L., Grebska-Kulowa, M, Kulow, I. 2002. The Site of Kovacevo and the Beginnings of the Neolithic Period in Southwestern Bulgaria. The French-Bulgarian Excavations 1986-2000. In: Lichardus-Itten, M., Lichardus, J., Nikolov, V. (eds.). *Beiträge zu Jungsteinzeitlichen Forschungen in Bulgarien*. Bonn, pp. 99-159.
- Lichardus-Itten, M., Demoule, J-P., Perniceva, L., Grebska-Kulowa, M. 2006. Kovachevo, an early Neolithic site in South-West Bulgaria and its importance for the European neolithization. In: Gatsov, I., Schwarzberg, H. (eds.), *Aegean-Marmara-Black Sea: the present state of research on the early Neolithic*. Schriften des Zentrums für Archäologie und Kulturgeschichte des Schwarzmeerraumes 5, pp. 83-94.
- Lilienberg, D. A., Popov, V. 1966. New data on glaciation of the Pirin massif (Rhodope). *Dokladi USSR Academy of Sciences* 167 (5), 1119-1122. (in Russian)
- Lotter, A. F., Eicher, U., Siegenthaler, U., Birks, H. J. B. 1992. Lateglacial climatic oscillations as recorded in Swiss lake sediments. *Journal of Quaternary Science* 7, 187-205.
- Lotter, A., Hofmann, G. 2003. The development of the late-glacial and Holocene diatom flora in Lake Sedmo Rilsko (Rila mountains, Bulgaria). In: Tonkov, S. (ed.), *Aspects of Palynology and Palaeoecology*. Pensoft Publishers, Sofia-Moscow, pp. 171-184.
- MacDonald, G. M. 2001. Conifer stomata. In: Smol, J. P., et al. (eds.), *Tracking Environmental Change Using Lake Sediments. Developments in Paleoenvironmental Research*. vol. 3. Springer. Netherlands, pp. 33-47.
- Magyari, E. K., Jakab, G., Bálint, M., Kern, Z., Buczkó, K., Braun, M. 2012. Rapid vegetation response to Lateglacial and early Holocene climatic fluctuation in the South Carpathian Mountains (Romania). *Quaternary Science Reviews* 35, 116-130.
- Marinova, E. 2006. *Vergleichende paläoethnobotanische Untersuchung zur Vegetationsgeschichte und zur Entwicklung der prähistorischen Landnutzung in Bulgarien*. *Dissertatione Botanicae* 401. J. Cramer. Stuttgart.
- Marinova, E. 2017. Archaeobotanical analysis of the Neolithic site Bâlgarčevo, Southwestern Bulgaria. In: Lechterbeck, J., Fischer, E. (eds.), *Kontrapunkte. Festschrift für Manfred Rösch, Universitätsforschungen zur prähistorischen Archäologie* 300. Verlag Dr. Rudolf Habelt. Bonn, pp. 147-158.
- Marinova, E., Cupere, B., Nikolov, V. 2016. Preliminary results of the bioarchaeological research at the Neolithic site of Mursalevo (Southwest Bulgaria): evidence on food storage, processing and consumption from domestic contexts. In: Băčvarov, K., Gleser, R. (eds.), *Southeast Europe and Anatolia in prehistory. Essays in honour of Vassil Nikolov on his 65th anniversary*. Universitätsforschungen zur prähistorischen Archäologie, 293. Verlag Dr. Rudolf Habelt. Bonn, pp. 509-518.
- Marinova, E., Ntinou, M. 2018. Neolithic woodland management and land-use in south-eastern Europe: The anthracological evidence from Northern Greece and Bulgaria. *Quaternary International* 496, 51-67.
- Marinova, E., Popova, Tz. 2008. *Cicer arietinum* (chick pea) in the Neolithic and Chalcolithic of Bulgaria: Implications for cultural contacts with

- the neighbouring regions? *Vegetation History and Archaeobotany* 17, 73–80.
