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Holocene vegetation history of the Western Rhodope Mountains (South Bulgaria): the paleoecological record of peat bog Beliya Kanton

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ABSTRACT. Pollen and plant macrofossil analyses supported with radiocarbon dating were conducted on a Holocene core from the peat bog Beliya Kanton (1547 m a.s.l.) located in the Western Rhodope Mountains (South Bulgaria). In the early Holocene until ~10 000 cal. BP the mountain slopes were covered by *Pinus*, admixed with *Betula*, *Juniperus* and shrubland of *Ephedra* among herb communities dominated by Poaceae, Cichorioideae, *Achillea*, *Artemisia*, Brassicaceae species. Subsequently, the afforestation continued with the expansion of broad-leaved oak forests with *Tilia*, *Ulmus* and *Corylus* which reached their maximum distribution ~8800 cal. BP. Gradually, these forests began to retreat, replaced at many places first by *Corylus* and later on by *Picea abies*, *Abies alba* and *Fagus.* The formation of the contemporary coniferous belt with the dominance of *Pinus – Picea abies* and fragmented mixed coniferous-deciduous communities in the late Holocene was attributed not only to climate change but also to diverse human interference in the natural forest cover. During the last 2000 years the continuous presence of *Juniperus*, *Juglans*, *Rumex, Cirsium, Plantago lanceolata* and *Hordeum* pollen indicated intensive stock-breeding, grazing and crop cultivation. The fragments of charred wood testify to tree felling and fire clearances on flat ground to obtain new pasture land.

KEYWORDS: vegetation history, pollen analysis, plant macrofossils, Holocene, Bulgaria, Western Rhodope Mountains

INTRODUCTION

The vast Rhodope Mountains are one of the non-glaciated areas on the Balkan peninsula located in South Bulgaria and North Greece, where various plants survived the harsh conditions of the last glaciation (Fig. 1). The characteristics of the main trends in the postglacial vegetation development, flora history and human impact were established from palynological investigations carried out on sediments from former lakes and peat bogs located in the western part of the mountains (Tonkov et al., 2014).

Three continuous sediment cores, one of Middle Pleniglacial, and two of Late Glacial age, were obtained from Mire Kupena, a former lake located in the Biosphere Reserve Kupena on the northern fringes of the mountains (Bozilova et al., 1989; Huttunen et al., 1992; Tonkov et al., 2013, 2014) (Fig. 1C). The palynological record for the time interval 30 000–24 000 cal. BP revealed the distribution of wooded steppe composed of *Pinus*, *Pinus peuce*, some *Betula*, *Juniperus* and cold-tolerant herb communities dominated by *Artemisia* and Chenopodioideae. After 15 000 cal. BP, the

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Figure 1. A. Map of Europe with the location of Balkan peninsula; **B.** Bulgaria and the study area; **C.** Sites mentioned in text: **1**. Peat bog Beliya Kanton (41°44′05.16″N, 24°08′23.17″E; 1547 m a.s.l.); **2**. Peat bog Shiroka Polyana (41°45′24.19″N, 24°08′44.55″E; 1500 m a.s.l.); **3**. Mire Kupena (41°59′07.5″ N, 24°19′05.1″E; 1356 m a.s.l.); **4**. Lake Blatisto (41°37′17.26″N, 24°40′41.27″E; 1540 m a.s.l.)

Late Glacial vegetation was composed of cold-resistant herbs with isolated stands of *Pinus*, *Betula* and shrubland of *Juniperus*-*Ephedra*. The afforestation in the early Holocene started with broad-leaved forests composed of *Quercus* with *Carpinus betulus*, *Ulmus*, *Tilia* and *Corylus*, and with the minor presence of *Pinus*, *Betula* and *Abies*.

From the area of the artificial reservoir Shiroka Polyana (Fig. 1C), located in the interior of the mountains, a sediment core of Late Glacial age (15 400 cal. BP) was analysed for pollen content (Filipovitch and Lazarova, 2001, 2003; Stefanova et al., 2006). The main stages in the vegetation development were compared with the results from Mire Kupena (Bozilova et al., 2011). However, the majority of the sites studied from the Western Rhodope Mountains cover only parts of the Holocene extending back either to the last 7200 years (Panovska and Bozilova, 1994; Bozilova et al., 2000) or to Subatlantic time (Lazarova, 2003; Lazarova and Filipovitch, 2004; Van Huis et al., 2013a, b). Moreover, with few exceptions, the radiocarbon control of these sites is insufficient or lacking and the time resolution of the upper parts of the pollen diagrams appears to be rather low. This objective reason does not allow to reconstruct a detailed picture of the environmental changes in historical times. In addition, plant macrofossil determination complement to pollen analysis was performed only on a core from Lake Blatisto (Fig. 1C) which extends to the last two millennia (Van Huis et al., 2013b).

In an attempt to enrich the paleoecological evidence on the postglacial vegetation development in the Western Rhodope Mountains the sediment core BK-2C was collected from the peat bog Beliya Kanton (Figs 1C, 2). The radiocarbon dates and the preliminary palynological results indicated early to late Holocene age (Lazarova et al., 2011). Here, we expand this study and present in more details the regional and local vegetation history based on pollen and plant macrofossil analyses, both placed in absolute chronological framework. Thus, our results are compared with the data from the first core BK-1 (Panovska and Bozilova, 1994; Bozilova et al., 2000) and with other already mentioned paleoecological investigations in the Western Rhodope Mountains. The new paleoecological information could be of interest also for botanists, foresters and ecologists working on problems of nature protection and long-term mountain ecosystem conservation.

