Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences

Tome 66, No 3, 2013

BIOLOGIE

Botanique

PALAEOECOLOGY AND GEOARCHAEOLOGY OF VARNA LAKE, NORTHEASTERN BULGARIA

Mariana Filipova-Marinova, Danail Pavlov*, Stoyan Vergiev, Vladimir Slavchev, Liviu Giosan*****

(*Submitted by Academician V. Golemansky on October 30, 2012*)

Abstract

Palaeoenvironmental data from the high-resolution spore-pollen analysis of laminated sediments from newly-taken Core 3 – Varna Lake were combined with analyses of dinoflagellate cysts, acritarchs and other non-pollen palynomorphs (NPP), including fossil algal and fungal remains. The location of the core is close to submerged prehistorical sites and permits the palaeoenvironmental correlations of obtained results with available archaeological and geochronological data. The established Age Model shows that the accumulation of lake sediments started after 7870 cal. BP and is connected with a rise of the Black Sea level. One-hundred-ninety-cm-long molluskan shell hash layer of *Mytilus galloprovincialis* covers the interval from 7776 to 6183 cal. BP. The mixed oak and hornbeam forests dominated the vegetation cover during the Atlantic, Subboreal and Subatlantic chronozones of the Holocene. An important change in the forest composition occurred at ca 5598 cal. BP, when *Carpinus betulus* increased its spreading due to climatic changes. The high-resolution reconstruction of palaeovegetation also reveals the extent of anthropogenic influence in Varna Lake area. Two periods of significant presence of pollen from cultivated cereals, weeds and ruderals were identified. According to the available AMS-radiocarbon data, these periods are attributed to the Late Eneolithic and Early Bronze Age. The anthropogenic impact on the natural vegetation has been identified by deforestation and agricultural practice. The Transitional period without human activities between these two periods lasted ca 319 years

The financial support of the bilateral project "Comparative PaleoEcology and GeoArchaeology of Varna Lake (Bulgaria) and Mamaia Lake (Romania) – E.G.A.L." funded by the Bulgarian National Science Fund and the Romanian National Authority for Scientific Research is greatly acknowledged.

and coincided with a rise of the Black Sea level, reflected by the increase of euryhaline marine dinoflagelate cysts and acritarchs.

Key words: pollen, dinocysts, non-pollen palynomorphs, AMS dating

Introduction. Over the last decades, archaeologists have faced the necessity to reconstruct ancient settlement history not only through the study of the material excavated, but also with the use of palaeoenvironmental parameters. The coastal lakes offer great possibilities for investigations of the Holocene sediments as reliable sources of rich biostratigraphic information in order to trace out the palaeoecological changes and human impact on the natural vegetation. The palaeoecological information for the northern Bulgarian Black Sea coastal area was retrieved from Durankulak Lake [1,2], Shabla–Ezerets Lake system [3], as well as Varna–Beloslav Lake system (submerged prehistorical settlements near the villages of Strashimirovo and Povelyanovo, and Arsenala area) [4]. Several stages of development of Varna Lake based on the character of sediments, hydrological conditions and radiocarbon dates were delimited. The palaeoecological data offered an opportunity for drawing a conclusion about the influence of the climate on the Black Sea transgressions and regressions and other palaeoenvironmental conditions along Varna Lake area. Based on a complex palaeobotanical and archaeological investigations, the human influence on vegetation from Eneolithic to present days was traced out. Unfortunately, because of the lack of AMS radiocarbon dates, precise and high-resolution geochronology could not be established and it was not possible to correlate adequately the results with archaeological chronology. On the other hand, laminated sediments (varves) have never been palynologically investigated from the upper-mentioned sites. With a view to addressing these unresolved questions, a new Core-3 with laminated sediments from Varna Lake was dated by AMS-radiocarbon dating and an Age Model was created. The core was analysed for pollen, spores, dinoflagellate cysts, arcritarchs and other non-pollen palynomorphs. The main results of this high-resolution palaeoecological study are discussed in attempt to shed additional light on vegetation dynamics during the Holocene and to get detailed information about the human impact particularly during the Late Eneolithic and Early Bronze Age. The obtained geoarchaeological information is compared with the results from the previous palaeoecological studies, the available archaeological evidence and radiocarbon chronology.

Material and methods. Varna Lake is situated in Northeastern Bulgaria (Fig. 1). It is the largest by volume and deepest liman along the Bulgarian Black Sea Coast with area of 17 km^2, maximal depth of 19 m, and water volume of 166 million m^3. The sediment Core-3 was obtained from the northern coast of Varna Lake near the wharf Transstroy area (Fig. 1) at a water depth of 6 m.

The core is 995 cm long but its palynologically-investigated length is 870 cm. It contains dark grey clay and laminated sediments (varves). Seven samples of

Fig. 1. Location of the investigated Core 3 – Varna Lake

sediments were submitted for radiocarbon dating (Table 1). The radiocarbon dates were obtained in the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) Facility of Woods Hole Oceanographic Institution. The dates have been calibrated using the latest version 6.1.0 of programme Calib [5] using the IntCal09 curve in order to be correlated with the available archaeological and geochronological data. An Age Model (Fig. 2) for the sedimentation rate of the core was created by the newest version 1.17.16 of the TILIA software [6]. The lithology of the core is shown in Fig. 3.

Thirty-five samples for pollen analysis were processed according to the acetolysis laboratory method slightly modified to remove the mineral components with sodium pyrophosphate and hydrofluoric acid [7]. By this procedure, cysts of some insignificant dinoflagellate species could be lost, but the main indicative taxa are preserved. The pollen types were determined using the reference collection of the Museum of Natural History of Varna and the available keys [8, 9].

