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Three millennia of vegetation history in the Vitosha Mountain, Bulgaria

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Abstract. Pollen analysis supported by radiocarbon dating was performed on a core collected from a peat bog in the central plateau area of the Vitosha Mountain. The palynological data provides information on the vegetation changes over the last three millennia. Between 3000 and 800 years ago forests of *Picea abies* with some *Pinus* sp. and less *Abies alba* dominated on the high slopes of the mountain. Below them were distributed forests of *Fagus sylvatica* and mixed oak communities with *Carpinus betulus*, *C. orientalis*, while *Corylus* was found on open terrains. In the time interval 800-560 cal. yrs. BP (1150-1400 AD) the spruce forests declined alongside with a slight increase for beech. By that time, the first signs of human activity are justified by an increase for Poaceae, *Artemisia*, Chenopodiaceae, *Cirsium*, *Plantago lanceolata*, *Rumex* and *Juniperus*, which points to partial deforestation, forest fires and acquisition of new pasture land. The last centuries witnessed the fragmentation of *Picea abies* forests, the disappearance of *Abies alba*, and intensification of the human interference in the vegetation cover particularly on the southern slopes.

Key words: pollen analysis, radiocarbon dating, vegetation history, human impact, Vitosha Mountain.

Introduction

The investigations on the postglacial vegetation history of Vitosha Mountain started in the first half of the past century with the pioneer pollen analyses of peat bogs located in the spruce forest belt and above the timber-line. The focus was placed on the changes in the presence of the most common coniferous and deciduous tree taxa since the Subatlantic period when peat started to accumulate (Stojanov & Georgiev, 1934; Petrov, 1956). In the following decades a number of pollen diagrams from sites located between 1400 and 2200 m were published which revealed the alternation of several forest phases (mixed deciduous and birch forests, hornbeam and coniferous forests, beech and coniferous forests, degradation of forest vegetation) during the second half of the Holocene but without sufficient and reliable chronological control. Only two radiocarbon dates were obtainned from a peat profile Matnitsa at 2000 m near the springs of the Struma river (Fig. 1) which indicated that the accumulation of peat started ca. 6500 years ago (Filipovitch, 1985). On the basis only of this study the age boundaries of the forest phases were provisionally correlated with the available palynological information from Stara Planina and Sredna Gora mountains (Filipovitch, 1988).

In the last years the pollen-analytical studies in the Vitosha Mountain were resumed by the publication of the results from two peat bogs bound to consistent radiocarbon chronology. The succession and duration of the forest phases as well as the diverse millennial human impact were unravelled since ca. 9000 years ago (Tonkov & Possnert, 2016; Tonkov et al., 2025). The present study marks a new step in the ongoing research in this montane area to obtain more information on the vegetation changes and human impact in the last 3000 years.

Materials and methods

Study area

Vitosha Mountain (peak Cherni Vrah, 2290 m) is one of the highest massifs in Bulgaria - a Nature Park in western Bulgaria located in the outskirts of the capital Sofia (Fig. 1). The mountain has a dome shape (23×17 km) with an area of 268.8 km^2 surrounded by three valleys. The mountain was formed during the Tertiary and Quaternary through several vertical uplifts and peripheral subsidence, which, together with denudation processes had formed levels of different ages and floodplain terraces. During the Pleistocene the mountain was not glaciated but the high parts were under the influence of the periglacial climate. Of particular importance for the water regime of the mountain are the plateaus with their peat cover, which retain moisture, and from there originate the rivers as small streams (Nikolov & Jordanova, 2002). The modern vegetation is developed in several altitudinal belts but their boundaries are not distinct and depend on the relief and the exposure. The slopes from 700 m to 1200 m (1400 m) are covered by mixed oak-hornbeam forests and above them are distributed forests of *Fagus sylvatica* L. (1200-1500 (1700 m)), mostly monodominant or mixed with *Carpinus betulus* L. and fragmented at many places. Nowadays, the coniferous belt (1500-1900 (2050 m)) which shapes the timber-line occupies two large territories on the northern and northeastern parts dominated by *Picea abies* (L.) Karst. with few *Pinus sylvestris* L., *Abies alba* Mill., *Sorbus aucuparia* L., *Populus tremula* L. and groups of *Betula pendula* Roth. The treeless subalpine zone above 1800 m is occupied by communities of *Juniperus sibirica* Burgsd., *Nardus stricta* L., *Festuca valida* (Uechtr.) Penz., *Sesleria comosa* Velen., *Phleum alpinum* L., etc. Scattered stands of *Pinus mugo* Turra are growing in a couple of places (Alexova & Gyurova, 2012; Filipovitch, 1988).