STUDY AREA

The Rhodope Mountains (2191 m) are part of the Rila-Rhodopes large massif in South Bulgaria and stretch ~240 km from west to east and 100 km from north to south. The territory of the mountains is ~18 000 km^2, 14 730 km^2 of which are in South Bulgaria and the rest is in North Greece (Fig. 1). The core of the mountains is a large granite pluton covered by metamorphic rocks (gneisses, shists and marble) of Palaeozoic and pre-Palaeoezoic ages. The mountains are divided into the Western Rhodopes (2191 m) which is characterized by vast stretches that are most prominent in the interior parts at 1500 m a.s.l. in the area of Shiroka Polyana, and the Eastern Rhodopes (1463 m), which is characterized by valleys and short ravines. During the Quaternary the highest parts, above 2000 m, were under the influence of periglacial processes (Galabov et al., 1977). The typical wide valleys in the Western Rhodopes are crossed by numerous small streams with narrow beds meandering downslope. These valleys provided favourable conditions for the formation of large peatland complexes. Most of them were destroyed during the construction of artificial reservoirs in the 1950 (Filipovitch and Lazarova, 2003).

The climate is a montane variant of the transitional continental type. The mean annual air temperature is 5°C–10°C at 1000 m a.s.l. and the mean annual precipitation is 600–800 mm with a maximum in May-June and a minimum in August-September.

The northern slopes of the mountains are in a precipitation shadow and the amount of annual precipitation is less than in the interior part (Velev, 2002).

In the most recent geobotanical division the Western Rhodope Mountains are recognized as a separate region characterized by a wide distribution of coniferous forests dominated by *Picea abies* (L.) Karst. and *Pinus sylvestris* L. with an admixture of *Abies alba* Mill, *Fagus sylvatica* L., *Betula pendula* Roth. and *Pinus peuce* Griseb. in some places. The deciduous forests occupy areas at lower altitudes predominantly in the eastern and northern parts. They are composed mainly of *Quercus daleschampii* Ten. with occasional presence of *Q. frainetto* Ten. and *Q. cerris* L. on south-facing slopes. Mixed forests of *Q. daleschampii*, *F. sylvatica*, *Carpinus betulus* L. with some *Ostrya carpinifolia* Scop. occur in the valleys. Above the *Quercus* vegetation belt, *Fagus* forests grow mixed with *Acer pseudoplatanus* L., *Populus tremula* L. and *A. alba* on north-facing slopes. Quite often, mixed coniferous-deciduous communities are also found. The present-day vegetation has been influenced by grazing herbivores, cultivation of potatoes and crops, timber production and more recently by an increase in the intensity of touristic activities (Bondev, 2002; Tonkov et al., 2014).

The study site Beliya Kanton (1547 m a.s.l) is a peat bog located in the coniferous belt of the central part of the Western Rhodope Mountains. It was formed in a depression and has almost a rectangular shape, ~380 m long and 250 m wide, crossed by a meandering stream. The site is bordered today by a *Pinus sylvestris – Picea abies* forest and *Nardus stricta* L., *Agrostis capillaris* L., *Eriophorum angustifolium* Honck., *Deschampsia cespitosa* (L.) P. Beauv., *Carex* spp., *Sphagnum* spp. grow on the bog surface (Lazarova et al., 2011) (Fig. 2).

MATERIAL AND METHODS

SEDIMENT CORE SAMPLING AND DATING

The core BK-2C is 105 cm deep and was collected with a Russian corer from the central part of the peat bog. The lithology of the sediments is the following: 0–47 cm, slightly decomposed Cyperaceae peat; 47–52 cm, gyttja; 52–57 cm, grey-yellow clay (Fig. 3); 57–78 cm, gyttja; 78–105 cm, grey sandy clay.

The radiocarbon age of terrestrial plant macrofossils and charcoal concentrated from four bulk sediment samples was determined in the Radiocarbon Dating Laboratory at the University of Lund, Sweden. The calibration (95.4% probability) was performed using the software OxCal v4.4 (Bronk Ramsey, 2009), and

Figure 2. A view of peat bog Beliya Kanton in 2009 (photo by D. Ivanov)

Figure 3. The interval of 30–83 cm of core BK-2C showing the band of grey-yellow clay deposits (52–57 cm) (photo by D. Ivanov)

the results are shown in Table 1. The radiocarbon age of the single sample from core BK-1 is also included (Bozilova et al., 2000).

POLLEN ANALYSIS

The samples for pollen analysis were taken at 5 cm intervals. The laboratory preparation of the samples followed the standard acetolysis procedure (Faegri and Iversen, 1989). The pollen sum (PS) used for percentage calculations is based on AP (arboreal pollen) + NAP (non-arboreal pollen), excluding spores of mosses and pteridophytes, pollen of aquatics and Cyperaceae. Their presence is expressed as percentages of the PS. The average number of pollen grains (PS) counted per sample was 700–900. The identification of spores and pollen grains was made using reference collections, the pollen keys in Faegri and Iversen (1989), Moore et al. (1991) and Beug (2004). For calculations and construction of the pollen diagram (Fig. 4) the software Tilia ver. 2.0.41 was used (Grimm, 1991–2015). The delimitation of the boundaries of the four local pollen assemblage zones (LPAZ) was obtained by CONISS (Grimm, 1987). A modified version of the pollen diagram from core BK-1 (Bozilova et al., 2000) is also presented (Fig. 5).

PLANT MACROFOSSIL AND CHARCOAL ANALYSES

The core was subsampled for macrofossil analysis in ~5 cm thick slices. The sample volume ranging from 34–41 cm^3 was estimated by volumetric displacement. Also, for quantification of the main peat components, subsamples of 3 cm^3 were taken and all of the recognisable plant fragments, for example *Sphagnum* leaves, were counted. After soaking in water for ~24–48 hours all 15 samples were sieved with mesh sizes of 1, 0.5 and 0.25 mm. The macrofossils were sorted and identified under stereomicroscope with magnification up to 56×. Charcoal particles were classified into two classes: >2 mm and <2 mm, i.e. identifiable and non-identifiable wood. The charred wood fragments from the first group were determined under reflecting light microscope. The determination of the material was achieved by comparison to the reference collection from the Department of Botany at Sofia University and relevant literature sources on plant macrofossils (Beijerink, 1947; Katz et al., 1977; Schweingruber, 1990; Tobolski, 2000). The results of the analysis were plotted on a plant macrofossil diagram (Fig. 6) with the computer software Tilia ver.2.0.41 (Grimm, 1991–2015). The plant macrofossils (needles, seeds, nutlets, fruits, coniferous wood, charcoal particles) were quantified as absolute numbers per sample volume of 40 ml, while the main peat components such as fragments of leaf epidermis, roots and leaves of mosses as absolute numbers per sample volume of 3 ml.