Table 1

Chronology of the investigated Core 3 – Varna Lake

Lab. No.	Depth (cm)	^{14}C Age (uncal. BP)	Median Probability Age (cal. BP)	Median Probability Age (cal. BC)	Material dated
OS-97757	421.5–422.5	3030 ± 50	3230	1280	Sediment organic carbon
OS-97758	500.5–501.5	4260 ± 60	4842	2892	Sediment organic carbon
OS-97756	581.5–582.5	4750 ± 35	5518	3568	Sediment organic carbon
OS-97754	659.5–660.5	5360 ± 50	6139	4189	Sediment organic carbon
OS-97832	679.5–680.5	6140 ± 104	7021	5071	Molluskan shells
OS-97833	869.5–870.5	7076 ± 109	7870	5920	Molluskan shells
OS-97755	989.5–990.5	17800 ± 210	21129	19179	Sediment organic carbon

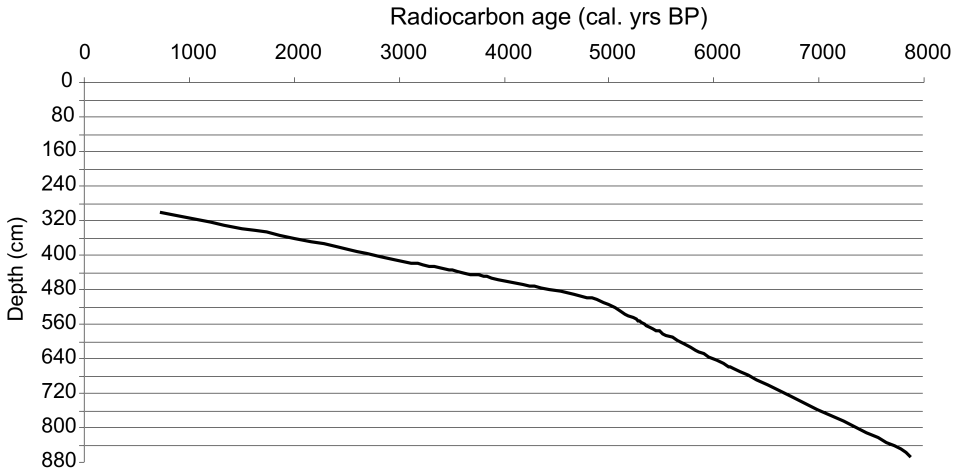

Fig. 2. Sedimentation rate of Core-3 based on the established Age Model

For non-pollen palynomorphs (NPP), the key of Bas van Geel [10] was used. Up to 400 pollen grains of terrestrial plants were counted per sample. The dinoflagellate cysts and other non-pollen palynomorphs (NPP) were counted in the samples prepared for routine pollen analysis. The percentage values of the pollen taxa were calculated on the basis of AP + NAP pollen sum (arboreal plus non-arboreal plants excluding spores, aquatics, dinoflagellate cysts and other algae, acritarchs, and other NPP) and a pollen diagram was constructed (Fig. 3*A*–*C*). The frequency of the dinoflagellate cysts and NPP is also presented in percentages based on this pollen sum. The spore-pollen percentage diagram was divided into local pollen assemblage zones and subzones (Table 2) to facilitate description and understanding of vegetation succession. The zones are numbered from the base upwards and prefixed by the site designation (Vn). The computer programme TILIA v.1.17.16 [6] was used for percentage pollen calculations. Cluster analysis programme CONISS [11] was applied for more precise zonation as well. All 117 identified taxa are shown in the pollen diagram (Fig. 3*A*–*C*). The Blytt–Sernanders' Northern European climatostratigraphic subdivision of the Holocene, the archaeological chronology [12] and the regional palynostratigraphy [13] were used for the correlations of pollen assemblages (Table 3).

Results. The pollen diagram of Core-3 is divided into three local pollen assemblage zones (*LPAZ* Vn-1 to Vn-3) and five subzones (*LPASZ* Vn-1a, 1b, 2a, 2b, 2c) (Fig. 3). One hundred and seventeen taxa have been determined altogether, of which 25 are trees and shrubs (arboreal plants, AP), 42 are herbaceous plants (non-arboreal plants, NAP), 17 are aquatics, seven are algae (including four dinoflagellate cysts), three are acritarchs and 23 are other non-pollen palynomorphs (including 15 fungal NPP).

