History of vegetation and landscape during the last 4000 years in the area of Straldzha mire (SE Bulgaria)

Spassimir Tonkov[1], Elissaveta Bozilova[1], Elena Marinova[2] & Høgne Jűngner[3]

[1] Department of Botany, Faculty of Biology, Sofia University St. Kliment Ohridski, 1164 Sofia, Bulgaria, e-mail: tonkov@biofac.uni-sofia.bg (corresponding author)

[2] CAS, Katholieke Universiteit Leuven, 3001 Leuven, Belgium

[3] Dating Laboratory, University of Helsinki, 00014 Helsinki, Finland

Received: May 14, 2008 ▹ Accepted: May 20, 2008

Abstract. Pollen analysis was conducted on a 290 cm deep core collected from the central part of the former Straldzha mire in northeastern Toundzha Hilly Plain. The radiocarbon dating indicated that the sediments were deposited during the last ca. 4200 years. Three stages of vegetation development were established: a) distribution of wet meadow and halophilous herbaceous mire communities and groups of deciduous and coniferous trees on the surrounding hills (4200–2830 cal. yrs. BP); b) expansion of halophilous vegetation dominated by *Chenopodiaceae* (2830–1330 cal. yrs. BP) and c) partial regeneration of the tree vegetation (*Quercetum* mixtum) and formation of the present-day composition of mire vegetation (since 1330 cal. yrs. BP). The palynological and archaeobotanical evidence suggests a marked human impact on the landscape and natural vegetation in the study area since the Bronze Age, with practice of agriculture and stock-breeding. The paleovegetation reconstruction of the last four millennia shows features in common with similar investigations from the Thracian Plain.

Key words: human impact, Late Holocene, pollen analysis, Straldzha mire, vegetation history

Introduction

The available paleoecological information on the Post Glacial vegetation development, climate changes and human impact in the lowlands of South Bulgaria is still scarce and incomplete. Recently were published the first results from the investigation of Late Glacial sediments in the vicinity of Dyadovo and Ezero villages, Nova Zagora district, dated at ca. 13000 ^{14}C yrs. BP and containing well preserved pollen and plant macrofossil remains (Gaydarska & al. 2003; Magyari & al. 2008). Palaeobotanical evidence indicates predominantly open vegetation during the Late Glacial, although macrofossil remains of woody taxa demonstrate local presence of patches of wooded steppe and gallery forest. A palynological study of a former peat bog near Sadovo, Thracian Plain, revealed intensive human interference in the natural vegetation cover during the Late Holocene, when the fragments of *Quercetum mixtum* woods were heavily destroyed and replaced by herbaceous communities (Filipovitch & Stojanova 1990).

The present investigation of sediments from Straldzha mire aims to expand our knowledge on the Holocene vegetation history and human impact during the last millennia in the Toundzha Hilly Plain, Karnobat district. A preliminary palynological report (Bozilova & Tonkov 2004) was published on this lowland mire and data was contributed to the European Pollen Database (Tonkov & al. in press).

Study area

Physico-geographical characteristics

Straldzha mire is situated 15 km westwards of the town of Karnobat (42°37'81" N, 26°50'36" E; 150 m a.s.l.), in the northeastern corner of the Toundzha Hilly Plain. It borders in the north on Terziyski Hill (472 m), which is part of the southernmost spurs of the Eastern Balkan Range, on the railway line to the city of Bourgas in the south, and on Hisar Hill (405 m) in the southeast (Fig. 1, 2). At the turn of the last century this mire was the largest inland freshwater basin, with an area of ca. 40 000 ha, before it was drained for agricultural needs after 1920. The mire is formed in a shallow depression, 25 km long and with an inclination of 2 m southwards, lying on Pleistocene sediments. The soil is sandy-clayish, with a thick peat layer (Pushkarov & Doncheva-Mateeva 1932). Geologically, the surrounding hills are composed of Upper Cretaceous marls and limestones (Joakimov 1909; Bonchev 1929). The mire was fed by river Marash, several small riverlets and karst springs, and was drained in its southern part by river Mochouritsa. A characteristic feature was the relatively small area of open water surface throughout the year, covered by floating islands of reed. Nowadays, mire vegetation occupies only one-third of its former area, because a large part of it was converted into arable land. River Mochouritsa was transformed into a canal, while the water from river Marash was directed into a system of canals crossing the territory of the mire. An artificial reservoir was constructed in the easternmost part. The climate is transitional continental, the average annual temperature is 12 °C and the annual precipitation is ca. 530–540 mm. The snow cover in winter is unstable. The prevailing winds are northeasterly and southeasterly (Kostadinova & al. 1999).