RESULTS

RADIOCARBON DATING AND CHRONOSTRATIGRAPHICAL CONSIDERATIONS

The radiocarbon ages and the lithology of the core provide valuable information on the complicated sedimentation process. Regarding this the followings are worth noting:

1. The interval 105–78 cm of grey sandy clay deposits lacks radiocarbon control but the pollen stratigraphy, when compared with radiocarbon dated sites from the same area, indicates early Holocene age.

2. The change in the lithology from grey sandy clay to gyttja at 78 cm occurred ~10 000 cal. BP, if the deposition time based on the two radiocarbon dates LuS 8985 and LuS 8986 is accepted (Table 1).

3. After ~7900 cal. BP, a significant change in the local hydrological regime of the site is registered, manifested by the deposition of grey-yellow clay. Part of the underlying peat accumulation was probably eroded by the stream thus causing a hiatus, the duration of which is difficult to estimate (Lazarova et al., 2011). One hypothesis might be that it

Table 1. Radiocarbon dates from the peat bog Beliya Kanton in the Western Rhodope Mountains (South Bulgaria)

Lab. code	Depth (cm)	^{14}C age (BP)	^{14}C age cal. BP, ±2σ (mid-point)	Material dated
Core BK-2C				
LuS 8983	21–23.5	405 ± 50	530–310 (420)	*Carex rostrata* fruits
LuS 8984	42.5–45	1445 ± 50	1520–1280 (1400)	*Carex rostrata* fruits
LuS 8985	57.5–60	7015 ± 60	7960–7710 (7835)	Charcoal
LuS 8986	65–67.5	8020 ± 60	9030–8640 (8835)	Charcoal
Core BK-1				
KI-3415	45–65	6300 ± 70	7420–7010 (7215)	Peat

probably covered several centuries or a thousand years if we consider that the transition from sand to peat observed in core BK-1 took place just before ~7200 cal. BP (Fig. 5). After the stream changed its course again, the sedimentation was eventually re-established very slowly with gyttja overlain by quickly accumulated sedge peat.

POLLEN STRATIGRAPHY

Four LPAZ are recognized (BK-1 to BK-4) and their brief description is as follows (Fig. 4):

LPAZ BK-1, 105–77 cm: *Pinus diploxylon – Betula* – Poaceae – NAP. Pollen of herb taxa prevails in this zone in a couple of samples represented by Poaceae (10–20%), *Achillea*-type (10–12%), Cichorioideae (up to 12%), Brassicaceae (7%), etc. The tree pollen is attributed mainly to *Pinus diploxylon*-type (30–58%), *Betula* and *Quercus* with 5% each. The share of *Juniperus*, *Picea*, *Abies*, *Ephedra*, *Tilia*, *Ulmus*, *Corylus*, *Juglans* is below 5% each or sporadical. A peak of trilete fern spores (40%) is recorded at the level 85 cm. Aquatic plants are represented by *Potamogeton* and *Typha*/*Sparganium*-type.

LPAZ BK-2, 77–57 cm: *Pinus diploxylon – Quercetum mixtum*. The AP curve rises and reaches 85%, contributed by *Pinus diploxylon*-type (40–60%), *Quercus* (11%), *Corylus* (8%), *Ulmus* (4.7%), *Betula* (3.7%), *Fagus* (2%), *Tilia* (2.3%). Single pollen grains are determined from *Abies*, *Picea*, *Ephedra*, *Salix*, *Carpinus orientalis*/*Ostrya*, *Juglans*. The herb pollen types are represented by Poaceae (up to 15%) and low frequencies for *Artemisia*, *Achillea*-type, Ranunculaceae, Rosaceae, *Galium*-type, *Rumex*. The share of Cyperaceae pollen and trilete fern spores is below 10% each.

LPAZ BK-3, 57–37 cm: *Pinus diploxylon – Picea – Fagus*. The share of pollen of *Pinus diploxylon*-type is ~50%, followed by *Picea* (up to 13%), *Fagus* (6.8%), *Betula* (up to 7%), *Alnus* (8.2%), *Carpinus orientalis*/*Ostrya* (4%), *Abies* (2%), etc. The herb pollen types are represented by Poaceae (4–8%) and a number of taxa with low percentage values. In this zone pollen of Cyperaceae displays a maximum of 48–52%.

LPAZ BK-4, 37–0 cm: *Pinus diploxylon – Fagus – Picea – Abies*. Pollen of *Pinus diploxylon*-type dominates with 55–60%. The pollen curve of *Picea* declines to 4% followed by a rise to 13% in the uppermost sample. A similar tendency is observed for the pollen curve of *Fagus* after a maximum of 9% at the level 25 cm. The pollen percentages of other tree taxa such as *Quercus*, *Carpinus orientalis*/*Ostrya*, *Betula, Abies* and *Corylus* are below 5% each. Pollen of *Juglans* is regularly found in this zone. No significant changes in the presence of the herb taxa are recorded compared to the previous zone.

PLANT MACROFOSSIL AND CHARCOAL ANALYSES

Five local macrofossil assemblage zones (LMAZ) are recognized (BKm-1 to BKm-5) and their content is briefly presented (Fig. 6):

LMAZ BKm-1, 90–78 cm. The macrofossil record is poor and comprises few finds of *Vaccinium* seeds, *Eriophorum* sp. fruits and *Sphagnum* leaves.

LMAZ BKm-2, 78–57 cm. Seeds of *Vaccinium*, fruits of *Eriophorum* sp. and *Juncus* sp., nutlets of *Carex* cf. *rostrata*, *Carex* sp. and *Sphagnum* leaves are present. Fragments of charred coniferous wood and charcoal particles of various sizes are abundant in the upper part of the zone between 8800 and 7800 cal. BP. The macrofossil record of the zone finishes with a compact, dried layer (at a depth of ~58–62 cm) with relatively high concentrations of macrocharcoal (smaller than 2 mm and bigger than 0.25 mm). Careful observation of the charred material shows that its origin is mainly from non-arboreal vegetation. Few traces of *Sphagnum* leaves could be observed but charred stems of mosses are numerous.

