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Biostratigraphical Analysis and Paleoecolgical Conditions in the Bulgarian Black Sea Zone During the Quaternary

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Introduction

The elucidation of peculiarities of the formation of Quaternary sediments in the Western Black Sea zone and their stratigraphy is of great significance not only with regard to the theoretical research of palaeoenvironmental changes but with the land and marine resources reclamation and prognostication of unfavourable natural phenomena and their averting.

During past decades much of the lithostratigraphic and biostratigraphic research has focused on the reconstruction of the palaeoecological conditions along the coast and shelf zone.

Materials and methods

In this paper results of the investigations of palaeoenvironmental changes during the historical development of the Black Sea basin are restored through complex application of several research methods such as: molluscan fauna analysis, spore and pollen analysis, dinoflagellate analysis, lithology, archaeology and 14C radiocarbon dating. Data from surveys conducted between 1980-1999 has been summarised (table 1). Stratigraphic scheme (Шопов, 1991) is used for description of the Black Sea Quaternary sediments.

Results and discussion

The most ancient of the sediments under study in the investigated area are the Lower Pleistocene deposits. According to the regional stratigraphic scale these deposits refer to the Tschaudinian (Федоров, 1982). They are revealed in the peripheral and in the central part of the shelf. In the region of peripheral bars the Tschaudinian sediments exhibit a strip lying in parallel to the shore-line and stretching south from cape Emine at depths 80-140 m. They are presented by terrigenous shelly and clayey deposits (Khrischev, Shopov, 1978). The lithological features and fauna contents of the cores from the Aprilska Structure, Samotino East and Yuriiy Godin allow tracing the following new facts about the Tschaudinian sediments on the Bulgarian Black Sea shelf. They are presented by aleuritic sandy silts with high content of clayey-carbonate components. The biogenic component comprises rounded, whole or broken shells of fossilised Tschaudinian species *Dreissena rostriformis tschaudae Andrus, Didacna crassa* Eichw, shallow water Gastropod *Turricaspia lincta* Mil. The most characteristic feature of the studied thanatocoenosis is the presence of Pliocene relict *Theodoxus ex. gr. lichordopoly*. The poor state and ancient character of the molluscan fauna as well as the presence of Pliocenian relicts prove the Upper Tschaudinian age and a Pont-Caspian type of fauna.

The Upper Tschaudinian sediments from the above-mentioned three investigated cores are assumed as relicts from an ancient shore-line. Spore-pollen analysis allows reconstruction of the palaeoecological conditions under which the Tschaudinian sediments were formed. Most probably they were deposited at low temperatures and dry climate which ensured the spreading of steppe vegetation with dominating species of *Chenopodiaceae, Artemisia, Poacea, Asteraceae, Ephedra,* characterising the Pleistocene glacial periods. The presence of

Table 1. Biostratigraphical Scheme and Palaeoecological Reconstruction of the Quaternary Sediments of the Bulgarian Black Sea Shelf