Contemporary flora and vegetation

Information on the contemporary flora and vegetation in the study area is found in several publications (Joakimov 1909; Jordanov 1931; Dimitrov & Tzonev 1999; Dimitrov 2004). Before the drainage of the mire, large areas were occupied by *Phragmites australis,* with the participation of *Typha latifolia, Schoenoplectus lacustris, Lythrum salicaria, Stachys palustris*, *Lycopus europaeus*. The presence of *Potamogeton fluitans, P. crispus, Ranunculus aquatilis* depended on the water level, while in the drier parts were found *Alisma-plantago aquatica, Butomus umbellatus, Mentha aquatica, Solanum dulcamara, Calystegia sepium, Bidens tripartita,* etc. The flora in the peripheral parts was more diverse in the existing wet meadows, together with halophilous plant communities, the latter composed of *Atriplex hastatum, Camphorosma monspeliaca, Suaeda maritima, Spergularia salina, Aster tripolium, Artemisia maritima, Limonium gmelini,* etc. (Jordanov 1931).

The main factor responsible for the present state of the mire flora and vegetation is the anthropogenic impact. It has caused additional enrichment of the soil with salts and a partial block-up of the drainage system. Today, the marshy vegetation is distributed mainly inside and along the canals in the Gyola locality and is represented by *Phragmites australis*, *Heleochasris palustris, Lycopus europaeus, Typha latifolia, T. laxmanii, Bolboschoenus maritimus*, *Ceratophyllum demersum, Potamogeton crispus, Ranunculus pseudofluitans, Lemna*

Fig. 1. Map of Bulgaria with the location of Straldzha mire.

minor, L. gibba, L. trisulca. The wet meadows are covered by *Poa palustris, P. pratensis, Carex hirta, C. rostrata, Trifolium pratense, Lathyrus pratense, Ranunculus acris, Potentilla reptans, Thalictrum lucidum, Th. flavum* and ruderals/weeds, such as *Aristolochia clematis, Hordeum murinum, Galium aparine, Cirsium arvense, Sambucus ebulus,* etc. Patches of halophilous vegetation are preserved in the vicinity of Straldzha town and Atolovo village (Dimitrov & Tzonev 1999).

The vegetation on the surrounding hills is xerothermic, secondary in origin and formed in the place of destructed forests of *Quercus cerris, Q. frainetto* and *Ulmus minor*. Isolated groups of trees and shrubs are found, composed of *Carpinus orientalis, Fraxinus ornus, Quercus pubescens, Q. cerris, Prunus mahaleb, Acer campestre, A. tataricum, Paliurus spina-christii, Syringa vulgaria, Cornus mas*. Commercial plantations of *Pinus nigra* are also present (Dimitrov 2004).

Material and methods

Core and lithology

The core for pollen analysis was 320 cm deep and was collected with a Dachnowsky hand-corer from the central part of the mire, Gyola locality, at a water depth of 20 cm. It has the following lithology: 0–110 cm grey clay-gyttja with fragments of *Phragmites* and *Typha*; 110–240 cm dark-grey clay-gyttja; 240–290 cm light-grey clay-gyttja; 290–320 cm grey-brown clay. Peat layers overlaying the clay, as earlier reported from different parts of the mire (Pushkarov & Doncheva-Mateeva 1932), were not found.

Fig. 2. A view of Straldzha mire (photo: J. Stateva).