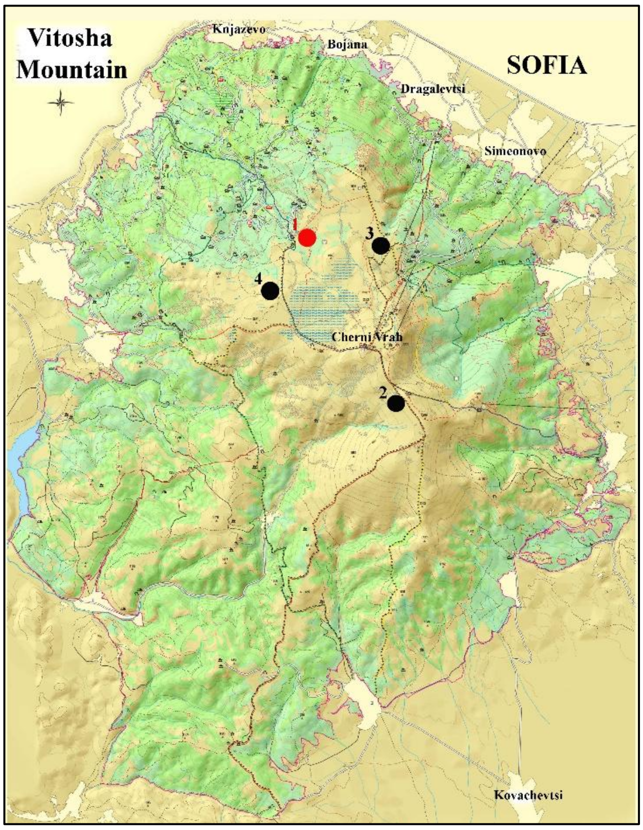

Fig. 1. Map of Vitosha Mountain with the location of peat bogs mentioned in the text: 1 Konyarnika – this study, 2 Kapaklivets-Platoto (Tonkov et al., 2025), 3 Kumata 1 (Tonkov & Possnert, 2016), 4 Matnitsa (Filipovitch, 1985).

Fig. 2. A view of peat bog Konyarnika in 2023. (Photo: D. Gyurova)

Site of investigation, coring, lithology and radiocarbon dating

The study site is a peat bog named Konyarnika with northwest exposure located at 1789 m (42°35′11.3″ N, 23°14′46.7″ E) in the treeless central plateau zone (Fig. 1). It occupies an area of ca. 0.6 ha and borders to the west a forest of *Picea abies*. The bog vegetation is composed of *Sphagnum* sp., *Carex nigra* (L.) Reichard, *Carex echinata* Murray, *Molinia caerulea* (L.) Moench., *Potentilla erecta* (L.) Rausch., *Dactylorhiza cordigera* (Fr.) Soo, *Sanguisorba officinalis* L., *Eriophorum vaginatum* L., *Juniperus sibirica*, *Bruckenthalia spiculifolia* Rchb., *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., etc. (Fig. 2).

A sediment core 80 cm deep was obtained with modified Wardenaar corer. The lithology of the sediments is: 0-23 cm live *Sphagnum* mosses, 23-50 cm slightly decomposed *Sphagnum*-Cyperaceae peat and 50-80 cm decomposed peat with plant remains. The radiocarbon age of 5 bulk sediment samples was determined and the results are shown in Table 1. All radiocarbon dates have been calibrated to calendar years (±2σ range) with the computer program OxCal 4.3 (Bronk Ramsey, 2009). The mid-point calibration value is also indicated. In this way the calibrated dates (cal. yrs. BP or cal. BC/AD) can also be accepted as calendar years.

Pollen analysis

The core was sampled every 5 cm and the standard acetolysis procedure for preparation was applied (Faegri & Iversen, 1989). The counting of the fossil pollen grains and spores was done with microscope Leitz at magnification 400-800x (1000x). Their identification was performed to the lowest possible taxonomic level with the help of a reference collection, the pollen keys and microphotographs in Beug (2004), Faegri & Iversen (1989), Moore et al. (1991) and other literature sources. The pollen sum (PS) of ca. 500 grains used for percentage calculations is based on tree (AP) + herb (NAP) pollen=100%, excluding taxa of local origin (L) i.e., spores of mosses, pteridophytes, pollen of Cyperaceae and aquatics. Their presence is expressed as percentages of the PS. A percentage pollen diagram with the most common/important pollen taxa with values >0.5%, including also a linear depth-age model, is constructed with the computer program Tilia (Grimm, 1991-2020) (Fig. 3) The pollen diagram is divided into local pollen assemblage zones (LPAZs) which reflect successive changes in vegetation development.