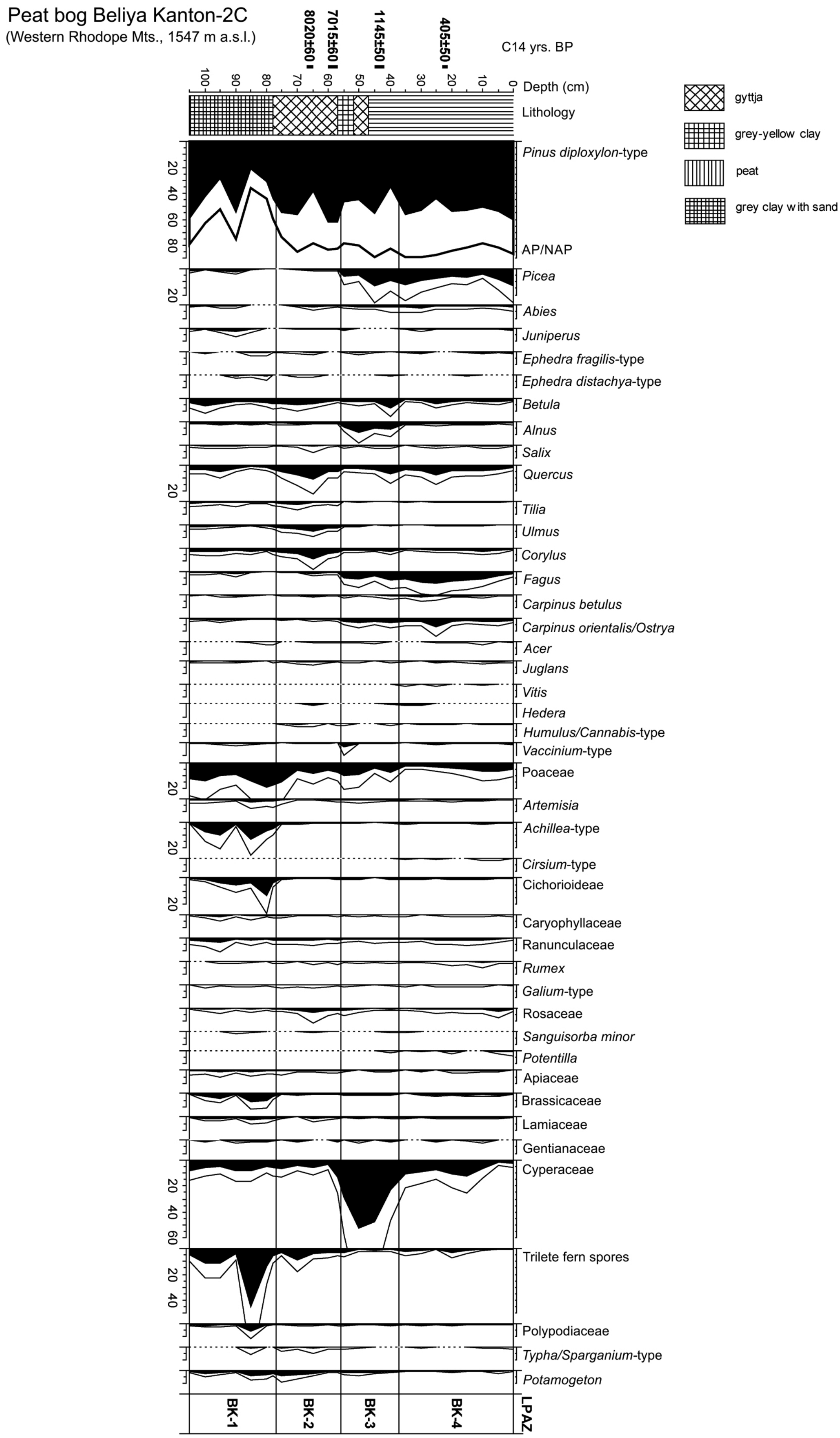

Figure 4. Percentage pollen diagram from core BK-2C (Analysis: M. Lazarova)