Pollen analysis

The core was sectioned at intervals of 10 cm and the samples were treated with HF acid before acetolysis (Faegri & Iversen 1989). The interval 290–320 cm contained no pollen. The abundance of fossil pollen and spores was not high. The pollen sum (PS) includes AP (tree/shrub pollen) and NAP (herb pollen). Spores of mosses, pteridophytes and pollen of aquatics and Cyperaceae are not included in the PS. In most instances a PS of 250–280 was achieved. Identification of spores and pollen was made using the reference collection of the Laboratory of Palynology and the keys in Beug (2004), Faegri & Iversen (1989) and Moore & al. (1991). For calculation and drawing of the pollen diagram, TGView ver. 2.0.2 software was used (Grimm 2004). The pollen diagram is subdivided into Local Pollen Assemblage Zones (LPAZ), which are numbered from the base upward (Strl-1…Strl-3) (Fig. 3).

Radiocarbon dating and local chronology

The radiocarbon age of plant macrofossils extracted from three bulk sediment samples was determined in the Dating Laboratory of the University of Helsinki, Finland. The calibration (±2σ range) was performed with the OxCal v3.9 program (Bronk Ramsey 2001) and the results are shown in Table 1. The estimated age of the profile is ca. 4200 cal. years BP. The provisional depth/time model implies a faster rate of sedimentation (13 yrs/cm) for the interval 270–150 cm, as compared to the interval 150–40 cm (22 yrs/cm). The uppermost 35–40 cm of clay-gyttja were deposited during the last few decades.

Table 1. Radiocarbon dates of mire Straldzha

^{14}C Lab. No.	Depth (cm)	^{14}C Dates (yrs. BP)	Calibration
Hela-589	35–40	modern	1962 or 1990 AD
Hela-690	145–150	2350±70	2160–2700 BP (2430)
Hela-691	265–270	3695±65	3860–4230 BP (4040)

Archaeobotanical analysis

In addition to the palynological record, archaeobotanical samples collected from dwelling pits of sites located southwards of Karnobat were analyzed. After flotation of the samples, carbonized seeds/fruits from cultural and wild plants were found. Fragments of wood were also identified. The age of these sites is attributed to the middle of 1st millennium BC (Momchilov personal commun).