Chronologycal scale [10^3 years]	Section	Subsection	Alpine Stratigraph. scale	Archaeological chronology (Todorova, 1986)	Transgressions and hydrological regime (Fedorov, 1982)	Chronological scheme of the Black Sea Shelf (Shopov, 1991)		Molluscan fauna	Pollen assemblages	Coastal vegetation	Dinoflagellate assemblages	Palaeoecological reconstructions
					horizonts	regional layers	sublayers					
1	Holocene		Subatlantic	Iron Epoch	Nymphaean	Black Sea layer	New Black Sea sublayer	*Modiolus phaseolinus* *Spisula triangulata*	*Quercus, Ulmus, Carpinus, Fagus, Alnus, Salix*	Mixed oak forests and formations of flooded forests along the river valleys	*Lingulodinium machaerophorum, Spiniferites ramosus, Peridinium sp.*	Increase of humidity and decrease of temperature; salinity - similar to the present days
2					Fanagorian Regression							
3			Sub-boreal	Bronze Age	New Black Sea Transgression		Old Black Sea sublayer	*Mytilus galloprovincialis* *Cardium papillosum* *Cardium exiguum* *Cardium edule* *Hydrobia ventrosa*	*Quercus, Carpinus betulus, Corylus, Ulmus*	Mixed oak forests; increase of *Carpinus betulus*	*Lingulodinium machaerophorum, Cymatiosphaera globulosa,* maximum of *Lingulodinium machaerophorum*	Slight drying up of the climate
4												
5			Atlantic	Transitional period					Maximum of *Quercus, Carpinus betulus, Corylus, Ulmus, Tilia*	Balanced mixed oak forests		Climatic optimum: maximum of temperature and humidity; increase of salinity
6												
7				Eneolithic	Increase of salinity							
8				Neo-lithic	First invasion of Mediterranean waters						*Tectatodinium psilatum, Spiniferites cruciformis*	
9			Boreal						*Quercus, Carpinus betulus, Corylus, Ulmus, Tilia*	Open mixed oak forests		Amelioration of the climate
10			Pre-boreal		Regression			*Dreissena rostriformis distincta* *Dreissena polymorpha regularis* *Monodacna caspia* *Clessiniola variabilis*				
	Pleistocene	upper	Würm		Transgression (-90+20m) Outflow to the Mediterranean Sea	Neoeuxinian	Upper		*Artemisia, Chenopodiaceae*	Steppe		Cold and dry climate; fresh and cold water
					Postkarangatian Regression (-100m)		Lower	Continental sediments				
			Riss-Würm		Influx of Mediterranean waters - max transgression	Karangatian	Upper	*Corbula gibba* *Cardium paucicostatum* *Nucula nucleus* *Retusa sp.* *Eulimela pointelli*	*Quercus, Carpinus betulus, Tilia, Fagus*	Oak and hornbeam forests		Warm and humid climate; high salinity and increase of water temperature
							Middle					
					Riss II Regression		Lower					
		middle	Riss		Uzunlarian (transgression)	Uzunlarian		*Abra alba* *Cardium edule* *Hydrobia ventrosa*	*Pinus, Artemisia, Poacea, Chenopodiaceae*	Pine forests and steppe	*Spiniferites cruciformis*	Cool climate; slight increase of salinity
					Late eoeuxinian	Eoeuxinian		*Didacna crassa pontocaspia* *D. crassa parvula* *D. pallasi* *D. cf. baericrassa* *Turricaspia kolesnikoviana*	*Chenopodiaceae, Artemisia, Poacea*	Steppe		Cold climate; cold brackish water
					Riss I Regression							
			Mindel-Riss		Palaeo-uzunlarian							
					Early eoeuxinian							
		lower	Mindel		Regression	Tschaudinian	Upper	*Dreissena rostriformis tschaudae* *Dr. rostr. abchasica* *Didacna tschaudae* *Didacna crassa* *Turricaspia caspia lincta* *Theodoxus ex. gr. lichordopoli*	*Chenopodiaceae, Artemisia, Pinus,* redeposited: *Taxodium, Taxus, Carya, Cedrus*	Steppe with stands of pine		Cool and dry climate; cold brackish water
2000			Günz				Lower					

re-deposited pollen grains of the Tertiary taxons such as *Taxus, Carya, Cedrus, Taxodium* proves that these sediments belong to the Lower Pleistocene (Mindel).

The Middle Pleistocene (Riss) sediments on the Bulgarian shelf are presented mainly by Eoeuxinian and Usunlarian deposits. In the central shelf part in the cores C-3 Aprilska, C-5 Yuriiy Godin and C-2 Northern Structure the Eoeuxinian sediments cover transgressively the Tschaudinian with an abrupt washout boundary. In the first two cores the Eoeuxinian sediments are presented by carbonates and clays with uneven distribution of the pellitic component, in some intervals – enriched with detritus. The prevailing presence of typical Eoeuxinian species *Didacna crassa parvula* Nalivkini, *Didacna crassa pontocaspia* Eichw, as well as the re-deposited Tschaudinian *Dreissena rostriformis tschaudae* Andrus, allows to determine the lower borders of the Eoeuxinian sediments.

The palynologycal data testify that during the deposition of these sediments the climate was dry and cold and favoured the distribution of steppe vegetation with predominance of the species of *Chenopodiaceae* and *Artemisia*.