- Marinova, E., Tchakalova, E., Stoyanova, D., Grozeva, S., Dočeva, E. 2002. Ergebnisse archäobotanischer Untersuchungen aus dem Neolithikum und Chalcolithikum in Südwestbulgarien. *Archaeologia Bulgarica* 6, 1–11.
- Marinova, E., Thiebault, S. 2008. Anthracological analysis from Kovacevo, southwest Bulgaria: woodland vegetation and its use during the earliest stages of the European Neolithic. *Vegetation History and Archaeobotany* 17, 223–231.
- Marinova, E., Tonkov, S. 2003. Macrofossil records of tree species in the sediments of Lake Panichishte (Northwestern Rila Mts.). In: Rosnev, B. (ed.), Proceedings International Scientific Conference “75 Years of the Forest Research Institute of Bulgarian Academy of Sciences”. vol. 1, pp. 266–270.
- Marinova, E., Tonkov, S. 2012. Holocene vegetation history of the northwestern Pirin Mountain (Bulgaria). Plant fossil record from peat-bog Mozgovitsa. *Comptes rendus de l'Academie bulgare des Sciences* 65 (8), 1087–1094.
- Marinova, E., Tonkov, S., Bozilova, E., Vajsov, I. 2012. Holocene anthropogenic landscapes in the Balkans: the palaeobotanical evidence from southwestern Bulgaria. *Vegetation History and Archaeobotany* 21 (4–5), 413–427.
- Marinova, E., Valamoti, S. 2014. 3.2. Crop diversity and choices in the prehistory of SE Europe: the archaeobotanical evidence from Greece and Bulgaria. In: Chevalier A., Marinova, E., Peña-Chocarro, L. (eds.), *Plants and People: Choices and Diversity Through Time*. Oxbow Books. Oxford, pp. 64–74.
- Mauri, A., Davis, B. A. S., Collins, P. M., Kaplan, J. O. 2013. The influence of atmospheric circulation on the mid-Holocene climate of Europe: a data-model comparison. *Climate Past Discussions* 9, 5569–5592.
- Moore, P., Webb, J. 1978. *An Illustrated Guide to Pollen Analysis*. Hodder and Stoughton. London.
- Moore, P., Webb, J., Collinson, M. 1991. *Pollen Analysis*. 2nd edition. Blackwell. Oxford.
- NGRIP Members. 2004. High-resolution record of Northern Hemisphere climate extending into the last interglacial period. *Nature* 431, 147–51.
- Nikolov, V. 2007. Problems of the early stages of the neolithisation in the southeast Balkans. In: Spataro, M., Biagi, P. (eds.), *A Short Walk through the Balkans: the First Farmers of the Carpathian Basin and Adjacent Regions*. Quaderno (Trieste). vol. 12, pp. 183–188.
- Nikolov, V., Jordanova, M. 2002. The mountains in Bulgaria. Academic Publishing House “Prof. Marin Drinov”. Sofia. (in Bulgarian)
- Ninov, N. 1997. Soils. In: Jordanova, M., Donchev, D. (eds.), *Geography of Bulgaria*. Academic Publishing House “Prof. Marin Drinov”. Sofia, pp. 225–259. (in Bulgarian)
- Panovska, H., Bozilova, E., Tonkov, S. 1990. Late Holocene vegetation history in the western Part of Belasitza Mountain. In: Lazaros, S. (ed.), *Geographica Rhodopica 2. Scientific Annals*. Aristotle University Press. Thessaloniki, pp. 1–7.
- Panovska, H., Bozilova, E., Tonkov, S. 1995. A palaeoecological investigation on the vegetation history in the Southern Pirin Mts. (Southwestern Bulgaria). In: Bozilova, E., Tonkov, S. (eds.), *Advances in Holocene Palaeoecology in Bulgaria*. Pensoft Publishers, Sofia-Moscow, pp. 32–46.