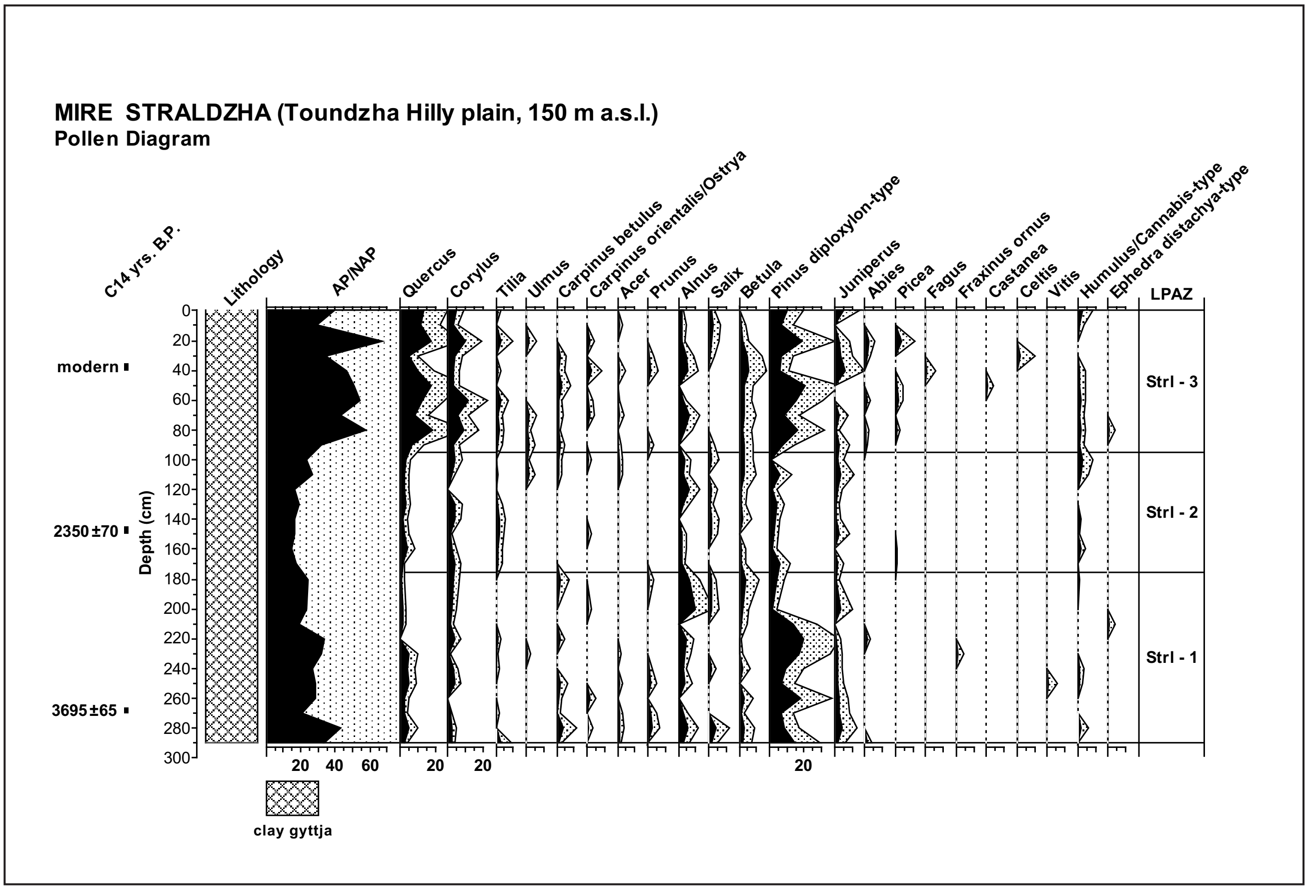

Fig. 3. Pollen diagram of Straldzha mire.