In the studied cores Usunlarian sediments are discovered in the core C-3 Aprilska Structure presented by sandy-aleuritic clays with many shells of *Abra ovata* Wood., *Cardium edule* L. and single shells of *Hydrobia ventrosa* Mnt. In the cores C-2 Northern Structure together with salt-water *Dreissena polymorpha* Pal and the small-sized *Paphia rugata*, euryhalinic Mediterranean *Cardium edule* L., *Hydrobia ventrosa* Mont. and *Turricaspia* Mil from Gastropods are also met. In spite of the poor taxonomic spectrum the molluscan community can be defined as Mediterranean in character. The deposition of Unsularian sediments which contain it became under conditions of the Mediterranean transgression. From that time two transgressions are known in the history of the Black Sea – the Usunlarian and the Karangatian. Most probably the studied sediments were deposited during the Usunlarian. However, it must be noted that there is insufficient data for the solution of this matter.

The Usunlarian sediments correspond to the lower part of the interglacial Riss-Würm. The high participation of the pollen of *Pinus diploxylon* proves that most probably during that time in the higher areas of the coast forests of *Pinus nigra* were distributed. In the lower parts xerophytic herbaceous communities with groups of *Quercus, Ulmus, Betula* and *Carpinus betulus* were spread. These herbaceous communities differ from those of the previous periods. The dominant role was played by *Artemisia* while the species of *Chenopodiaceae* decreased its distribution to some extent. The presence of *Poaceae* was increased. We can assume that the development of such a type of vegetation had been determined by climatic improvement.

The Upper Pleistocene sediments on the Bulgarian shelf are presented by Karangatian and Upper Neoeuxenian deposits. Karangatian sediments are determined in the core C-5 Yuriiy Godin Structure and they lay on the Eoeuxinian sediments. Aleuritic silts enriched with preserved shells and detritus are deposited over the Eoeuxinian sediments. Dominating species are *Corbula gibba* Olivi, *Cardium paucicostatum* Sow., *Nucula nucleus* L. The stratigraphic position of the aleuritic-pellitic silts and the molluscan fauna give reason to refer them to the abyssal facies of the Karangatian basin. The abundant presence of *Corbula gibba* Olivi allows to refer these sediments to the age of the Early Karangatian. The significance of so determined Karangatian sediments is strengthened considering the geomorphological position of the studied core. It is found in the Dolna Kamchia Depression of the peripheral shelf zone, at 85 m depth.

Evidence for the existence of the Karangatian transgressive complex corresponding to the interglacial Riss-Würm (Eemien) is found along the Black Sea coast: on terraces at elevation 8-12 m (Попов, Мишев, 1974); on the shore of the Varna Lake – at 12 m depth with absolute age according to ^{14}C 30200 ± 950 B.P. and 39100 ± 900 B.P. (Семененко, Коюмджиева, Ковалюх, 1976). The palynologic data of the Karangatian sediments along the mouth of the Kamchia River shows that during that period the northern part of the Bulgarian Black Sea coastal zone was covered with mixed oak forests. The presence of *Fagus* and *Juglans* shows that the climate was warm and humid

(Bozilova, Djankova, 1976). The radiocarbon dates of the Karangatian sediments are significantly "rejuveniled" and do not show their real age.

Upper Neoeuxinian marine deposits are discovered almost in all cores on the shelf bellow the 30 m isobath. In the peripheral shelf zone they are represented by shell-detritus, aleuritic and clayey silts with thickness from several centimetres to one meter and form clearly defined accumulative bodies of coastal or barrier type. These sediments record the lowest level of the Neoeuxinian Basin. Their age determined by the radiocarbon method varies from 17190 ± 300 B.P. to 11590 ± 250 B.P. (Димитров, 1982).

In the Core C-3 of the Aprilska Structure the Neoeuxinian deposits cover transgressively the Usunlarian sediments. They are represented by aleuritic and pellitic silt – uniform with obscure stratification, enriched with detritus that appears as an important component for their lithification. In the Core C-2 of the Northern Structure and in the Core C-E-3 of the Samotino Sea structure the sediments are clayey and sandy. The most characteristic species of the Neoeuxinian faunal complex is *Dreissena rostriformis distincta* Andrus. The complex comprises also *Dreissena polymorpha regularis* Andrus, *Clessiniola variabilis* Eichw. The presence of euryhalinous Mediterranean species *Cardium edule* L., *Paphia sp.* should be also noticed for it marks the deposition of sediments at the end of the Neoeuxinian during the Neoeuxinian transgression.