- Pernicheva, L. 1995. Prehistoric cultures in the middle Struma valley: Neolithic and Eneolithic. In: Bailey, D., Panayotov, I. (eds.), *Prehistory of Bulgaria*. Monographs in World Archaeology. Madison, Wisconsin. vol. 22, pp. 99–128.
- Petrov, S. 1956. Peat bogs nearby springs in the spruce forests of Vitosha Mountain. *Bulletin Botanical Institute. Bulgarian Academy of Sciences* 5, 293–346. (in Bulgarian)
- Popov, V. 1966. Pirin. *Nauka i Izkustvo*. Sofia. (in Bulgarian)
- Popova, Tz. 1998. Etude carpologique et anthracologique de tell Kajmenska Cuka (Blagoevgrad). Bronze final. In: Roman, P. (ed.), *The Thracian World at the crossroad of civilisation II*. Bucharest, pp. 477–483.
- Popova, Tz. 2003. Paleobotanical investigations in the area of Koprivlen. In: Delev, P., Bozkova, A. (eds.), *Koprivlen*. vol. 1. Bulgarian Academy of Sciences, pp. 279–289. (in Bulgarian)
- Popova, Tz. 2009. Paleobotanic catalogue of the studied sites and studied remains (debris) in the territory of Bulgaria (1980–2008).

- Interdisciplinary Studies* 20/21, 71-165. (in Bulgarian)
- Popova, Tz., Marinova, E. 2007. Palaeobotanical Data in South-Western Region of Bulgaria. In: Todorova, H., Stefanovic, M., Ivanov, G. (eds.), *In the Steps of James Harvey Gaul. The Struma/Strymon River Valley in Prehistory*. vol. 2. Gerda Henkel Stiftung. Sofia, pp. 499-508.
- Ravazzi, C. 2002. Late Quaternary history of spruce in southern Europe. *Review of Palaeobotany and Palynology* 120 (1-2), 131-177.
- Reimer, P. J., Bard, E., Bayliss, A., et al. 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon* 55 (4), 1869-1887.
- Roces-Díaz, J., Jiménez-Alfaro, B., Chytrý, M., Díaz-Varela, M., Álvarez-Álvarez, P. 2018. Glacial refugia and mid-Holocene expansion delineate the current distribution of *Castanea sativa* in Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology* 491, 152-160.
- Rohling, E. J., Palike, H. 2005. Centennial-scale climate cooling with a sudden cold event around 8,200 years ago. *Nature* 434, 975-979.
- Schoch, W., Pavlik, B., Schweingruber, F. 1988. Botanical macroremains. Paul Haupt. Bern.
- Schweingruber, F. 1990 *Anatomy of European woods*. Haupt. Stuttgart.
- Seppä, H., Alenius, T., Muukkonen, P., Giesecke, T., Miller, P., Ojala, A. 2009. Calibrated pollen accumulation rates as a basis for quantitative tree biomass reconstructions. *The Holocene* 19 (2), 209-220.
- Stanev, S., Kyuchukova, M., Lingova, S. (eds.). 1991. *The Climate of Bulgaria*. Bulgarian Academy of Sciences. Institute of Meteorology and Hydrology. Sofia. (in Bulgarian)
- Stefanova, I. 1997. New data on the Late Holocene vegetation succession in the Northern Pirin Mountains: pollen and macrofossil analyses of depositions from the peat bogs of Goče Delchev and Visokata Ela. *Phytologia Balcanica* 3 (2-3), 53-64.
- Stefanova, I., Ammann, B. 2003. Lateglacial and Holocene vegetation belts in the Pirin Mountains (southwestern Bulgaria). *The Holocene* 13 (1), 97-107.
- Stefanova, I., Atanassova, J., Delcheva, M., Wright, H. E. 2006. Chronological framework for the Late Glacial pollen and macrofossil sequence in the Pirin Mountains, Bulgaria: Lake Besbog and Lake Kremensko-5. *The Holocene* 16 (6), 877-892.