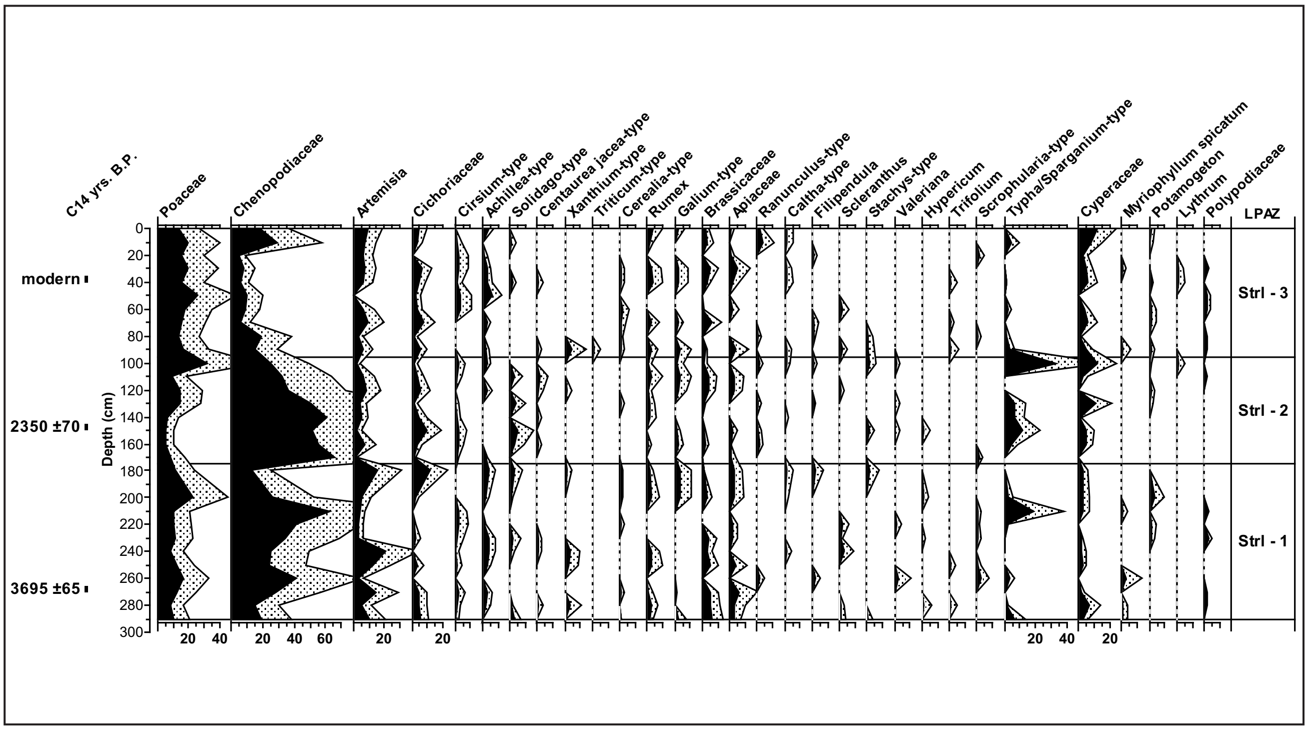

Fig. 3. Pollen diagram of Straldzha mire (continuation).

Results

The three LPAZ reflect successive changes in the development of local and regional vegetation. Their description is briefly as follows (Fig. 3):

LPAZ Strl-1: 290–175 cm (NAP-*Chenopodiaceae-Pinus diploxylon*; 4200–2830 cal. yrs. BP)

In this zone, herb pollen (NAP) dominates with 45–60 %, contributed by *Chenopodiaceae* (20–40 %, maximum of 63 % at 210 cm), *Artemisia* (5–20 %), *Poaceae* (10–20 %), *Cichoriaceae* (5–15 %), *Brassicaceae* (5 %), *Achillea*-type (up to 5 %), *Apiaceae* (up to 5 %), *Scrophularia*-type, etc. Arboreal pollen (AP) is ca. 30–35 %, represented mainly by *Pinus diploxylon*-type (8–20 %), *Alnus* (5–10 %), and *Quercus, Corylus, Carpinus betulus, Juniperus* – each below 5 %. Pollen grains of *Ulmus, Abies, Fraxinus ornus, Ephedra distachya*-type, *Humulus/Cannabis*-type have been identified. Anthropogenic pollen indicators (*Cerealia*-type, *Rumex, Galium*-type, *Scleranthus*) are also present. The group of hygro- and hydrophytes comprises pollen of *Cyperaceae* (up to 6 %), *Typha/Sparganium*-type (up to 20 %), *Myriophyllum spicatum,* and *Potamogeton*.

LPAZ Strl-2: 175–95 cm (NAP-*Chenopodiaceae*; 2830–1330 cal. yrs. BP)

The highest amount of NAP (70–80 %) is registered in this zone. The pollen spectra are dominated by *Chenopodiaceae* (55–65 %), accompanied by *Poaceae* (15 %), and *Cichoriaceae*, *Artemisia, Solidago*-type, and *Brassicaceae* – each with 5–10 %, *Achillea*-type, *Apiaceae*, and *Ranunculus*-type. AP curve does not exceed 20 % contributed by *Quercus, Corylus*, *Tilia, Alnus, Betula, Salix*. Maximum values are recorded for *Cyperaceae* (10 %) and *Typha/Sparganium*-type (35 %). At the transition to the next zone the pollen curve of *Chenopodiaceae* starts to decline.

LPAZ Strl-3: 95–0 cm (*Quercus-Pinus diploxylon-Poaceae*; 1330 cal. yrs. BP until present)

The amount of AP increases up to 45–60 % (maximum of 70 % at 20 cm), due to the participation of *Quercus* (10–18 %), *Pinus diploxylon*-type (up to 20 %), *Corylus* (10 %), *Betula, Carpinus betulus, C. orientalis/Ostrya, Ulmus* and *Juniperus* - each with 2–5 %. Single pollen grains of *Fagus, Castanea* and *Celtis* are registered only in this zone. Indicative is the regular find of *Picea* and *Abies* pollen. *Poaceae* is present with 15–25 %, together with *Artemisia*, *Cichoriaceae*, *Brassicaceae*, and *Apiaceae*. The amount of *Chenopodiaceae* pollen is 5–10 %, with the exception of the uppermost samples. A continuous pollen curve for *Cerealia*-type has been established. The local elements are represented by *Cyperaceae*, *Potamogeton, Typha/Sparganium*-type, and *Myriophyllum spicatum*.