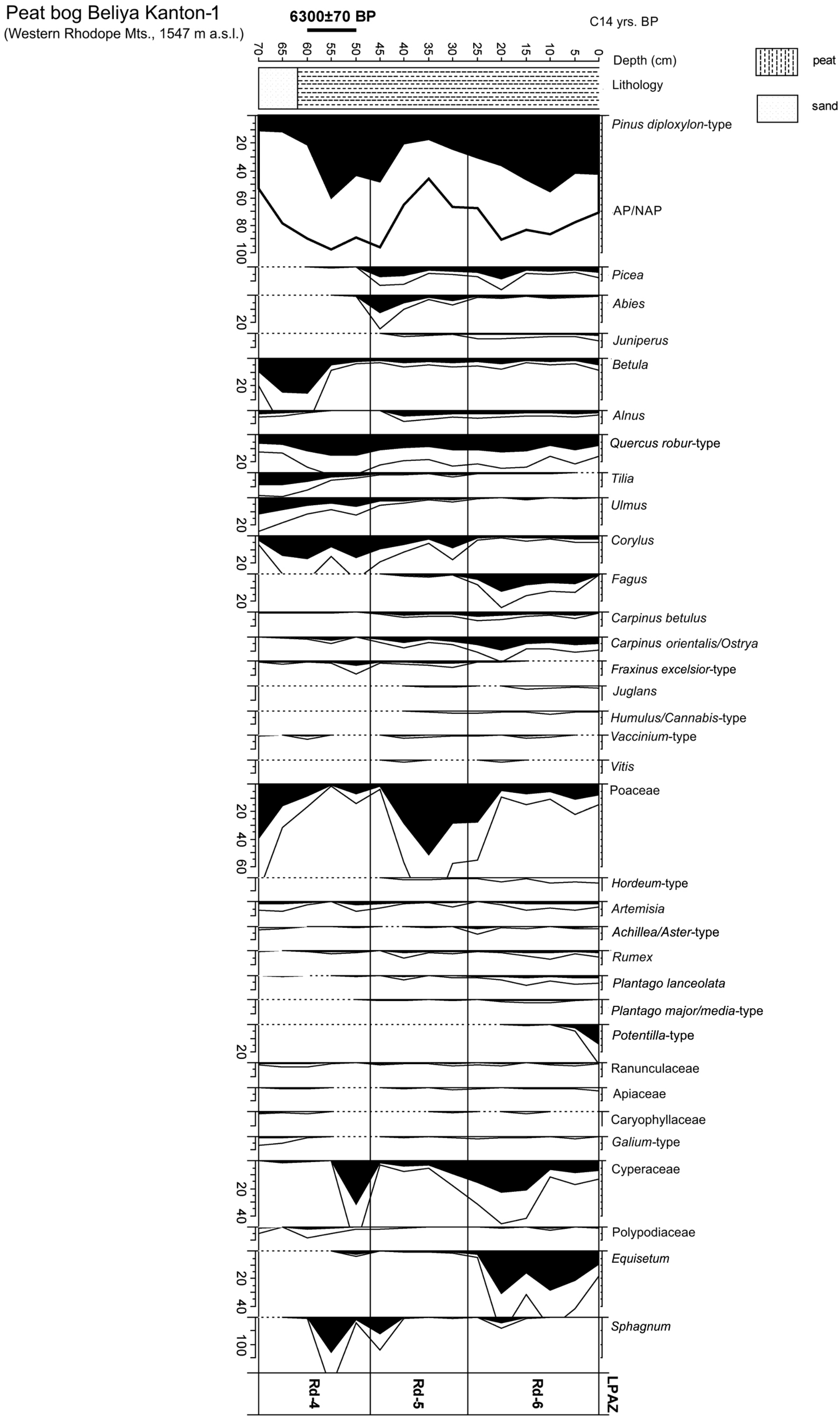

Figure 5. Percentage pollen diagram from core BK-1 (Modified after Bozilova et al., 2000)

LMAZ BKm-3, 57–50 cm. This zone corresponds to a hiatus. Nutlets of *Carex* cf. *rostrata*, *Carex* sp., fruits of *Juncus* sp., *Sphagnum* leaves and charcoal particles are found in the single sample analysed. A fragment of *Pinus* sp. needle is also determined.

LMAZ BKm-4, 50–26 cm. A large number of *Carex* cf. *rostrata* and *Carex* sp. nutlets, *Eriophorum* sp. and *Juncus* sp. fruits are identified, alongside with vegetative parts (fragments of leaf epidermis, roots and stems) of various sedges, *Sphagnum* leaves and charcoal particles.

LMAZ BKm-5, 26–4 cm. The presence of conifers around the site is proved by needles of *Pinus* sp., *Picea abies*, *Abies alba*, male cones of *Picea abies* and fragments of charred coniferous wood. Seeds and fruits of various herbs (*Potentilla* sp., *Luzula* sp., Poaceae, *Carex curta*, *Carex* sp., *Juncus* sp.) and vegetative remains of mosses are identified. Charcoal particles are also present.

DISCUSSION

VEGETATION HISTORY AND HUMAN IMPACT

The pollen stratigraphy and the radiocarbon dates of core BK-2C, when compared to other available data from the study area (Fig. 7), indicate that this core spans the entire Holocene. In the early Holocene until ~10 000 cal. BP, the vicinity of the site and the nearby slopes were covered by *Pinus*, admixed with *Betula*, *Juniperus*, shrubland of *Ephedra* and undergrowth of ferns among herb communities dominated by Poaceae, Cichorioideae, *Achillea*, *Artemisia*, Brassicaceae, Ranunculaceae, Apiaceae species. At lower altitudes were distributed groups of broad-leaved tree vegetation composed of *Quercus*, *Tilia*, *Ulmus*, *Carpinus orientalis*/*Ostrya carpinifolia*. In places with sufficient air and soil humidity were thriving stands of *Fagus, Abies alba* and *Picea abies*, while *Alnus* and *Salix* were distributed along streams and brooks (Fig. 4, zone BK-1). The scarce macrofossil record provides little information on the local vegetation (Fig. 6, zone BKm-1) but, quite probably, the deposition of sandy clay points to the existence of a shallow lake overgrown with sedges in the peripheral parts, while *Typha*, *Sparganium* and *Potamogeton* were spread on open water surfaces.

The development of the forests until 8800 cal. BP featured an expansion of the broad-leaved tree vegetation dominated by *Quercus* with *Tilia*, *Ulmus* and *Corylus* which reached its maximum distribution. At higher altitudes *Pinus* forests with stands of *Abies alba* and *Betula*, as well as few *Picea abies*, enlarged their area mainly at the expense of the herb vegetation (Fig. 4, zone BK-2). The shallow water basin was gradually transformed into a peat bog overgrown with sedges, mosses and semi-shrubs, confirmed by the finds of seeds and fruits from *Vaccinium* sp., *Carex* sp., *Juncus* sp., *Eriophorum* sp. and *Sphagnum* leaves as well. Indications of local fires are provided by numerous charcoal fragments, charred stems of *Eriophorum* sp. and charred coniferous wood (Fig. 6, zone BKm-2).

Around the peat bog Shiroka Polyana, the nearest studied site at a distance of 2.5 km from Beliya Kanton (Figs 1, 7), for 1000–1500 years after the onset of the Holocene the herb vegetation was still preserved but dominated by various Poaceae species and with lower participation of *Artemisia* and Chenopodioideae. The arboreal vegetation was represented by stands of *Pinus* (including *Pinus peuce*), some *Betula*, *Juniperus*, *Ephedra*, and at lower altitudes by groups of *Quercus* and *Corylus.* A short-term spread of trees ~10 000 cal. BP was followed again by the dominance of the non-arboreal pollen assemblage. According to the local depth-age model, only after 9300 cal. BP, the remnants of the Late Glacial herb communities gave way to the dominance of *Betula* – *Quercus* like the situation at Beliya Kanton. This implies that in the early Holocene the landscape was still a steppe or forest steppe with *Betula* (Stefanova et al., 2006; Bozilova et al., 2011) and the present-day major conifer trees in this area had restricted populations, while the deciduous forest belt may have expanded to higher elevations because of warmer summers related to higher summer insolation (Kutzbach et al., 1993).