- Stefanova, I., Bozilova, E. 1992. Model of palynological investigation with the application of correction factors from northeastern Pirin Mountain. *Annual Sofia University, Faculty of Biology* 81 (2), 31-43. (in Bulgarian)
- Stefanova, I., Bozilova, E. 1995. Studies on the Holocene history of vegetation in the Northern Pirin Mts. (Southwestern Bulgaria). In: Bozilova, E., Tonkov, S. (eds.), *Advances in Holocene Palaeoecology in Bulgaria*. Pensoft Publishers. Sofia-Moscow, pp. 9-31.
- Stefanova, I., Lazarova, M., Wright, H. E. 2006a. Elevational gradients during the Late-Glacial/Holocene vegetational transition in southern Bulgaria. *Vegetation History and Archaeobotany* 15 (4), 333-343.
- Stefanova, I., Oeggl, K. 1993. Zur holozänen Vegetationsgeschichte SW-Bulgariens: Das Moor Praso (1900 m) im Pirin Gebirge. *Berichte des naturwissenschaftlichen-medizinischen Verein Innsbruck* 80, 69-80.
- Stefanova, I., Ognjanova-Rumenova, N., Hoffmann, W., Ammann, B. 2003. Late Glacial and Holocene environmental history of the Pirin Mountains (SW Bulgaria): a palaeolimnological study of Lake Dalgoto (2310 m). *Journal of Paleolimnology* 30, 95-111.
- Stockmarr, J. 1971. Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13, 615-621.
- Stoichev, K., Petrov, P. 1980. Rila. Nature and Resources. Nauka i Izkustvo, Sofia. (in Bulgarian)
- Stojanov, N., Georgiev, T. 1934. Pollenanalytische Untersuchungen auf dem Vitosa-Gebirge. *Journal of Bulgarian Academy of Sciences*, XLVII (25), 73-104.
- Stojanov, N. 1921. Floristic materials from Belasitsa. *Annual Sofia University, Faculty of Physics and Mathematics* 15/16, 1-134. (in Bulgarian)
- Stojanov, N. 1935. Notes on the vegetation of the former Kyustendil district. *Collection of Bulgar-*

- ian Academy of Sciences 30 (14), 3-15. (in Bulgarian)
- Stojanov, N. 1941. An attempt to characterize the main phytocenoses in Bulgaria. *Annual Sofia University, Faculty of Physics and Mathematics* 37 (3), 93-187. (in Bulgarian)
- Struzkova, D. 2002. Cuticular analysis - a method to distinguish the leaves of *Pinus sylvestris* L. (Scots Pine) from those of *Pinus mugo* s. str. (Dwarf Mountain-pine). *Vegetation History and Archaeobotany* 11 (3), 241-246.
- Stuiver, M., Grootes, P., Braziunas, T. 1995. The GISP2 ¹⁸O climate record of the past 16500 years and the role of the sun, ocean and volcanoes. *Quaternary Research* 44, 341-354.
- Sweeney, C. A. 2004. A key for the identification of stomata of the native conifers of Scandinavia. *Review of Palaeobotany and Palynology* 128, 281-290.
- Tanno, K.-L., Willcox, G. 2006. How Fast Was Wild Wheat Domesticated? *Science* 311, 1886.
- Tanno, K.-I., Willcox, G. 2006a. The origins of cultivation of *Cicer arietinum* L. and *Vicia faba* L.: Early finds from Tell el-Kerkh, north-west Syria, late 10th millennium B.P. *Vegetation History and Archaeobotany* 15 (3), 197-204.
- Tinner W., Hu, F. S. 2003. Size parameters, size-class distribution and area-number relationship of microscopic charcoal: relevance for fire reconstruction. *The Holocene* 13 (4), 499-505.