Results

Radiocarbon dating

In accordance with the results listed in Table 1 the age of the core is estimated at 2750 cal. yrs. BP or 800 yrs. BC. The lowermost 10 cm of peat were deposited very slowly for ca. 1400 years while the uppermost 50 cm of slightly decomposed peat and live *Sphagnum* plants were accumulated quite probably over several centuries. The ^{14}C age 36±49* BP needs a critical view because it falls within an interval from modern time to a couple of centuries ago. In this case the best solution is to disregard it. The age-depth model allows the age of each pollen sample and the boundaries of the pollen zones to be assigned to the relevant cal. yrs. BP.

Table 1. Radiocarbon dates from peat bog Konyarnika.

Lab. code	Depth (cm)	^{14}C age (BP)	^{14}C age cal. BP, ±2σ (mid-point)	Cal. (BC/AD)	Material dated
AWI-14476.1.1	39-41	36±49*	270-20 (145)	1680-1930 (1805) AD	slightly decomposed peat
AWI-16309.1.1	50	431±14	540-320 (430)	1410-1630 (1520) AD	decomposed peat
AWI-14477.1.2	59-61	981±51	960-740 (850)	990-1210 (1100) AD	decomposed peat
AWI-16310.1.1	70	1462±15	1370-1310 (1340)	580-640 (610) AD	decomposed peat
AWI-13183.1.2	79-80	2631±22	2770-2730 (2750)	820-780 (800) BC	decomposed peat

Pollen analysis

On the pollen diagram four local pollen assemblage zones (LPAZs) can be recognized (Kon-1 to Kon-4) and their brief descriptions are as follows:

LPAZ Kon-1 (80-67 cm, *Picea - Pinus diploxylon – Abies - Fagus*) (2750-1150 cal. yrs. BP)

The total tree pollen curve (AP) dominates with 85-75%, attributed to *Picea* up to 35% (level 75 cm), *Pinus diploxylon*-type up to 20%, *Abies* 8-2% and a rise of *Fagus* up to 10%. The rest of tree/shrub taxa are present with values below 5-10%. Among the herb pollen taxa (NAP) can be mentioned Poaceae, *Artemisia*, Cichoriaceae, Apiaceae, Brassicaceae, etc.

LPAZ Kon-2 (67-53 cm, *Pinus diploxylon – Picea - Fagus*) (1150-560 cal. yrs. BP)

The total tree pollen is ca. 80%, contributed by *Pinus diploxylon*-type up to 35%, *Picea* 10%, an increase for *Fagus* from 10% to 20% at the transition to the next zone, *Abies* 1-2%, *Quercus*, *Corylus*, *Carpinus betulus* and *Betula* each below 5%. The presence of Poaceae pollen rises to 10%, accompanied by some *Artemisia*, *Cirsium*-type, Apiaceae, Chenopodiaceae, etc. The pollen curve of Cyperaceae starts in this zone.

LPAZ Kon-3 (53-27 cm, *Fagus - Pinus diploxylon* - Poaceae) (560-150? cal. yrs. BP)

The pollen curve of *Fagus* reaches a maximum of 30% (level 45 cm), accompanied by *Pinus diploxylon*-type 20%, the disappearance of *Abies* pollen curve, a steep decline of *Picea*, a short-term slight rise of *Juniperus* and the establishment of *Juglans* pollen. The share of the total herb pollen increases to 45%, attributed mainly to Poaceae 15%, *Artemisia* 10%, Chenopodiaceae 5%, etc. A group of anthropogenic pollen indicators (*Plantago lanceolata* 5%, *Rumex*, *Centaurea cyanus*, *Triticum*-type, *Secale*) is recorded. A characteristic feature is the presence of Cyperaceae pollen up to 15% and the determination of the first spores of *Sphagnum*.

LPAZ Kon-4 (27-5 cm, *Picea - Pinus diploxylon - Fagus*) (150? cal. yrs. BP-until present)

The total tree pollen curve rises again to ca. 90%, due to *Pinus diploxylon*-type up to 65% and *Picea* up to 20%. Pollen of *Fagus* declines to 10%, whilst a slight rise is established for the pollen curves of *Carpinus orientalis*/*Ostrya*, *Corylus* and *Quercus cerris*-type. The herb pollen taxa such as Poaceae, *Artemisia*, *Rumex*, *Geum*-type, etc. are present with rather low values. Spores of *Sphagnum* dominate in the fossil assemblage.