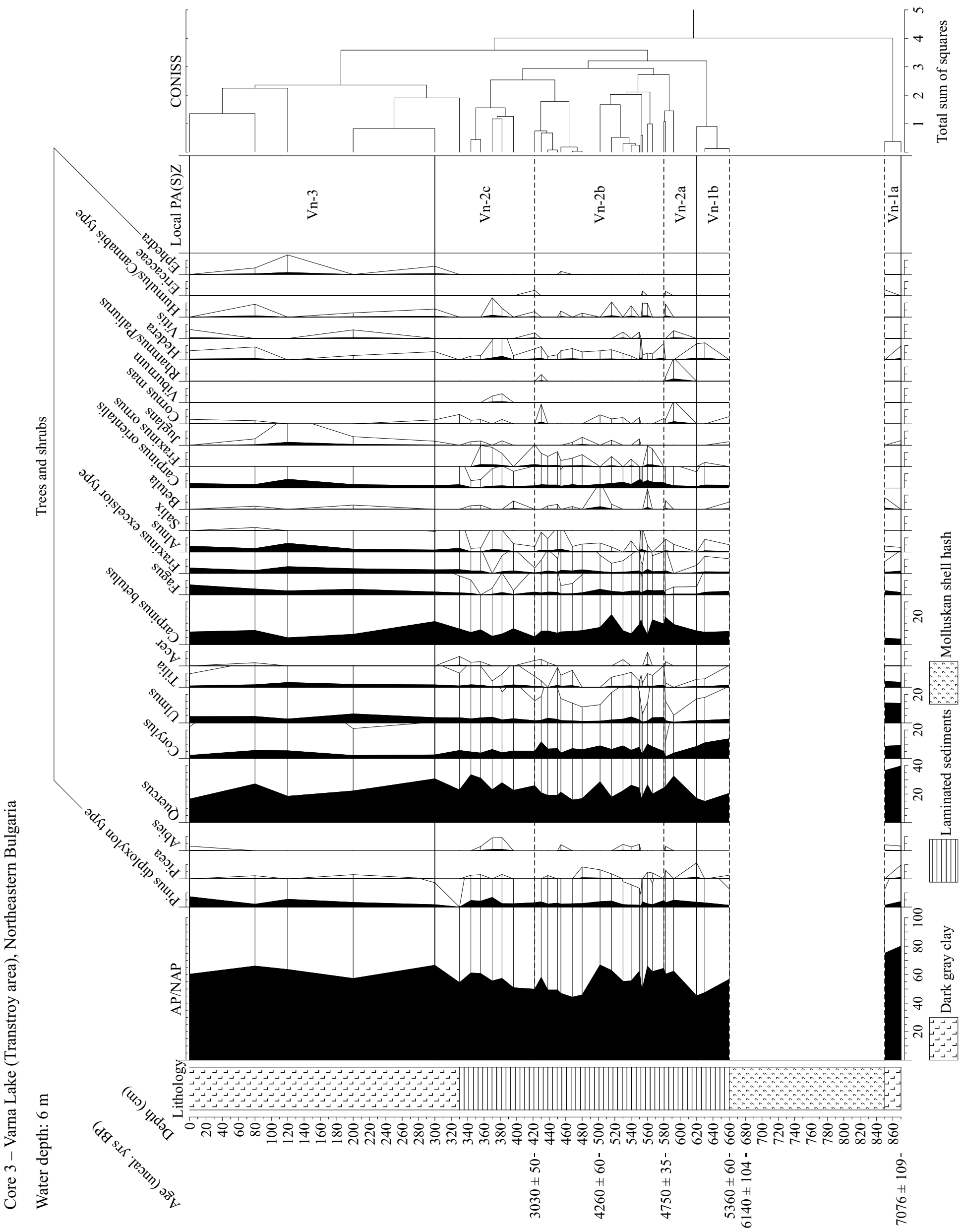

Fig. 3A. Percentage pollen diagram of Core 3 – Varna Lake: arboreal plants

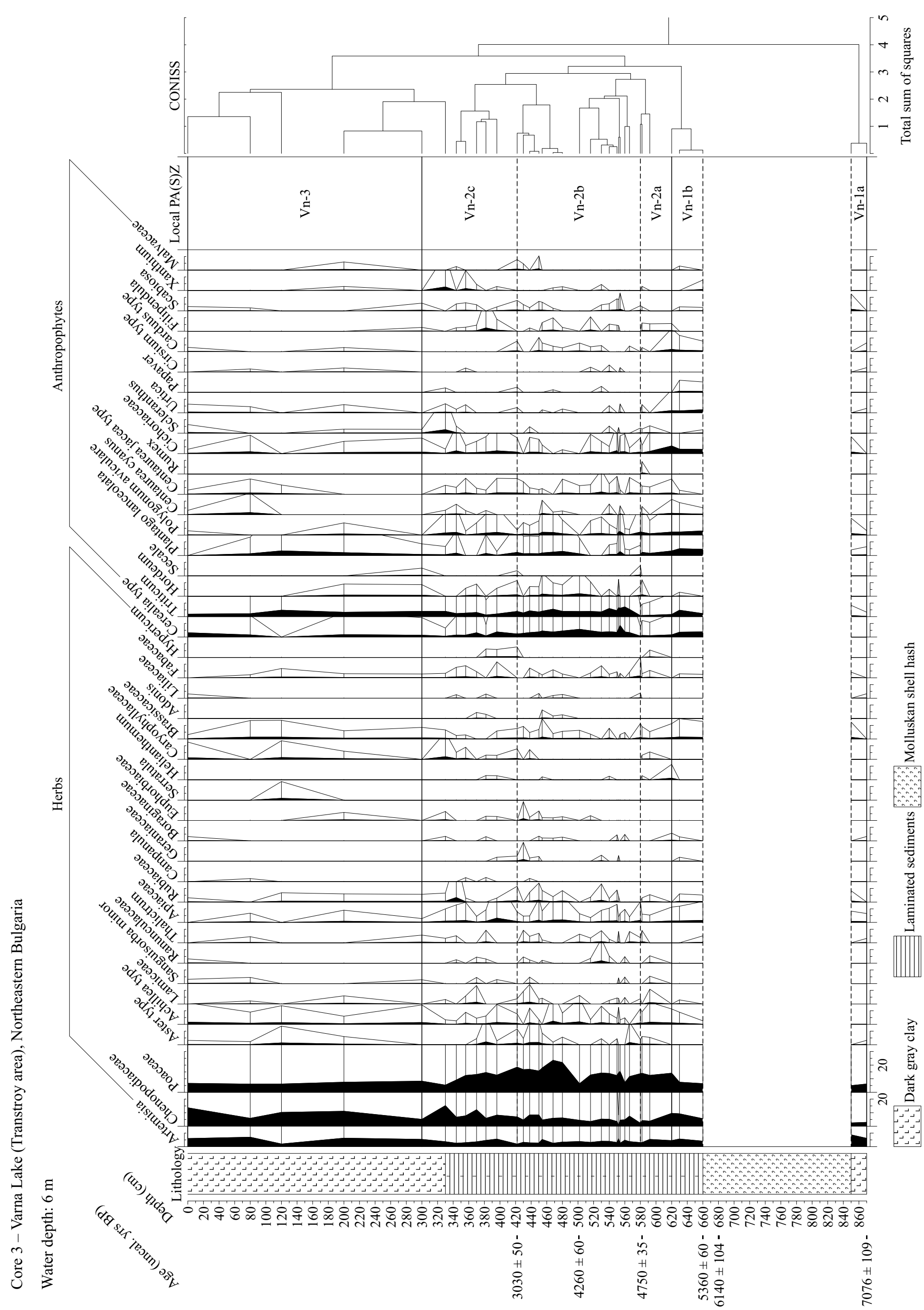

Fig. 3*B*. Percentage pollen diagram of Core 3 – Varna Lake: non-arboreal plants

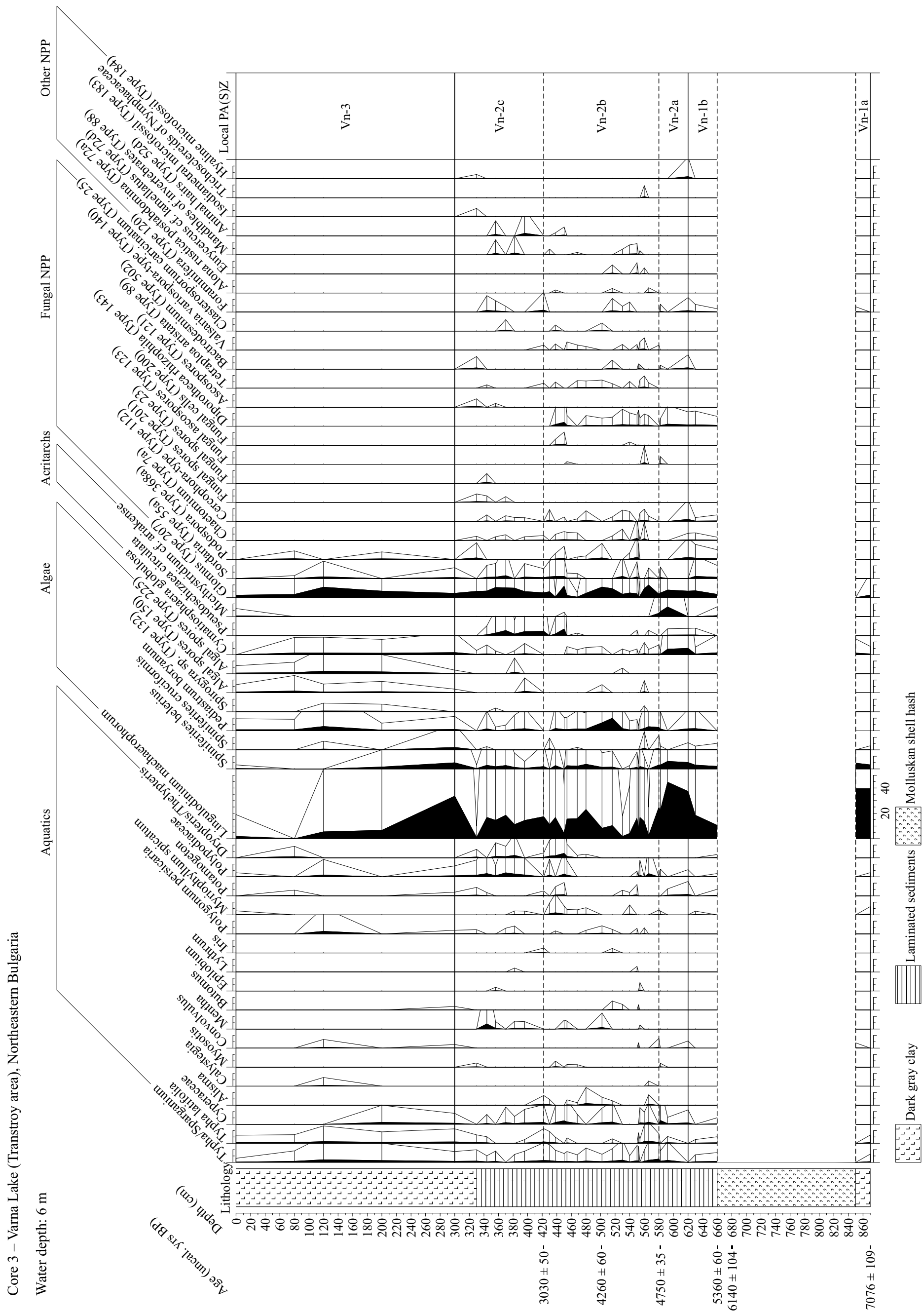

Fig. 3*C*. Percentage pollen diagram of Core 3 – Varna Lake: aquatics, algae, acritarchs and other non-pollen palynomorphs (NPP)

T a b l e 2

Description of the local pollen assemblage zones and subzones from Core 3 – Varna Lake

LPASZ Vn-1a (870–850 cm) 7870–7781 cal. BP ***Quercus* – *Ulmus* – *Corylus*** Dominant *Quercus* (max. 39.7%), *Ulmus* (max. 13.8%) and *Corylus* (below 9.1%) from 7076 ± 109 ^{14}C yrs BP. *Tilia* and *Carpinus betulus* make ca 4%, *Fagus* and *Fraxinus excelsior*-t. ca 2%, while *Alnus*, *Betula*, *Juglans*, *Pinus diploxylon*-t., *Hedera* and Ericaceae become sporadic. *Artemisia* and Poaceae below 6%, Chenopodiaceae ca 3%. Sporadic occurring of various herb taxa including *Aster*-t., Cichoriaceae, *Plantago lanceolata*, *Polygonum aviculare*, *Triticum*, *Cirsium*-t., Brassicaceae and *Thalictrum*. High values of marine dinoflagellates *Lingulodinium machaerophorum* ca 39.4%, *Spiniferites belerius* ca 4% and acritarchs *Cymatiosphaera globulosa* ca 1%.	LPASZ Vn-1b (660–620 cm) 6139–5821 cal. BP ***Quercus* – *Corylus* – *Carpinus betulus* – *Triticum* – *Cerealia*** Rise of *Corylus* up to 13.5% and *Carpinus betulus* up to 9.6% from 5360 ± 60 ^{14}C yrs BP. Falls of *Quercus* up to 14.9%, *Ulmus* up to 1.7% and *Tilia* up to 0.6%. Constant presence of *Fagus* and *Fraxinus excelsior*-t. ca 2%, *Hedera* ca 1%. First appearance of *Carpinus orientalis*. Increased values of Chenopodiaceae up to 9.6% and Poaceae up to 14.1%. Reduced values of *Artemisia* up to 4%. Constantly present *Achillea*-t., Apiaceae and Caryophyllaceae. First appearance and