- Tishkov, H. 1976. The climate of the mountainous areas in Bulgaria. Sofia. (in Bulgarian)
- Tobolski, K. 2000. A Guide to Peat and Lake Deposits. *Vademecum Geobotanicum*. Naukowe PWN. Warszawa. (in Polish)
- Todorov, N., Penin, R., Cholakova, Z., Konteva, M., Stoilkova, T. 2014. Landscape features of the southern part of Vlahina Mountain. *Annual Sofia University, Faculty of Geology and Geography* 106 (2), 135-170. (in Bulgarian)
- Todorov, N., Penin, R., Cholakova, Z., Konteva, M., Stoilkova, T. 2016. Spatial structure and geo-ecological problems of Maleshevska Mountain landscapes. *Annual Sofia University, Faculty of Geology and Geography* 108 (2), 183-216. (in Bulgarian)
- Todorova, H. 1989. Das Frühneolithikum Nordostbulgariens in Kontext des Ostbalkanischen Neolithikums. In: Hiller, St., Nikolov, V. (eds.), *Tell Karanovo und das Balkan-Neolithikum*. Salzburg, pp. 9-25.
- Todorova, H., Stefanovich, M., Ivanov, G. 2007. Introduction. In: Todorova, H., Stefanovic, M., Ivanov, G. (eds.), *In the Steps of James Harvey Gaul. The Struma/Strymon River Valley in Prehistory*. vol. 2. Gerda Henkel Stiftung. Sofia, pp. 1-8.
- Todorova, H., Vaisov, I. 1989. The Neolithic in Bulgaria. *Nauka i Izkustvo*. Sofia. (in Bulgarian)
- Tolonen, K. 1986. Charred particle analysis. In: Berglund, B. (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley & Sons. Chichester, pp. 485-496.
- Tonkov, S. 1988. Sedimentation and local vegetation development of a reference site in SW Bulgaria. In: Lang, G., Schluchter, Ch. (eds.), *Lake, Mire and River Environments*. Balkema. Rotterdam, pp. 99-101.
- Tonkov, S. 1992. Pollen-analytical study on the vegetation history in the Vlahina Mountain. *Annual Sofia University, Faculty of Biology* 81 (2), 22-30. (in Bulgarian)
- Tonkov, S. 1994. Pollen analysis of peat-bog in Osogovo mountain (Southwestern Bulgaria). *Annual Sofia University, Faculty of Biology* 85 (2), 63-68.
- Tonkov, S. 2003. Holocene palaeovegetation in the northwestern Pirin Mountains as reconstructed from pollen analysis. *Review Palaeobotany and Palynology* 124 (1/2), 51-61.
- Tonkov, S. 2003a. A 5000-year pollen record from Osogovo Mountains, Southwestern Bulgaria. In: Tonkov, S. (ed.), *Aspects of Palynology and Palaeoecology*. Pensoft Publishers. Sofia-Moscow, pp. 233-244.
- Tonkov, S. 2007. Paleobotanical and paleoecological investigations on the postglacial vegetation history in southwestern Bulgaria. DSc Theses. Sofia University St. Kliment Ohridski. Sofia. (in Bulgarian)
- Tonkov, S., Atanassova, J., Bozilova, E., Skog, G. 1998. Pollen analysis of Lake Suho Ezero (Rila Monastery area, Central Rila Mts.). *Phytologia Balcanica* 4/3, 31-38.

- Tonkov, S., Bozilova, E. 1988. Distribution of *Abies* in southwestern Bulgaria in postglacial time. In: Velkov, D. (ed.), Papers 10th Congress of Dendrologists. Bulgarian Academy of Sciences. Sofia, pp. 338-342. (in Russian)
- Tonkov, S., Bozilova, E. 1992. Paleoeological investigation of Tschokljovo marsh (Konyavska Mountain). *Annual Sofia University, Faculty of Biology* 83 (2), 5-16.
- Tonkov, S., Bozilova, E. 1992a. Pollen analysis of a peat bog from Maleshevska Mountain (south-western Bulgaria). *Annual Sofia University, Faculty of Biology* 81 (2), 11-21. (in Bulgarian)
- Tonkov, S., Bozilova, E., Possnert, G. 2013. Postglacial vegetation history as recorded from the subalpine Lake Ribno (NW Rila Mts.), Bulgaria. *Central European Journal of Biology* 8 (1), 64-77.