Discussion

The fossil pollen record and the radiocarbon ages confirm that the sediments studied were deposited during the last ca. 4200 years, i.e. since the Subboreal. By that time (zone Strl-1), mire vegetation consisted of halophilous and wet meadow communities, quite similar in composition to the present-day ones. On salty terrains the herbaceous communities were dominated by various *Chenopodiaceae* species, while in the meadows were found representatives of *Cichoriaceae*, *Apiaceae*, *Brassicaceae*, *Filipendula*, *Scrophularia*. Hygrophyte vegetation was widely distributed, represented by the formation of *Phragmites*, together with *Typha*, diverse *Carex* and *Poaceae* species. In places with permanent open-water surface, hydrophytes developed, such as *Potamogeton* and *Myriophyllum,* which indicated a higher water level. The peripheral parts of the mire were overgrown with *Salix* and *Alnus*. The slopes of the hills, surrounding the mire from the north, were covered by stands of pine (most probably *Pinus nigra*) and deciduous trees (*Quercus, Carpinus betulus, Acer, Corylus*). These groups of trees were already fragmented and destroyed to a large extent by the population of the local Bronze Age settlements. Secondary shrubby communities of *Carpinus orientalis* and *Juniperus* developed in their place. Human activity in the vicinity of the mire is proved by the continuous presence of the pollen of Cerealia-type, defined as a primary pollen anthropogenic indicator, and such secondary indicators as *Xanthium, Rumex, Scleranthus,* and *Galium,* indicative mainly of stock-breeding (Bozilova & Tonkov 1990; Tonkov & al. 2007). The archaeological finds of tools and ceramic fragments from the nearby Chokoiska Settlement Mound have been attributed to the Eneolithic and Bronze Age (Momchilov & al. personal commun.). This area was populated already in the middle of 6th millennium BC, when the Neolithic people migrated with their animals upstream of river

Maritza and settled along its tributaries, including river Toundzha (Lihardus & al. 2002).

The subsequent changes in the vegetation development (zone Strl-2) coincide with the onset of the Subatlantic ca. 2830 cal. yrs BP. In the course of 1500 years, the vegetation appearance in and around the mire had considerably changed. The remnants of deciduous and coniferous vegetation on the hills were almost completely destroyed. In the mire itself, the halophilous communities composed of various *Chenopodiaceae* species gained wider distribution on clayish soils. The absence of hydrophytes, the spread of *Typha*, Cyperaceae and some *Poaceae* species indicate a lower water level and overgrowing of the mire.

Although that time interval coincides broadly with the Iron Age, the Hellenic and Roman periods, palynological evidence on the practice of agriculture is considerably insufficient and represented only by single pollen grains of *Cerealia*-type. The archaeological material excavated from the settlement mounds nearby the mire consists of ceramic vessels (Momchilov & al. personal commun.). On the other hand, the analyzed archaeobotanical samples from the dwelling pits contain abundant material of cultivated and wild plants. Grains of cultivated cereals such as *Triticum aestivum/durum, T. monococcum, T. dicoccum,* and *Hordeum vulgare* var. *vulgare* prevail, accompanied by *Panicum milliaceum*. Seeds/fruits of weeds and ruderals, such as *Ranunculus arvensis, Polygonum convolvulus, Bromus sterilis/tectorum, Chenopodium album,* and *Galium* sp. *Rumex* spp. are also present in the samples. These finds indicate winter-sown fields and well-developed agriculture in the middle of the 1st millennium BC. The carbonized wood from *Quercus,* together with single fragments from *Ulmus* and *Rosaceae* prove the existence of patches of deciduous tree vegetation in this part of the Toundzha Hilly Plain.