The sediments from the end of the Neoeuxinian that can be correlated to the Late Glacial were deposited between 15000 - 10300 BP. Concerning the Black Sea region these sediments are dated as 14610 + 200 B.P. and 11430 + 330 B.P. (Димитров, 1982). Pollen spectra show domination of herb communities over the arboreal vegetation. The climate was dry and cold during the stadials and permitted spreading of the s.c. cold steppes with predominance of species from *Artemisia, Chenopodiaceae, Poaceae* and many other taxons of *Asteraceae*. Among herb communities stands of *Pinus, Betula, Quercus* and *Corylus* were spread. Probably the stands of *Pinus* have occupied the higher parts of the coastal plateaus where the conditions were more favourable for the growth of aboreal vegetation since with the altitude rise increases atmospheric humidity. During the Late Glacial not only the low temperatures but mainly the low humidity was a limiting factor for the development of arboreal vegetation. The considerable presence of *Pinus diploxylon* pollen showing two maxima in the Neoeuxinian sediments is probably also connected with the spreading of *Pinus nigra* forests covering the lower terrains together with some deciduous species of *Quercus, Carpinus betulus, Ulmus, Corylus, Tilia, Betula* etc. during the interstadials of the Late Glacial - Bölling (14 000- 13 000 B.P.) and Alleröd (12000-11000 B.P.).

The presence of the dinoflagellate cysts *Tectatodinium psilatum* and *Spiniferites cruciformis* which lived at extremely low salinity (7 ‰ or less) in the sediments from the Late Glacial in almost all of the cores from the Black Sea, continental slope and depresion and the lack of these species in the contemporary deposits testifies that they are subarctic, cold - water species (Wall, Dale, 1974). Their maximal presence in the pollen spectra reflects the arid climate and serves as a good basis for the stratigraphic determination of the Neoeuxinian sediments.

In the beginning of the Holocene the Black Sea transgression marks a new stage in the geological history of the Black Sea basin and changes the palaeoecological environment. The inflow of Mediterranean waters raises the Black sea water salinity. The changes in palaeoecological paramaters formed new molluscan and dinoflagellate complexes, which determined the division between the Pleistocene and the Holocene. Some authors (Degens, Hecky, 1973) considerthe beginning of the Black Sea increase of salinity started before 9300 years and the influx of Mediterranean water became at 7300 B.P., others (Chepalyga, 1984) dates the beginning of Holocene by 14C from 10700 to 9700 B.P. According to radiocarbon data for the Bulgarian shelf the boundary between the Pleistocene and the Holocene varies from 7040 B.P. to 8620+70 B.P. (Димитров, 1982). On the basis of the biostratigraphic evidence the begining of the Holocene is dated at about 9000 B.P. (Шопов, 1991).

The materials available as well as the active hydrodynamic regime do not afford to carry out detailed biostratigraphic division in all cores referring molluscan fauna and to identify the sediments from Early, Middle and Late Holocene. The analysed Holocene cores prove a heterogeneous, mechanically formed thanatocoenosis in which redeposited Neoeuxinian Kaspian species: *Dreissena rostriformis distincta* Andrus, *Monodacna caspia pontica* Eichw., Mediterranean immigrants as *Cardium edule* L., *Hydrobia rentrosa* Mnt, marine euryhalinious species inhabiting waters close to the contemporary salinity: *Mytilus galloprovincialis* Lam., *Cardium exiguum* Gmel., *Cardium papillosum* Poli and contemporary stenohalinous species as *Spisula subtruncata triangulata* Ren., *Pitar rudis* Poli, *Chione gallina* Linne, *Nassa reticulata* Linne, *Scala communis* Lam. are present simultaneously.

The palynological data available allows to provide more detailed palaeoecological reconstructions. The Preboreal and the Boreal (10300 - 8000 B.P.) are characteristic with spreading of xerophytic herb communities and with quick migration of the arboreals *Pinus, Betula, Quercus* and *Ulmus* which survived the severe conditions of the Late Glacial in the nearby refugia. The distribution of open mixed oak forests during the Early Preboreal were probably stimulated by temperatures rise and preservation of the continental climate. Besides *Quercus* several thermophilous taxa were present in those forests: *Ulmus, Tilia, Fraxinus excelsior, Acer*. The climate improvement during the Boreal caused a gradually replacement of the xerophytic herb communities with arboreals, mainly *Quercus, Ulmus, Corylus*, and *Tilia*.