- Tonkov, S., Bozilova, E., Possnert, G., Velchev, A. 2008. A contribution to the postglacial vegetation history of the Rila Mountains, Bulgaria: The pollen record of Lake Trilistnika. *Quaternary International* 190, 58-70.
- Tonkov, S., Marinova, E. 2005. Pollen and plant macrofossil analyses of mid-Holocene radiocarbon dated profiles from two subalpine lakes in Rila Mountains, Bulgaria. *The Holocene* 15 (5), 663-671.
- Tonkov, S., Marinova, E., Feurdean, A. 2018. 38. Peat bog Vapsko-1, Rila Mountains (Bulgaria). *Grana* 57 (1-2), 158-160.
- Tonkov, S., Marinova, E., Feurdean, A. 2019. 44. Peat bog Vapsko-2, Rila Mountains (Bulgaria). *Grana* 58 (5), 393-395.
- Tonkov, S., Panovska, H., Possnert, G., Bozilova, E. 2002. The Holocene vegetation history in the Northern Pirin Mountain, southwestern Bulgaria: pollen analysis and radiocarbon dating of core from Lake Ribno Banderishko. *The Holocene* 12 (2), 201-210.
- Tonkov, S., Lazarova, M., Bozilova, E., Ivanov, D., Snowball, I. 2014. A 30,000-year pollen record from Mire Kupena, Western Rhodopes Mountains (south Bulgaria). *Review of Palaeobotany and Palynology* 209, 41-51.
- Tonkov, S., Possnert, G. 2014. 25. Mire Gyola, Belasitsa Mountain (south-western Bulgaria). *Grana* 53 (4), 312-314.
- Tonkov, S., Possnert, G. 2021. Lake Ribno Banderishko, Pirin Mountain (Bulgaria). *Grana* (in press).
- Tonkov, S., Possnert, G., Bozilova, E. 2006. Lateglacial vegetation and radiocarbon dating of Lake Trilistnika, Rila Mountain (Bulgaria). *Vegetation History and Archaeobotany* 16 (1), 15-22.
- Tonkov, S., Possnert, G., Bozilova, E. 2020. 46. Lake Panichishte, Rila Mountains (Bulgaria). *Grana* 59 (5), 396-398.
- Tonkov, S., Velichkov, I., Popov, G., Possnert, G., Zlatanov, Tz., Hinkov, G. 2012. On the Holocene history of sweet chestnut forests in Belasitsa Mountain, Southwestern Bulgaria. *Comptes rendus de l'Academie bulgare des Sciences* 65 (11), 1549-1554.
- Trautmann, W. 1953. Zur Unterscheidung fossiler Spaltöffnungen der mitteleuropäischen Coniferen. *Flora* 140, 523-533.
- Tzedakis, P. C. 2004. The Balkans as Prime Glacial Refugial Territory of European Temperate Trees. In: Griffiths, H. I., Kryštufek, B., Reed, J. M. (eds.), *Balkan Biodiversity*. Springer. Dordrecht, pp.49-68.
- Valamoti, S. M. 2007. Agriculture and Use of Space at Promachon/Topolnica. Preliminary observations on the archaeobotanical material. In: Todorova, H., Stefanovic, M., Ivanov, G. (eds.), *In the Steps of James Harvey Gaul. The Struma/Strymon River Valley in Prehistory*. vol. 2. Gerda Henkel Stiftung. Sofia, pp. 523-530.
- van Geel, B., Raspopov, O., van der Plicht, J., Renssen, H. 1998. Solar Forcing of Abrupt Climate Change around 850 Calendar Years BC. In: Peiser, B. J., Palmer, T., Bailey, M. E. (eds.), *Natural catastrophes during Bronze age civilisation*. BAR International series 728, pp. 162-168.