According to the pollen record and the local radiocarbon chronology, the last period of vegetation development (zone Strl-3) began in the 6th century AD. It was characterized by partial regeneration of deciduous vegetation composed of *Quercus, Carpinus betulus*, *Tilia, Acer*, and shrubby communities of *Carpinus orientalis* and *Juniperus*. The regular occurrence of *Abies* and *Picea* pollen in that zone is explained by aerial transport from the Balkan Range. The find of *Castanea* pollen confirms its cultivation by the local population. The uppermost pollen spectra reflect the contemporary state of mire vegetation. Substantial decrease of the areas occupied by the halophilous vegetation resulted from the construction of a drainage system of canals, which in turn favoured the wider distribution of wet-meadow herbaceous communities composed of Poaceae, Brassicaceae, *Trifolium*, Ranunculaceae species, etc. A change in the hydrological regime of the mire at the coring place, the Gyola locality, towards a higher water level is presumed from the presence of pollen of hydrophytes. The rising participation of *Pinus* pollen originates mainly from the commercial plantations of *Pinus nigra* on the surrounding hills. Reappearance of the primary anthropogenic pollen indicators testifies to the intensification of human activities in the study area. The drainage of the mire for agricultural needs has had a negative effect on the natural vegetation and presently a number of rare plants are considered as threatened (Dimitrov & Tzonev 1999).

The vegetation history in the area of Straldzha mire during the last four millennia can be easily compared with the palynological results from the Sadovo lowland peat bog, located near river Maritsa in the Thracian Plain. The age of both studied profiles is comparable, supported by radiocarbon dates. The pollen diagram from Sadovo reveals that scattered stands of *Quercus* with *Tilia* and *Ulmus,* still preserved in the Subboreal, were subsequently heavily destroyed by the local population. On wetter terrains, groups of *Salix, Alnus* and *Populus* developed, but on the whole herbaceous vegetation prevailed in this area. The rich palaeoethnobotanical and palynological evidence also presumes the existence of vast stretches of arable land, where *Triticum* and *Hordeum* were cultivated (Filipovitch & Stojanova 1990).

Conclusions

1. The pollen record from Straldzha mire dates back to ca. 4200 cal. yrs. BP, when natural vegetation in the vicinity was already destroyed by the local population from the Bronze Age settlements. The mire vegetation was composed of wet-meadow and halophilous herbaceous communities.
2. The halophilous communities dominated by *Chenopodiaceae* species expanded between 2830 and 1330 cal. yrs. BP, when the water level decreased.
3. A partial regeneration of the mixed *Quercus* forests on the surrounding hills occurred after 1330 cal. yrs. BP.

4. According to the palynological data, the most marked human impact on the landscape and natural vegetation in the study area is related to the Late Bronze Age and since Mediaeval times.
5. Archaeobotanical evidence confirms the existence of well-developed agriculture in this part of the country in the middle of the 1st millennium BC.
6. Paleovegetation reconstruction of the northeastern part of the Toundzha Hilly Plain during the last four millennia has features in common with similar investigations from the Thracian Plain.

Acknowledgements: Field work for collection of the core for pollen analysis was done with the assistance of Dr D. Momchilov and J. Stateva from the Museum of History in Karnobat. Both colleagues provided also the material for archaeobotanical analysis and the archaeological information. The financial support of the local commune and the Bulgarian Society for Protection of Birds in Sofia is gratefully acknowledged. Thanks are also extended to an anonymous reviewer of the manuscript.

References

Beug, H-J. 2004. Leitfaden der Pollenbestimmung fur Mitteleuropa und angrenzende Gebiete. Verlag Dr Friedrich Pfeil, München.

Bonchev, G. 1929. The Mires in Bulgaria. Ministry of Agriculture and State Property, Sofia (in Bulgarian).

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. & al.** (eds), Man's Role in the Shaping of the Eastern Mediterranean Landscape. Pp. 327-332. Balkema, Rotterdam.