In the early Holocene, at lower elevations around Mire Kupena (Figs 1, 7) tree communities started to dominate the landscape, particularly deciduous forests of *Quercus* with *Carpinus betulus*, *Carpinus orientalis*/*Ostrya carpinifolia*, *Ulmus*, *Tilia* and *Corylus*. The temporary increase of *Fagus* and *Abies alba,* and the minor quantities of *Picea abies* pollen, indicate that the climate became milder

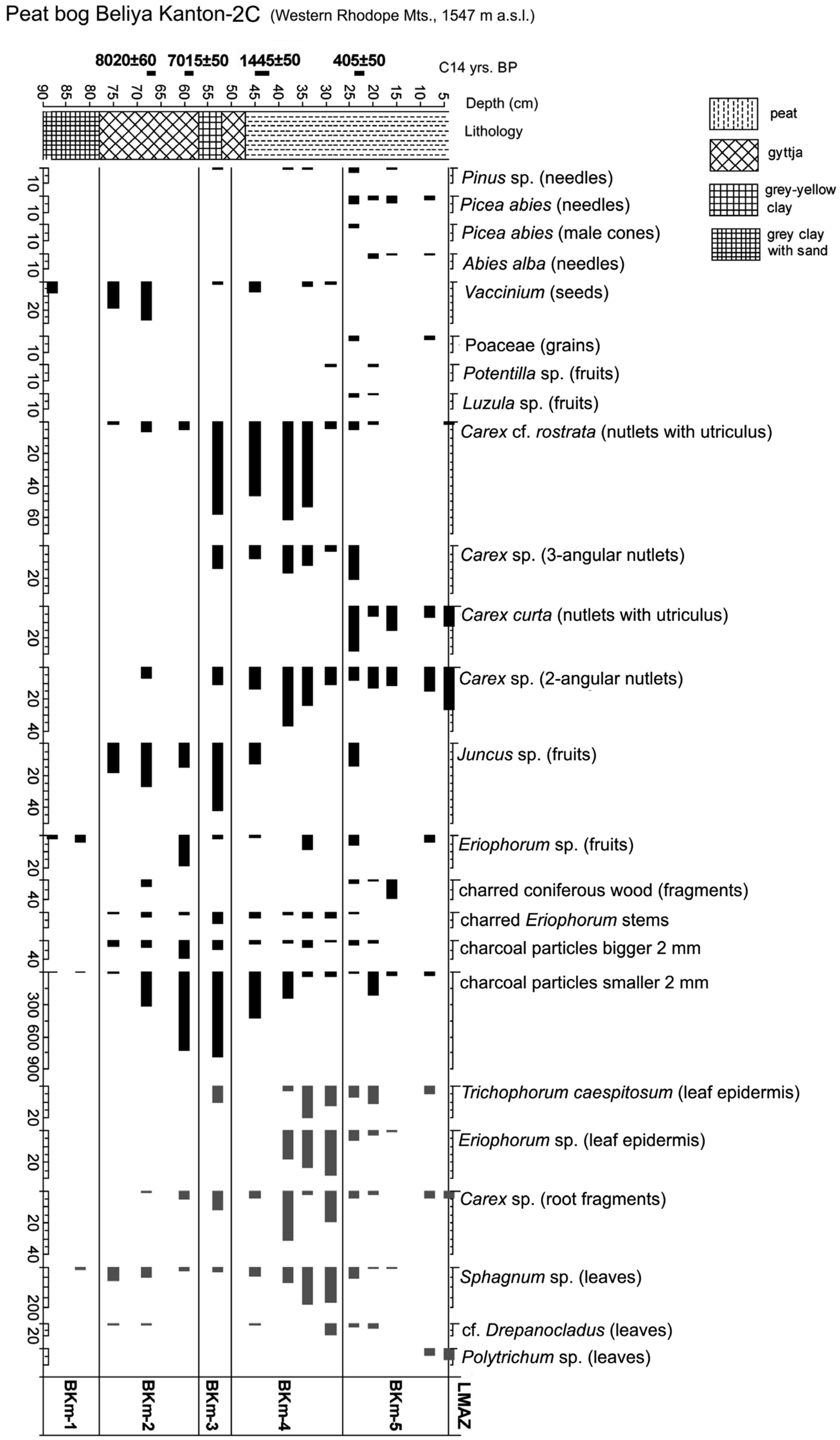

Figure 6. Plant macrofossil diagram from core BK-2C (Analysis: E. Marinova)