significant presence at 5360 ± 60 ^{14}C yrs BP of *Cerealia*-t. up to 3.8%, *Triticum* up to 4.8%, *Hordeum* sporadic. Regularly appearing *Plantago lanceolata* (5%), *Polygonum aviculare* (3%), *Urtica* (2.2%). Sporadic Cichoriaceae, *Papaver*, *Centaurea cyanus*, *Centaurea jacea*-t. and *Carduus*-t. Marine dinoflagellates *Lingulodinium machaerophorum* at decline up to 10.2%. First appearance of *Pediastrum boryanum* and *Spiniferites cruciformis*. Increasing values of *Glomus* (Type 207), *Cercophora* (Type 112), *Sordaria* (Type 55a), *Podospora* (Type 368a) and *Chaetomium* (Type 7a).
LPASZ Vn-2a (620–580 cm) 5821–5502 cal. BP ***Quercus* – *Carpinus betulus* – *Corylus*** Increasing *Quercus* from 14.9 to 32.6% and *Carpinus betulus* to 19.2% at 4750 ± 35 ^{14}C yrs BP coincidentally with decreasing *Corylus* from 13.5 to 1.2%. *Fagus*, *Tilia*, *Fraxinus excelsior*-t. and *Carpinus orientalis* continuous up to 2%. First appearance of *Acer*, *Vitis*, and *Humulus/Cannabis*. Rise of Poaceae up to 14%, simultaneously with decrease of *Artemisia* up to 3% and Chenopodiaceae up to 2.2% at subzone top. Cereals and other human indicators reduced. Sporadic *Typha/Sparganium*, *Typha latifolia* and Cyperaceae.	LPASZ Vn-2b (580–422 cm) 5502–3230 cal. BP ***Quercus* – *Carpinus betulus* – *Corylus* – *Fagus* – *Carpinus orientalis* – *Cerealia*** Consistently rising *Carpinus betulus* to a maximum at ca 21% (4990 cal. BP) in a pattern with reduced *Quercus*. Both taxa oscillating. Increasing *Corylus* up to 11%, *Fagus* up to 3.8% and *Carpinus orientalis* up to 5.8%. *Humulus/Cannabis* up to 1%. *Tilia* and *Fraxinus excelsior*-t. continuous up to 2%. Maximum of Poaceae up to 22% at 4260 ± 60 ^{14}C yrs BP. *Artemisia* and Chenopodiaceae continuous. Rise of *Cerealia*-t. and *Triticum* up to 6%, and *Hordeum* up to 2%. Regularly appearing *Plantago lanceolata* and