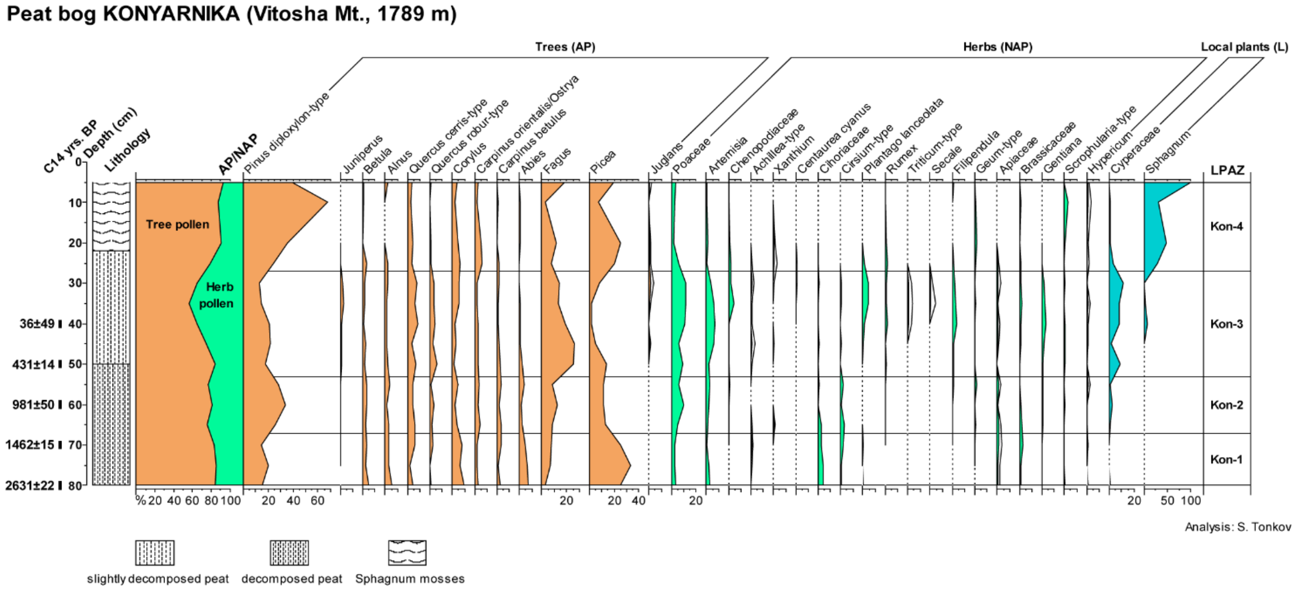

Fig. 3. Percentage pollen diagram of peat bog Konyarnika.

Discussion

The new pollen record presents the vegetation history in the study area during the last three millennia. The oldest pollen assemblages reveal that between 3000 and 800 years ago forests of *Picea abies* with some *Pinus* sp. and less *Abies alba* dominated on the high slopes of the mountain. Below them were distributed forests of *Fagus sylvatica* and mixed oak communities with *Carpinus betulus*, *C. orientalis*, while *Corylus* was found on open terrains. Stands of *Betula pendula* occupied more sandy areas and *Alnus* was growing on wetter places along streams and mountain brooks. The bog vegetation was represented by Poaceae, *Artemisia*, Cihoriaceae, *Cirsium*, *Achillea*, Apiaceae, Brassicaceae and *Gentiana* species (pollen zone Kon-1, Fig. 3). Direct evidence for human interference is rare, represented only by sporadical finds of pollen grains of *Rumex* and *Plantago lanceolata*, considered as secondary anthropogenic pollen indicators after Bozilova & Tonkov (1990).

The upper part of the long pollen record from the peat bog Kapaklivets-Platoto (Fig. 1) which dates back to 9000 years ago reveals that after 3500 cal. yrs. BP the existing forests of *Abies alba* and *Carpinus betulus* quickly declined. They were subsequently replaced by communities of *Picea abies* and *Fagus*. Spruce started to play a dominant role in the coniferous forest belt and reached a maximum expansion at ca. 2900 cal. yrs. BP (Tonkov et al., 2025). This change in the vegetation cover established also for the Rila and Pirin mountains (Tonkov, 2021) was basically climate driven as a shift to lower average temperatures and an increase in precipitation at the beginning of the Subatlantic that has occurred in the Northern Hemisphere (van Geel et al., 1999). The presence of beech predominantly on the northern slopes remained relatively stable until recent times.