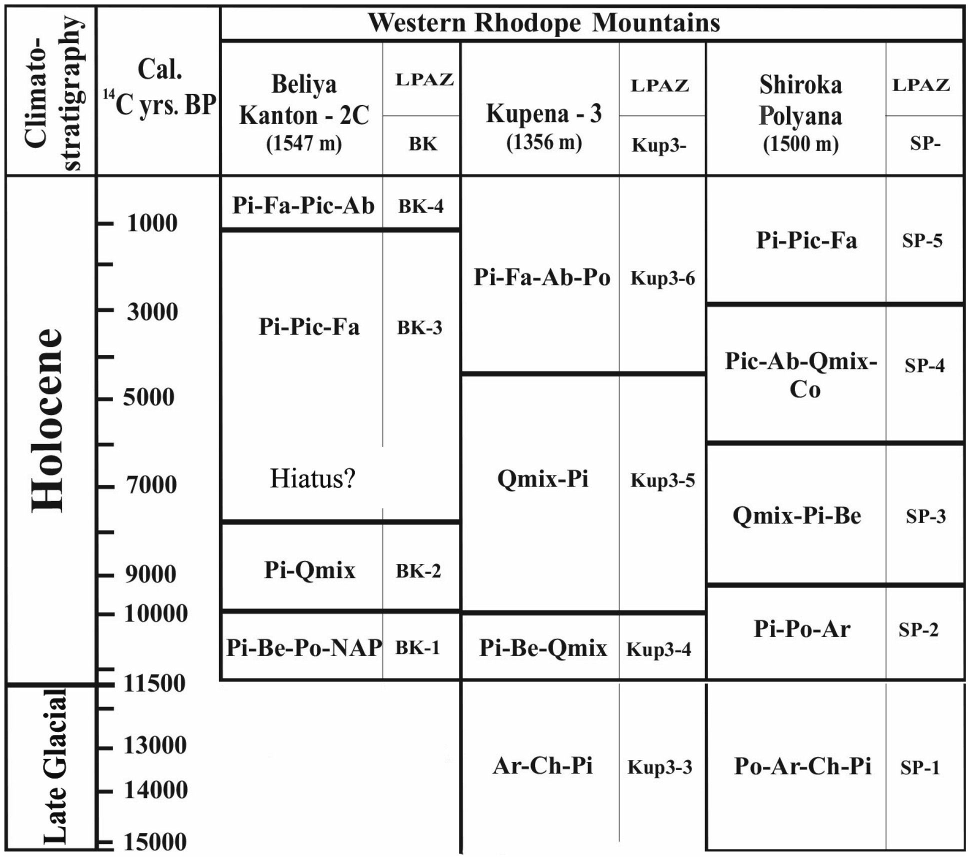

Figure 7. Correlation of the vegetation stages (LPAZ) for the last 15 000 years in the Western Rhodope Mountains established for Beliya Kanton-2C, Shiroka Polyana (Stefanova et al., 2006; Bozilova et al., 2011) and Mire Kupena (Tonkov et al., 2014) (Abbreviations: Ar = *Artemisia*, Ch = Chenopodioideae, Po = Poaceae, NAP = non-arboreal pollen, Pi = *Pinus*, Pic = *Picea abies*, Ab = *Abies*, Be = *Betula*, Ju = *Juniperus*, Fa = *Fagus*, Co = *Corylus*, Qmix = *Quercetum* mixtum)

and moister. At higher elevations, on more open places with stable soils, pine communities (*Pinus sylvestris*/*nigra* and *Pinus peuce*) slightly expanded together with stands of *Betula* and *Juniperus.* The herb vegetation became more diverse, particularly enriched with species from Rosaceae, Brassicaceae, Apiaceae and Ranunculacae. The patches of the Late Glacial steppe-vegetation with dominance of *Artemisia* and Chenopodioideae species withdrew from the site after ~10 600 cal. BP. and, by that time, the share of *Tilia* and *Ulmus* in the oak communities slightly increased. After ~9300 cal. BP, sedge peat started to accumulate indicating a lowering of the water level and the spread of marshy communities which became dominated by Cyperaceae species after 8300 cal. BP (Tonkov et al., 2014).

After ~7900 cal. BP, significant changes in the local hydrological conditions around the place of core BK-2C occurred. Such changes were also observed when the core BK-1 was studied (Bozilova et al., 2000). They were most probably caused by the meandering stream which resulted in partial erosion of peat material and subsequent very low sedimentation rate. Thus, the picture of the vegetation development around the Beliya Kanton for most of the middle Holocene could be derived from the other palynologically investigated sites.

Around 6200 cal. BP, at Shiroka Polyana a short-term expansion of *Pinus peuce* was recorded followed by the final establishment and spread of *Picea abies*, some *Abies alba* and a bit later *Fagus* and *Carpinus betulus*. By that time the mixed oak forests began to retreat replaced by *Corylus* and *Betula* at many places (Stefanova et al., 2006; Bozilova et al., 2011).

In the area of Mire Kupena from 8300 cal. BP onwards until 4700 cal. BP, the composition of the forests remained nearly the same, except for some reduction of *Fagus*, *Carpinus orientalis*/*Ostrya carpinifolia* and *Corylus*. The share of *Tilia* and *Ulmus* in the oak forests slightly increased (Fig. 7). A wider distribution of *Abies alba* was reached 5660 years ago while around Shiroka Polyana this succession was not so well pronounced. The last tree immigrant in the Western Rhodope Mountains was *Picea abies*, which tree began to invade areas about 6000 years ago, particularly in the interior parts, when the shaping of a coniferous belt started. Spruce occupied the higher elevations simultaneously with beech, especially in the area of Shiroka Polyana (Stefanova et al., 2006; Bozilova et al., 2011).

The pollen record of core BK-1 clearly manifests the spread of *Picea abies* after 6500 cal. BP together with a short-term enlargement of *Abies alba* (Fig. 5, zone Rd-5). Later on, after 4000–3500 cal. BP, *Fagus* has also become an important constituent of the forest cover (Fig. 5, zone Rd-6).

In the late Holocene the paleoecological record displays important changes in the tree vegetation. The contemporary coniferous belt in the Western Rhodope Mountains dominated by *Pinus* was established and communities of *Picea abies* and *Fagus*, mixed with *Pinus* and *Abies alba* in some places, spread in the region. In general, the broad-leaved tree vegetation declined, particularly its components *Tilia* and *Ulmus*, and it was restricted to its present-day distribution range. Some enlargement of *Carpinus betulus* and *Carpinus orientalis*/*Ostrya carpinifolia* is observed, as well as of *Alnus* in wetter places. The proportion of the herb vegetation around Beliya Kanton continued to decrease although its diversity was enriched with various species of Ranunculaceae, Rosaceae, Apiaceae, Brassicaceae, etc. The peat bog began intensively to be overgrown by sedges and mosses while water plants such as *Potamogeton* were preserved in isolated places with deeper water. This vegetation reconstruction is supported by the macrofossil record which is rich in fruits and seeds of various *Carex, Juncus, Eriophorum* species and vegetative remains of sedges, together with *Sphagnum* leaves. Also, leaf fragments of *Pinus* sp. and seeds of *Vaccinium* were found in a couple of samples (Fig. 6, zone BKm-4).