Continued on next page

Maximum of marine dinoflagellates *Lingulodinium machaerophorum* up to 44.5%, *Spiniferites belerius* up to 6% and acritarchs *Cymatiosphaera globulosa* up to 4.3% and *Micrhystridium* cf. *ariakense* up to 7.6%. Decrease of *Pediastrum boryanum*. Constant presence of *Glomus* (Type 207) ca 5%.	*Polygonum aviculare* ca 2%, *Centaurea jacea*-t. and Cichoriaceae ca 1.4%. Sporadic *Centaurea cyanus*, *Papaver*, *Carduus*-t., *Urtica*, *Cirsium*-t. and *Scabiosa*. Small rises of *Typha/Sparganium*, *Typha latifolia*, Cyperaceae and *Polygonum persicaria*. Sporadic *Alisma*, *Mentha* and *Butomus*. Sharp decrease of marine dinoflagellates: fall of *Lingulodinium machaerophorum* initially up to 2.4%, later continuous from 7 to 16%. Decline of *Spiniferites belerius* to ca 1%. Maximum of *Pediastrum boryanum* up to 9.9%. Increasing values of *Valsaria variospora*-t. (Type 140) and *Diporotheca rhizophila* (Type 143), occurring *Spirogyra* sp. (Type 132), Algal spores (Types 150 and 225). Increasing *Cercophora* (Type 112), *Sordaria* (Type 55a), *Podospora* (Type 368a) and *Chaetomium* (Type 7a) continuous around 1–2%. Two small maxima of *Glomus* (Type 207).
LPASZ Vn-2c (422–300 cm) 3230–717 cal. BP ***Quercus* – *Carpinus betulus* – *Corylus* – *Ulmus* – *Triticum* – *Cerealia*** Rising *Quercus* up to 33.6%, *Carpinus betulus* up 10.9% and *Ulmus* up to 3.6% from 3030 ± 50 ^{14}C yrs BP. *Corylus* slightly decreasing. *Tilia*, *Fagus*, *Fraxinus excelsior*-t., *Alnus* and *Carpinus orientalis* continuous around 1.5%. *Cornus mas*, *Viburnum*, *Juglans*, *Rhamnus/Paliurus* and *Hedera* sporadic. At 1335 cal. BP: Poaceae at decline from 18 to 5.3%, rise of Chenopodiaceae from 6 to 15.2%. Continuous values of *Triticum* ca 3–4%. *Cerealia*-t. decreasing from 4.4 to 0.6%, *Hordeum* from 2.7 to 0.5%. Gradual decrease below 1% of *Plantago lanceolata*, *Polygonum aviculare*, *Centaurea jacea*-t., Cichoriaceae, *Filipendula*, *Scabiosa* and *Xanthium*-t. Aquatics reduced. Polypodiaceae shows some rise up to 2.1%. Marine dinoflagellates *Lingulodinium machaerophorum* oscillating from 11 to 16.7%, than increasing sharply up to 33.6% at 717 cal. BP. *Spiniferites cruciformis* stable around 2%. Rise of *Pseudoschizaea circulata* up to 4%. Increasing *Glomus* (Type 207) up to 8%. *Sordaria* (Type 55a) starting continuously from 0.7 to	LPAZ Vn-3 (300–0 cm) 717 cal. BP – ***Quercus* – *Ulmus* – *Alnus* – *Fagus* – *Carpinus orientalis* – *Triticum*** Constant presence of *Quercus* ca 22% and *Ulmus* ca 4.5%. Consistently rising *Alnus* up to 6.1%, *Fagus* up to 7%, *Fraxinus excelsior*-t. up to 4.7%, *Tilia* up to 3.4% and *Carpinus orientalis* up to 6.1%. *Corylus* at decline to 2.2%. *Salix* and *Ephedra* appear. Nearly continuous over 1% *Juglans*, *Hedera*, *Vitis* and *Humulus/Cannabis*. *Artemisia* and Poaceae constantly present ca 7%. Increasing of Chenopodiaceae from 5.1 to 13.6% at zone top. Increasing *Cerealia*-t. from 1.4 to 3.1% and *Triticum* up to 4.7% at zone top. *Hordeum* and *Secale* sporadic. Slight rise of *Plantago lanceolata* up to 3.4%. *Polygonum aviculare*, *Centaurea cyanus*, *Centaurea jacea*-t., Cichoriaceae, *Scleranthus*, *Urtica*, *Cirsium*-t. and *Xanthium* start occurring occasionally. Low values of aquatics *Typha/Sparganium*, *Typha latifolia*, Cyperaceae, *Calystegia* and *Convolvulus*. Sporadic *Myriophyllum spicatum* and *Potamogeton*. Marine dinoflagellates in decline: *Lingulodinium machaerophorum* up to 1.9% and *Spiniferites belerius* up to 0.3%. Continuous

Continued on next page

2.2%. *Cercophora* (Type 112), *Podospora* (Type 368a) and *Chaetomium* (Type 7a) sporadic.	*Pediastrum boryanum*, Algal spores (Type 150 and 225) and *Spyrogyra* sp. (Type 132) over 1%. Constant presence of *Glomus* (Type 207) from 2 to 8%. *Sordaria* (Type 55a) and *Podospora* (Type 368a) ca 1%.