During the Atlantic (8000 - 5000 B.P.) the optimum climatic conditions (high temperature and humidity) were favourable for the wide spreading of balanced oak forests. Main components were various kinds of oak as well as *Ulmus, Tilia, Fraxinus* and *Acer*. The most characteristic feature of the coastal zone is the increase of *Carpinus belutus* which besides being a part of the mixed oak forests has also formed separate communities on higher latitudes and on the northern slopes at the end of the period - about 5650 ± 100 B.P. During that period steppe vegetation was preserved only in the coastal part of South Dobrudzha due to the insignificant increase of humidity which could not compensate the temperature rise and the withering wind impact. Even during the climatic optimum only steppe forest vegetation was spread in this region.

During the climatic optimum which can be correlated according to the archaeological chronology (Т о д о р о в а, 1986) to the Eneolithic (7000 - 6000 B.P.)(5000 - 4000 B.C.) human impact was significant. It is reflected in the pollen diagrams in the decrease of arboreals and the establishment of pollen of cultivated cereals such as *Triticum, Hordeum* and some weeds and ruderal plants such as *Plantago lanceolata, Polygonum aviculare, Urtica and Centaurea cyanus*. There is no doubt that mixed oak forests degradation is connected with the so called "Eneolithic revolution" in agriculture as well as with the increase of population.

There is a change of the dinoflagellate complex after 7600 B.P. The considerable presence of the typical marine euryhalinous species of dinoflagellate cysts of *Lingulodinium machaerophorum* and the acritarhs *Cymatiosphaera globulosa* testifies that the salinity of the seawater was higher than the contamporary one. According to some authors (W a l l, D a l e, 1974) it should be attributed to several factors – influx of saline water, lowering of the rate of raise of the sea level, slow overflow of the shelf areas and considerable improvement of the climate.

Changes in the forests composition are observed during the Subboreal period (5000-3000 B.P.). The most characteristic feature is significant presence of *Carpinus betulus* and the decrease of *Ulmus. Carpinus orientalis* increases which marks the beginning of the degradative human activities during the Early Bronze Age (5100-4000 B.P.) (3100-2000 B.C.).

Humidity increase is observed during the begining of Subatlantic period (3000-0 B.P.). It caused the formation of contemporary overflooded forests along the mouths of the rivers running into the Black Sea dated 3185 + 100 B.P. (B o z i l o v a, B e u g, 1992). Beach (*Fagus*) forests were spread in the regions with higher altitude. This last stage of vegetation development is connected with the formation of the contemporary plant

communities along the coastal zone.

Conclusion

As a result of the complex investigations evidence has been collected which support a possible subdivision of the Quaternary sediments. Representative molluscan, pollen and dinoflagellate assemblages, characteristic of the Tschaudinian, Eoeuxinian, Karangatian, Neoeuxinian and Black Sea layers are separated.

Regularities of distribution of the established lithostratigraphic and biostratigraphic layers in the peripheral and central shelf zone as well as in the deep sea zone of the Western Black Sea have been obtained. Our understanding of the complex palaeoecological events during some of principal phases of the Pleistocene and Holocene were extended. Information has been obtained also about the vegetation dynamics and subsequent changes in natural plant cover.

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Биостратиграфски анализ и палеоекологични условия в българския сектор на Черно море през кватернера

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(Резюме)

В настоящата статия са проследени палеоекологичните промени в българския сектор на Черно море през кватернера. Представените изводи се базират на дългогодишни експедиционни изследвания. В резултат от комплексното прилагане на няколко научни метода: литология и анализ на молюсковата фауна, споро-поленов анализ, динофлагелатен анализ, радиовъглеродни датировки са изведени основни параметри на палеоекологичната обстановка на ниво регионални етажи. Биостратиграфски са диференцирани чаудински, древноевксински, узунларски, карангатски, новоевксински и черноморски кватернерни седименти.