During the last centuries, the general trend in the vegetation development around Beliya Kanton comprised a further enlargement of *Pinus–Picea abies* forests, thus shaping the upper tree-line, alongside with a wider distribution of *Fagus* and *Carpinus betulus* predominantly on north-facing slopes. The abundance of needles of *Pinus* sp., *Picea abies*, *Abies alba* and male cones of *Picea abies* confirms the spread of the coniferous forests (Fig. 6, zone BKm-5). The diverse herb communities were composed of Poaceae, Ranunculaceae, Brassicaceae, Caryophyllaceae and Asteraceae species, and the bog vegetation was dominated by various *Carex* and moss species. Human presence and activities are indicated by the continuous pollen curves of *Juniperus*, *Juglans*, *Rumex, Cirsium*-type*, Galium* in the pollen diagram BK-2C (Fig. 4, zone BK-4), and by *Plantago lanceolata* and *Hordeum*-type in the pollen diagram BK-1 (Fig. 5, zone Rd-6). The fragments of charred wood testify to tree felling and fire clearances on flat ground in order to obtain pastures for cattle-breeding (Fig. 6, zone BKm-5).

In the vicinity of Shiroka Polyana the vegetation development in the late Holocene was characterized by the wide distribution of *Pinus* forests, partially replacing *Picea abies*, and resulting in the establishment of the contemporary coniferous belt composed of *Pinus*, *Picea abies* and mixed pine-spruce communities, with rare admixture of *Abies alba* and *Pinus peuce* (Fig. 7). Signs of lasting anthropogenic presence at altitudes of 1400–1500 m were registered by the sharp rising participation of *Artemisia*, Chenopodioideae, *Rumex*, *Urtica* and *Plantago lanceolata.* The pollen grains of *Juglans* probably originated from the foothills of the mountain slopes where walnut was cultivated around the settlements (Filipovitch and Lazarova, 2003).

The dynamic processes of tree migrations in the area of Mire Kupena during the late Holocene have been completed with the establishment of the recent vegetation pattern. Initially, *Fagus* started to gain importance and to some extent *Abies alba* and *Picea abies*, at the expense of the mixed oak forests. Subsequently, the coniferous forests dominated by *Pinus sylvestris* with some *Pinus peuce*, *Pinus nigra* and *Abies alba* began quickly to occupy the area around the mire. In these forests the admixtures of deciduous trees were preferably distributed on south-facing slopes. The local radiocarbon chronology marked precisely the start of *Pinus* expansion at 2070 cal. BP (Fig. 7). In many places fragmented mixed coniferous–deciduous communities developed which can be attributed not only to climate change but also to human interference in the natural forest cover (Tonkov et al., 2014).

The paleoecological study conducted on a core from Lake Blatisto in the Smolyan Lake area (Fig. 1C) with the application of pollen and plant macrofossil analyses, and radiocarbon dating, provides detailed information on vegetation history for the last ~2000 years. This information could be compared with the results from Beliya Kanton and other sites in the Western Rhodope Mountains. Several distinct periods in the vegetation development and human impact are recognized, starting with a cultural phase at ~400 AD when forest clearance took place on a large scale in the coniferous belt while *Fagus* and *Quercus* forests at lower altitudes remained less disturbed. The local population cultivated rye and other cereals as shown by the pollen records of *Secale* and *Cerealia*-type (*Avena, Hordeum*). During this old cultural phase, grazing was quite common indicated by the frequent occurrence of ruderals and grassland species. The period between 500 AD and 910 AD, was marked by the rapid regeneration of the coniferous forests composed of *Pinus*, *Picea abies* and some *Abies alba* after a period of human activity. The continuous presence of meadow plants points to the existence of grasslands frequently used for grazing. An enlargement of *Fagus* and *Abies alba* forests was recorded for the time interval 910–1600 AD with an intermediate short cultural phase at ~1360 AD when pioneers (*Corylus* and *Betula*) established in more open places and along the edges of the beech forests. Afterwards the largest enlargement of the coniferous vegetation followed in the area, attributed mainly to *Pinus*, that could be correlated with the climate change during the Little Ice Age when colder conditions prevailed. The conifers formed also mixed stands with *Fagus.* During the last centuries, the contemporary vegetation dominated by spruce forests was shaped under a strong anthropogenic pressure. Several alternating regression phases followed in the forest development caused most probably by tree felling, fires and grazing. The increasing intensification of human activities is shown by the cultivation of *Secale cereale, Triticum* and probably *Hordeum*, and by the extension of pasture and arable land. The macrofossil analysis allowed the reconstruction of the local vegetation in and around the lake. Initially, sandy gyttja was deposited but subsequently the basin was transformed into a lake with stagnant water when peat began to accumulate (Van Huis et al., 2013a, b).

CONCLUSIONS

1. The new paleoecological record from the peat bog Beliya Kanton enriches the information in the study area on the Holocene vegetation development which followed several stages. During the early Holocene until ~10 000 cal. BP, the mountain slopes were covered by open herb vegetation dominated by Poaceae, Cichorioideae, *Achillea*, *Artemisia* species, among which stands of *Pinus* with *Betula*, *Juniperus* and shrubland of *Ephedra* developed. Later on, the broad-leaved oak forests with *Tilia*, *Ulmus* and *Corylus* reached their maximum distribution at ~8800 cal. BP. The subsequent transformations in the forest cover included the spread of conifers (*Pinus*, *Picea abies*, *Abies alba*) after ~7000–6500 cal. BP and of *Fagus* after 4000–3500 cal. BP. In the late Holocene, the contemporary coniferous belt in the interior parts of the Western Rhodope Mountains was shaped, dominated by *Pinus* and *Picea abies*, and mixed also in places with coniferous-deciduous communities.

2. Reliable evidence of the anthropogenic impact on the natural vegetation was collected, particularly for the last 2000 years, manifested by the continuous presence of *Juniperus*, *Juglans*, *Rumex, Cirsium*-type*, Galium, Plantago lanceolata, Secale* and *Hordeum*-type pollen, indicative of stock-breeding, grazing and crop cultivation. The fragments of charred wood testify to tree felling and fire clearances on flat ground in order to obtain new pasture land.

3. The results from plant macrofossil determination and the changes in the lithology point to the existence of a shallow lake in the early Holocene which was afterwards transformed into a peat bog overgrown mainly by sedges, mosses and semi-shrubs.

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