Discussion. ***LPASZ Vn-1a.*** The palynological record and radiocarbon data imply that the vegetation palaeosuccession started from 7870 cal. BP and could be correlated to the Early Atlantic chronozone of the Holocene. Mixed oak forests were widespread and reached their maximal distribution. The extremely high values of arboreal pollen suggest dense forests dominated by *Quercus* with abundant other temperate species such as *Ulmus*, *Corylus*, *Tilia*, *Carpinus betulus*, *Fraxinus excelsior* and *Fagus*. The presence of indicator species such as *Hedera* suggests high humidity and temperature. Probably *Quercus* and other constituents of the mixed oak forests colonised the best soils in the area around Varna Lake as well as the neighbouring Momino and Frangensko Plateau. Low percentage values of *Pinus diploxylon*-type, *Abies* and *Picea* in the fossil record reflect a long-distance transport. Single pollen grains of *Juglans* found in this subzone confirm that the walnut was preserved along the Bulgarian Black Sea Coast during the Late Glacial [13]. Single pollen grains of *Triticum* probably belong to the wild species *Triticum boeoticum* Boiss. and are not indicative of human activity. The absence of anthropogenic activities is also suggested by the lack of fungal spores of dung inhabiting taxa.

The high percentage values of marine dinoflagellates *Lingulodinium machaerophorum* and *Spiniferites belerius*, as well as acritarchs *Cymatiosphaera globulosa* suggest that the lake formation started after 7076 ± 109 ^{14}C years BP (7870 cal. BP) due to the increase of the Black Sea level during the First Phase of the Vityazevyan Black Sea Transgression [14]. Most probably, Provadiyska River valley was submerged and turned into firth connected with the sea. The accumulation of dark gray clay over the light gray clay with Neweuxinian (Pleniglacial) Age of 17800 ± 210 ^{14}C years BP occurred. These data are in conformity with the results of previously investigated core "Arsenala" from the southern coast of Varna Lake, where the beginning of deposition of sandy clay mud started after 7495 ± 95 ^{14}C years BP. The beginning of accumulation of gyttja over the light gray clay with Neweuxinian Age of $11\,000 \pm 500$ ^{14}C was dated in Shabla Lake at 6800 ± 100 ^{14}C years BP. After a short time of ca 94 years, a change in sedimentation and formation of molluskan shell hash layer of *Mytilus galloprovincialis* Lamarck occurred after ca 7776 cal. BP during the Second Phase of the Vityazevyan Black Sea Transgression [14].

LPASZ Vn-1b. The palaeoecological record corresponds to the Late Eneolithic according to the AMS date 5360 ± 50 ^{14}C years BP (4189 cal. BC) from the base of the subzone. Arboreal taxa are presented with lower percentages

T a b l e 3

Correlation between local and regional pollen assemblage zones and subzones (modified after [16])

Uncal. kyrs. BP	Northerneuropean climatostratigraphy of Blytt – Sernander		Archaeological chronology [12]	Regional pollen assemblage zones (PAZ) [13]		Varna Lake-3		Urdoviza-F		Sozopol-D		Sozopol-I		Sozopol-F	
						Local PAZ	Pollen assemblages	Local PAZ	Pollen assemblages	Local PAZ	Pollen assemblages	Local PAZ	Pollen assemblages	Local PAZ	Pollen assemblages
3	HOLOCENE	Subatlantic	Iron Epoch	IX	*Q-U-Al-Cb-Sa-F*	3	*Q-U-Al-F-Cor-Tr*							4	*Q-Cb-Co-U- F-Al*
		Subboreal	Bronze Age	VIII	*Q-Cb-Co-F-Cor-Ce*	2c	*Q-Cb-Co-U-Tr-Ce*					4	*Q-Cb-Co-U-F-Tr*	3	*Q-Cb-Co-F-Cor-Ce*
						2b	*Q-Cb-Co-F-Tr-Ce*	2	*Q-Cb-F-Ce*						
5			Transitional Period			2a	*Q-Cb-Co*	1	*Q-Cb-Co-F-U*			3	*Q-Co-Cb-Ti-F*	2	*Q-Cb-Co-U-F*
		Atlantic		VII	*Q-Co-Cb-U-Tr-Ce*					2	*Q-Po-Tr-Ce*	2	*Q-Ti-F-Po-Tr*	1	*Q-Co-Cb-Ce*
			Eneolithic			1b	*Q-Co-Cb-Tr-Ce*								
						shell hash				1	*Q-Co-Cb-U-F*				
8			Neolithic			1a	*Q-U-Co*								

Legend: Al = *Alnus*, Cb = *Carpinus betulus*, Ce = *Cerealia*-type, Co = *Corylus*, Cor = *Carpinus orientalis*, F = *Fagus*, Po = Poaceae, Q = *Quercus*, Sa = *Salix*, Ti = *Tilia*, Tr = *Triticum*, U = *Ulmus*

compared to the previous *LPASZ* Vn-1a, despite the increase of humidity and temperature, indicated by the presence of *Hedera*. Human impact was the main reason for deforestation. The increased values of *Corylus* coincidentally with decrease of *Quercus* and *Ulmus* also suggest clearance of forests and enlargement of arable areas. The absence of microcharcoals and fungal spores of *Neurospora* sp. (Type 55c) [2] during the interval of deforestation provides evidence for clearance of oak woodlands by cutting. This is also confirmed by archaeological findings of stone tools such as axes and adzes from Varna Lake area during the Late Eneolithic. The appearance of *Carpinus orientalis* and *Fraxinus ornus* is connected with degradation of forests due to a strong anthropogenic influence. Palynological data confirm the archaeological information that agriculture was the basis of Eneolithic economy along the Bulgarian Black Sea Coast [15]. Significant pollen percentages of cultivated cereals including *Cerealia*-type and *Triticum*, and to a lower extent *Hordeum* occurred in this subzone. According to some authors [2,4], *Triticum monococcum*, *T. dicoccum*, *T. aestivum* and *Hordeum vulgare* were the main crops during the Late Eneolithic. Weeds such as *Centaurea cyanus*-type and *Papaver* were also presented. Ruderals *Plantago lanceolata*, *Polygonum aviculare*, Cichoriaceae, *Carduus*-type and *Urtica* confirmed well-developed farming, pasture formation and stockbreeding during the existence of Late Eneolithic settlements in Varna Lake area. The results are in accordance with data from previous palynological investigations of cores from the Varna–Beloslav Lake system [4] and from Sozopol Harbour (Table 3) [16]. The high anthropogenic influence on palaeoenvironment is also confirmed by dung indicators such as *Podospora*-type (Type 368a), *Cercophora*-type (Type 112), *Sordaria*-type (Type 55a) and *Chaetomium* (Type 7a).