- Velchev, A. 1995. The Pleistocene glaciations in the Bulgarian mountains. *Annual Sofia University, Faculty of Geology and Geography* 87 (2), 53-65. (in Bulgarian)
- Velchev, A. 1999. Glacial and cryogenic relief in the Musala part of the Rila Mountain. *Annual Sofia University, Faculty of Geology and Geography* 89 (2), 7-21. (in Bulgarian)
- Velchev, A. 2014. *General Geology and Geomorphology*. University Publishing House "St. Cyril and St. Methodius". Veliko Tarnovo. (in Bulgarian).

- Velchev, A. 2020. Pleistocene glaciations and present-day alpine and subalpine landscapes in Bulgaria. *Geograph BG*. Sofia. (in Bulgarian)
- Velchev, A., Kenderova, R. 1994. Some views on the Pleistocene and Holocene development of the Mozgovitsa river valley. *Annual Sofia University, Faculty of Geology and Geography* 85 (2), 29-42. (in Bulgarian)
- Velchev, A., Todorov, N., Kostadinov, K. 1994. Development and contemporary state of the subalpine landscapes at the Osogovo Mountain. *Annual Sofia University, Faculty of Geology and Geography* 85 (2), 181-198. (in Bulgarian)
- Velchev, A., Tonkov, S., Bozilova, E. 2011. Palaeogeomorphological and palaeoecological development of the northwestern Rila Mountains during the Pleistocene and Holocene. *Problems of Geography* 3-4, 35-47. (in Bulgarian)
- Velchev, V. 1971. The vegetation cover of Vratsa mountain. Bulgarian Academy of Sciences. Sofia. (in Bulgarian)
- Velchev, V. 2002. Basic features and regularities in the distribution of the recent vegetation. In: Kopravev, I. (ed.), *Geography of Bulgaria*. ForCom. Sofia, pp. 321-324. (in Bulgarian)
- Velchev, V., Tonkov, S. 1986. Vegetation and flora of Southwestern Bulgaria. In: Botev, B. (ed.), *Fauna of Southwestern Bulgaria*. Bulgarian Academy of Sciences. Sofia, pp. 20-43. (in Bulgarian)
- Velev, S. 2002. Climatic division. In: Kopravev, I. (ed.), *Geography of Bulgaria*. ForCom Publishers, Sofia, pp. 155-156. (in Bulgarian)
- Velev, S. 2010. The climate of Bulgaria. Heron Press. Sofia. (in Bulgarian)
- Velichkov, I., Hinkov, G., Zlatanov, Tz., Zlatanova, M., Hristova, H. 2010. Area distribution dynamics of *Castanea sativa* forests on the northern slopes of Belasitsa mountain. *Silva Balcanica* 11 (1), 21-26.
- von Grafenstein, U., Erlenkeuser, H., Muller, J., Jouzel, J., Johnsen, S. 1998. The cold event 8,200 years ago documented in oxygen isotope records of precipitation in Europe and Greenland. *Climate Dynamics* 14, 73-81
- Walker, M. 2005. *Quaternary Dating Methods*. Wiley. Chichester.
- Wasylikova, K. 1986. Analysis of fossil fruits and seeds. In: Berglund, B. (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley and Sons. Chichester, pp. 571-590.
- Weninger, B., Alram-Stern, E., Bauer, E., Clare, L., Danzeglocke, U., Jöris, O., Kubatzki, C., Rollefson, G., Todorova, H., van Andel, T. 2006. Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. *Quaternary Research* 66 (3), 401-420.
- Weninger, B., Clare, L., Rohling, E., Bar-Yosef, O., Böhner, U., Budja, M., Bundschuh, M., Feurdean, A., Gebe, H.G., Jöris, O., Linstädter, J., Mayewski, P., Mühlenbruch, T., Reingruber, A., Rollefson, G. 2009. The Impact of Rapid Climate Change on Prehistoric Societies during the Holocene in the Eastern Mediterranean. *Documenta Praehistorica*. 36, 7-59.