Bozilova, E. & Tonkov, S. 2004. History of the vegetation in the area of Straldzha mire (municipality of Karnobat): preliminary results. – In: **Momchilov, D. & al.** (eds), The Nature of Karnobat Area. Vol. 1, pp. 56-60. Zograf Publishing House, Karnobat (in Bulgarian).

Bronk Ramsey, C. 2001. OxCal Program v3.9. University of Oxford, Radiocarbon Accelerator Unit.

Dimitrov, D. 2004. Flora and vegetation of the Terziiski hill and Hissar - Eastern Stara Planina Mts. – In: **Momchilov, D. & al.** (eds), The Nature of Karnobat Area. Vol.1, pp. 61-64. Zograf Publishing House, Karnobat (in Bulgarian).

Dimitrov, D. & Tzonev, R. 1999. Flora and vegetation. – In: **Kostadinova, I. & al.** (eds), Flora and Fauna of the Area of the Former Straldzha mire. Report of the Bulgarian Society for Protection of Birds. Pp. 3-7. Sofia (in Bulgarian).

Faegri, K. & Iversen, J. 1989. Textbook of Pollen Analysis. 4th ed. John Wiley & Sons, Chichester.

Filipovitch, L. & Stojanova, V. 1990. Palynological study of the peat bog near Sadovo. – Fitologiya, **38**: 22-40 (in Bulgarian).

Gaydarska, B., Magyari, E., Tsonev, T., Goslar, T., Bozilova, E. & Chapman, J. 2003. The Human Impact on Later Prehistoric Communities in the Balkans – Interdiscipl. Res. Archaeol. Rep. Univ. Duram and Univ. Newcastle upon Tyne, **24**: 12-18.

Grimm, E. 2004. TGView ver.2.0.2. Illinois State Museum. USA.

Jordanov, D. 1931. Phytogeographical studies of the mires in Bulgaria in respect to their vegetation. Mire Straldzha. – God. Sofiisk. Univ., **27** (3): 110-113 (in Bulgarian).

Joakimov, D. 1909. Lake Straldzha. – Priroda, XII, **9** (in Bulgarian).

Kostadinova, I., Stefanov, T. & Petrov, B. (eds). 1999. Flora and fauna of the area of the former Straldzha mire. Report of the Bulgarian Society for Protection of Birds, Sofia (in Bulgarian).

Lichardus, J., Iliev, I. & Christov, Ch. 2002 Die Karanovo I-IV-Perioden an der unteren Tunda und ihre chronologische Stellung zu den benachbarten Gebieten. – In: **Lichardus, M. & al.** (eds), Beitrage zu jungsteinzeitlichen Forschungen in Bulgarien. Saarbrucker Beitr. Altkde **74,** pp. 325-410. Habelt, Bonn.

Magyari, E., Chapman, J.C., Gaydarska, B., Marinova, E., Deli, T., Huntley, J.P., Allen, J.R.M. & Huntley, B. 2008. The 'oriental' component of the Balkan flora: evidence of presence on the Thracian Plain during the Weichselian late-glacial. – J. Biogeogr., **35**(5): 865-883.

Moore, P., Webb, J. & Collinson, M. 1991. Pollen Analysis. 2nd ed. Blackwell Scientific Publications, Oxford.

Pushkarov, N. & Doncheva–Mateeva, L. 1932. Soil study of the Straldzha mire. – Proc. Bulg. Environm. Soc., **15-16:** 25-62 (in Bulgarian).

Tonkov, S., Bozhilova, E. & Panovska, H. 2007. Cerealia pollen evidence from pollen diagrams and palaeoethnobotany in Bulgaria. – In: **Stefanovich, M. & Angelova, Ch.** (eds), PRAE. In Honorem Henrieta Todorova. Pp. 311-317. Natl. Archaeol. Inst. with Museum. Publishing House Bulg. Acad. Sci., Sofia.

Tonkov, S., Bozilova, E. & Jüngner, H. In press. Contributions to the EPD. Lake Straldza (SE Bulgaria): Late Holocene vegetation history. – Grana.