The low percentage values of marine dinoflagellate cysts *Lingulodinium machaerophorum*, the presence of coenobia of *Pediastrum boryanum* and pollen of aquatic species such as *Myriophyllum spicatum* and *Potamogeton* suggest the brackish water environment and shallow open relatively eutrophic waters during the Late Eneolithic. The Black Sea level was low and soils around Varna Lake were humid, rich in humus and suitable for cultivation during the time of inhabitance of the area.

LPASZ Vn-2a. The AP/NAP ratio suggests enlargement of area covered by mixed oak forests. A characteristic feature is the significant increase of *Carpinus betulus* after the decrease of *Quercus* at ca 5821 cal. BP (3871 cal. BC). This species probably forms detached monodominant communities as well. The increase of *Carpinus betulus* is due to its migration from refugia in Strandzha Mt [13]. The decrease of pollen of cereals and other anthropogenic species such as *Plantago lanceolata*, *Polygonum aviculare*, Cichoriaceae, *Carduus*-type and *Urtica* and the gap in human activities confirm a cultural hiatus of ca 319 years between the Late Eneolithic and Early Bronze Age.

The maximum values of cysts of euryhaline marine dinoflagellates *Lingulodinium machaerophorum* and *Spiniferites belerius*, acritarchs *Cymatiosphaera globulosa* and *Micrhystridium* cf. *ariakense*, as well as Foraminifera (Type 120) at 5598 cal. BP suggest influx of marine waters and increase of salinity in the brackish water lake. Most probably, the sea level became higher and influenced Varna Lake area during the First Phase of the Kalamitian Black Sea Transgression [14]. This supports the assumption that settlements near Varna Lake were abandoned. According to the archaeological chronology [12], this subzone corresponds to the Transitional Period of the Northern Black Sea coast (Posteneolithic, Protobronze) and dated at 4150–3200 cal. BC [17]. For the Southern part of the Bulgarian Black Sea Coast and especially for the area of submerged prehistorical settlement in the harbour of Sozopol, the same period covers the time span 3850–3200 cal. BC [18]. According to some authors [12], the Eneolithic cultures in the northeastern part of the Balkan Peninsula were lost at ca 4200 cal. BC because of the ecological catastrophe caused by high annual temperatures during the culmination of the climatic optimum.

LPASZ Vn-2b. This subzone is marked by another decrease of arboreal vegetation with re-expansion of cereals and anthropophytes. Low values of AP could be explained as a succession related to a climate change during the Subboreal but also as an indicator of strong human impact. The decrease of AP mainly of *Quercus* and the constant presence of *Carpinus orientalis* could be associated with degradation of the mixed oak forests. The maximal presence of cultivated cereals such as *Cerealia*-type, *Triticum* and *Hordeum* marks their significant abundance and indicates the intensity of human impact. Cereal crop weeds such as *Centaurea cyanus*-type and *Papaver* also occur in the pollen record and are most probably connected with wheat cultivation. The increase of secondary anthropogenic indicators such as *Polygonum aviculare*, *Plantago lanceolata*, *Filipendula*, Cichoriaceae and *Centaurea jacea*-type suggests stockbreeding and enlargement of meadows and pastures. According to some authors [19], *Urtica* shows the formation of habitats rich in nitrates. Additional evidence for grazing comes from the fungal NPP record dominated by dung-inhabiting taxa such as *Cercophora* (Type 112), *Sordaria* (Type 55a), *Podospora* (Type 368a) and *Chaetomium* (Type 7a). The record of spores of these coprophyllous fungi indicates the presence of domestic animals near the sampling site. The maximum of coenobia of *Pediastrum boryanum* that is dominant in brackish waters with salinity of 6–8‰ could also be connected with human impact. *Pediastrum* species are ecologically classified usually as indicators of oligo- to meso-saprobic waters, but they have wide ecological tolerance [10]. The occurrence of NPP such as algal spores (Types 150 and 225), *Valsaria variospora*-type (Type 140) and *Diplotheca rhizophora* (Type 144) indicates eutrophic conditions and shallow open waters. The presence of fungal cells (Type 200) and fungal ascospores (Type 123) which proliferate on drying sediments and dead plant remains indicates low water depth during the growing season as well [10].

The increase of local elements such as *Typha/Sparganium*, *Typha latifolia*, Cyperaceae, *Alisma*, *Potamogeton*, *Myriophylum spicatum* and *Polygonum persicaria* during this period is probably also connected with lowering of the water level. The decrease of dinoflagellate cysts *Lingulodinium machaerophorum* and acritarchs *Cymatiosphaera globulosa* indicates that after the Transitional period the Black Sea level started to decrease and make area around Varna Lake inhabitable again. The soil was damp and settlers needed to build their dwellings on wooden platforms. Large stretches of the forests around the settlement came under strong anthropogenic influence due to the cutting of wood and timber for constructions of prehistoric settlements and horizontal platforms. Dendrochronological analyses of oak piles derived from house formations associated with three submerged Early Bronze Age sites in Kiten (Urdoviza), Harbour of Sozopol and Varna Lake show dates 2778–2715 cal. BC, 2190 cal. BC [18] and 3370–2935 cal. BC [20], respectively.

LPASZ Vn-2c. The AMS-radiocarbon date of 3030 ± 50 ^{14}C years BP (1280 cal. BC), the characteristic vegetation succession and the maximum values of acritarch *Pseudoschizaea circulata* that is characteristic of the Late Holocene marine sediments allow the correlation of this zone to the end of the Subboreal and the beginning of the Subatlantic. Mixed oak and hornbeam forest were still dominant. A main characteristic feature is the increase of *Ulmus* along with the increase of *Hedera* as indicator of increased humidity. The human impact during this period could be associated with the Late Bronze Age, when a decrease of percentage values of *Cerealia*-type, *Hordeum* and other anthropogenic indicators such as *Polygonum aviculare*, *Plantago lanceolata*, *Filipendula*, Cichoriaceae, *Scabiosa* and *Centaurea jacea*-type was registered. Dung indicator species *Podospora* (Type 368a), *Chaetomium* (Type 7a) and *Cercophora*-type (Type 112) decrease at the same time as coenobia of *Pediastrum boryanum* and confirm a decrease of intensity of human impact. Spores of *Glomus* (Type 207) that occur on roots of variety of arboreal host plants indicate erosion of soil in the catchment of Varna Lake.