- Willis, K., Rudner, E., Sumegi, P. 2000. The full-glacial forests of central and southeastern Europe: evidence from Hungarian macrofossil charcoal, pollen and molluscan records. *Quaternary Research* 53, 203-213.
- Wright, H. E., Ammann, B., Stefanova, I., Atanassova, J., Margalitadze, Wick, L., Blyakharchuk, T. 2003. Late-glacial and Early-Holocene dry climates from the Balkan peninsula to Southern Siberia. In: Tonkov, S. (ed.), *Aspects of Palynology and Palaeoecology*. Pensoft Publishers. Sofia-Moscow, pp. 127-136.
- Yokohama, Y., Lambeck, K., Decker, P., Johnston, P., Fifleds, K. 2000. Timing of the Last Glacial Maximum from observed sea-minima. *Nature* 406, 713-716.
- Zagorchev, I. 2001. Introduction to the geology of SW Bulgaria. *Geologica Balcanica* 31 (1-2), 3-52.
- Zohary, D., Hopf, M., Weiss, E. 2012. *Domestication of Plants in the Old World. The origin and spread of domesticated plants in southwest Asia, Europe, and the Mediterranean Basin*. 4th ed. Oxford University Press. Oxford.



Professor Spassimir Tonkov was a member of the teaching and academic staff of the Department of Botany at Sofia University St. Kliment Ohridski for the period 1979-2019. He was head of the department (2001-2008) and administered also the Laboratory of Palynology (2000-2019). His

main research interests are in the field of Quaternary paleobotany and paleoecology (palynology, plant macrofossils, vegetation history, radiocarbon dating, paleoclimatology), archaeobotany, pollen monitoring, forest ecology, pollination biology and floristics. Prof. S. Tonkov has realized scholarships in Quaternary paleobotany (University of Bergen, Norway, 1986), Palynology and plant macrofossils (University of Göttingen, West Germany, 1986) and Quaternary Paleocology (Lund and Uppsala Universities, Sweden, 1992).

In the course of several decades he published over 120 contributions in peer-reviewed journals (Nature Communications, The Holocene, Vegetation History and Archaeobotany, Review of Palaeobotany and Palynology, Quaternary Science Reviews, Grana, Quaternary International, Biogeosciences, etc.), books, monographs, conference proceedings. Prof. S. Tonkov participated actively in international and bilateral research projects. Most important of them were INQUA Project 158B Palaeohydrological Changes in the Temperate Zone in the Last 15000 years - Lake and

Mire Environments (1980-1988); Dynamic European Climate-Vegetation Impacts and Interactions (DECVEG) (2005-2008); European Climate Change at the End of the Last Glaciation (EUCLIM) (2008-2010); European Pollen Database (since 1994); European Pollen Monitoring Program (since 1996).

Prof. S. Tonkov has attended over 50 international congresses, conferences, symposia, workshops and meetings with oral and poster presentations, among them XIVth International Botanical Congress, West Berlin (1987); XIVth INQUA Congress, Berlin (1995); XIth International Palynological Conference, Granada (2004); Second PAGES Open Science Meeting, Beijing (2005); XVIIIth INQUA Congress, Bern (2011); 9th EPPC, Padova (2014); Symposium 100 Years Pollen Analysis, Stockholm (2016).

His teaching activity included lectures for students studying Plant Systematics, Botany, Palynology, Paleocology, Phytogeography, Global Environmental Impacts and Basic Biodiversity. He also advised PhD and MSc students and co-authored textbooks and practical guides.

The present book synthesizes the results from the palynological and paleoecological studies of the Late Quaternary vegetation history conducted in the montane area of Southwestern Bulgaria along the Struma river. The book will be of interest and use to scientists working in palynology, paleoecology, paleogeography, paleoclimatology, landscape ecology, forestry and archaeology.