In the interval 800-560 cal. yrs. BP (1150-1400 AD) a decline in the spread of the spruce forests is registered alongside with a slight increase of beech. The communities of *Pinus* sp. enlarged, whilst no significant changes were established in the distribution of the mixed oak forests. Signs of human activity are justified by an increase for Poaceae, *Artemisia*, Chenopodiaceae, *Cirsium*, *Plantago lanceolata* and *Rumex* species, which points to partial deforestation and acquisition of new land for livestock-grazing in the mountain meadows (pollen zone Kon-2, Fig. 3).

In the vicinity of the near-by investigated peat bog Kumata 1 (Fig. 1) which dates back to 1300 cal. yrs. BP (650 AD) the spruce forest was to some extent opened between 1200 and 1500 AD, and afterwards considerably reduced. The share of the herb component mostly composed of grasses, *Artemisia*, *Achillea* and Cichoriaceae species increased, accompanied by stands of *Juniperus*. A steep peak of microcharcoal particles recorded at ca. 1500 AD unequivocally suggests the occurrence of forest fires (Tonkov & Possnert, 2016).

After 560 cal. yrs. BP (1400 AD) followed a period with the strongest human impact that lasted several centuries. The coniferous forests dominated by spruce and pines were subjected to large-scale destruction by tree felling and fires. The enlargement of the pasture land continued as proved by the increase of Poaceae, *Artemisia*, Chenopodiaceae, *Plantago lanceolata*, *Juniperus* and *Rumex*. The flora of the peat bog was enriched with various Apiaceae, Brassicaceae, *Filipendula*, *Geum*, Cyperaceae species. The find of cereal pollen from *Secale*, *Triticum*-type (primary anthropogenic pollen indicators) and *Juglans* as well points to their cultivation on the foothills of the mountain (pollen zone Kon-3, Fig. 3).

The last 150-100 years witnessed a partial regeneration of *Picea abies* forests but they remained fragmented at many places. Despite the observed increase in the presence of *Pinus*, it is well-known that pine is an over-producer of pollen, so that its actual participation in the coniferous communities was considerably lower. By that time the subalpine communities of *Pinus mugo* (dwarf-pine) were heavily destroyed to enlarge the pasture land. Also, *Abies alba* completely disappeared from this part of the mountain. Even the areas occupied by *Fagus sylvatica* after a short period of restoration were subsequently reduced. The deciduous trees distributed at lower altitudes (*Quercus*, *Carpinus betulus*, *C. orientalis*) partly enlarged while the increase of *Corylus* indicated openings of the forest canopy. The presence of herb taxa such as *Xanthium*, *Plantago lanceolata*, *Rumex* confirms that the anthropogenic intervention has favored the enlargement of areas widely utilized for seasonal stock-breeding and grazing. An important change is observed in the sedimentation of the peat bog, characterized by the quick accumulation of slightly decomposed peat and live *Sphagnum* plants, which indicated a transformation in the local hydrological regime (pollen zone Kon-4, Fig. 3). The peat bog was already positioned in the treeless zone above the timber-line which was artificially lowered.

According to the historical sources, the southern mountain slopes were completely deforested to supply timber to the local population for various purposes. Several mines were discovered by the archaeologists in the southwestern foothills for metallurgy of iron ore and some precious metals such as gold mining (Cholakov, 2025).

Conclusions

The new pollen record and the local radiocarbon chronology provide detailed information about the vegetation changes and human impact on the high slopes of Vitosha Mountain in the last 3000 years. Between 3000 and 800 years ago forests of *Picea abies* with some *Pinus* sp. and *Abies alba* dominated the landscape and below them were spread forests of *Fagus sylvatica* and mixed oak communities with hornbeam and hazel on open canopy. In the time interval 1150-1400 AD the spruce forests declined and the first convincing signs of human activity were recorded by an increase of Poaceae, *Artemisia*, Chenopodiaceae, *Cirsium*, *Plantago lanceolata*, *Rumex* and *Juniperus*. Deforestation and forest fires pointed to supply of timber for various purposes and acquisition of new pasture land for stock-breeding. In the last centuries the forests of *Picea abies* became fragmented, *Abies alba* disappeared and even the beech and oak forests were subjected to exploitation by the local population.

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