The marine dinoflagelate cysts of *Lingulodinium machaerophorum* and *Spiniferites belerius* and acritarchs *Cymatiosphaera globulosa* are regularly presented together with *Typha/Sparganium*, *Typha latifolia*, Cyperaceae, *Potamogeton* and *Myriophylum spicatum* that are tolerant to brackish water conditions. At the end of the subzone, the increase of marine dinoflagelate cysts suggests a significant marine influence.

LPAZ Vn-3. This zone reflects vegetation dynamics during the Subatlantic. The most characteristic feature is the formation of the modern vegetation communities along the coast. Mixed oak and hornbeam forest decreased probably due to the human impact during the Iron Epoch. This is confirmed by the increase of cereals and other anthropophytes such as *Plantago lanceolata*, *Polygonum aviculare* and *Filipendula*. Most probably, *Carpinus orientalis* enlarged its spreading in the areas covered by oak after their degradation. The increase of *Alnus*, *Ulmus*, *Fraxinus excelsior* and *Fagus* is due to the increase of humidity and cooling of climate as suggested by the presence of single pollen grains of *Hedera*, *Vitis*, *Humulus/Cannabis*-type and *Ephedra*. This is connected with the formation of riverine-flooded forests along the river valleys of the Bulgarian Black Sea Coast. The sharp decrease of marine dinoflagelate cysts together with the presence of cysts of stenohaline dinoflagelate *Spiniferites cruciformis* coincides with the decrease of sea surface salinity (SSS) of Black Sea waters.

Conclusions. The multiproxy and high-resolution palaeoenvironmental study of the investigated Core-3 contributed to the elucidation of important details in the Holocene vegetation history and human activities along Varna Lake area for the last 7870 cal. BP. The main conclusions that could be drawn are: (1) The vegetation during the Early Atlantic was dominated by mixed oak forests; (2) An important change in the forest composition occurred at ca 5598 cal. BP, when *Carpinus betulus* increased its spreading due to climatic changes; (3) The anthropogenic impact on the natural vegetation was identified during the Late Eneolithic and Early Bronze Age by deforestation and agricultural practice; (4) The Transitional Period without human activities lasted ca 319 years and was connected with increase of salinity due to increased Black Sea level after ca 5821 cal. BP during the First Phase of Kalamitian Black Sea Transgression; (5) The lake sedimentation started after ca 7870 cal. BP due to an increase of sea level during the First Phase of the Vityazevyan Black Sea Transgression; (6) The formation of molluskan shell hash layer of *Mytilus galloprovincialis* occurred after 7776 cal. BP during the Second Phase of the Vityazevyan Black Sea Transgression.

REFERENCES

[1] Bozilova E., S. Tonkov. Veget. Hist. Archaeobot., **7**, 1998, 141–148.

[2] Marinova E., J. Atanassova. Rev. Paleobot. Palynol., **141**, 2006, Nos 1–2, 165–178.

[3] Filipova M. Ecologia Mediterranea, **11**, 1985, No 1, 148–158.

[4] Bozilova E., H.-J Beug. Veget. Hist. Archaeobot., **3**, 1994, 143–154.

[5] Stuiver M., P. Reimer. Radiocarbon, **35**, 1993, 215–230.

[6] Grimm E. Tilia, Version 1.7.16. Illinois State Museum, 2011.

[7] Faegri K., J. Iversen. Textbook of pollen analysis. Chichester, John Wiley & Sons, 1989.

[8] Reille M. Pollen et spores d'Europe et d'Afrique du nord. Marseille, 1992.

[9] Reille M. Pollen et spores d'Europe et d'Afrique du nord. Supplement 1. Marseille, 1995.

[10] Van Geel B. In: Tracking Environmental Change Using Lake Sediments – Vol. **3**: Terrestrial, Algal, and Siliceous Indicators (eds J. Smol, H. Birks, W. Last), New York, Kluwer, 2001, 99–119.

[11] Grimm E. Comp. Geosci., **13**, 1987, 13–35.

[12] Todorova H. Eneolithic in Bulgaria, Sofia, Nauka i Izk. Publ., 1986 (in Bulgarian).

[13] Filipova-Marinova M. Palynological data on vegetation dynamics and climate changes along the Bulgarian Black Sea coast during the Quaternary, Dr. Biol. Sci. Thesis, Museum of Natural History, Varna, 2006.

[14] Chepalyga A. In: Dynamics of Terrestrial Landscape Components and Inner Marine Basins of Northern Eurasia during the Last 130 000 Years (ed. A. Velichko), Moscow, GEOS Publishers, 2002, 170–182 (in Russian).

[15] Todorova H. In: Durankulak, Band **II**: Die Prähistorischen Gräberfelder (ed. H. Todorova), Sofia, Academic Publishing House, 2002, 17–24.

[16] Filipova-Marinova M., L. Giosan, H. Angelova, A. Preisinger, D. Pavlov, S. Vergiev. In: Submerged Prehistory (eds J. Benjamin, C. Bonsall, C. Pickard, A. Fischer), Oxford, Oxbow Books, 2011, 230–244.

[17] Vajsov I. In: Durankulak, Band **II** Die Prähistorischen Gräberfelder (ed. H. Todorova), Sofia, Publishing House of the BAS, 2002, 159–176.

[18] Draganov V. In: James Harvey Gaul – In memoriam (eds M. Stefanovich, H. Todorova, H. Hauptmann), Sofia, James Harvey Gaul Foundation, 1998, 203–221.

[19] van Geel B. A study of non-pollen objects in pollen slides. Utrecht, Utrecht University Press, 1998.

[20] Orcel C., A. Orcel. In: Thracia Pontica **IV** (eds M. Lazarov, M. Tatcheva, C. Angelova, M. Georgiev), Sofia, 1991, 145–160.

Museum of Natural History – Varna
41, Maria Louisa Blvd
9000 Varna, Bulgaria
e-mail: marianafilipova@yahoo.com

* *Society of Innovative Ecologists of Bulgaria*
10, Dr. Bassanovich Str.
9010 Varna, Bulgaria

** *Archaeological Museum – Varna*
41, Maria Louisa Blvd
9000 Varna, Bulgaria

*** *Woods Hole Oceanographic Institution*
360, Woods Hole Rd
Woods Hole, MA 02543, USA