Морска биология

Palynological investigation of marine sediments from the western sector of the Black Sea

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In this paper are presented and discussed some resluts from the complex research programme „Lithogenesis of the Quaternary sediments from the continental slope of the Bulgarian shore" initiated at the Institute of Geology (Bulgarian Academy of Sciences).

Material and methods. The materials for the present investigation were collected during the joint Soviet-Bulgarian expedition with the research scientific vessel „Horizont" from the southwestern range and with „Hydrograph" from the northwestern continental slope (Fig.1).

The laboratory treatment of the samples was performed according to the acetolysis methods (F a e g r i, I v e r s e n, 1975) with slight modifications for the removal of the mineral components with sodium pyrophosphate and hydrofluoric acid (B i r k s, B i r k s, 1980).

The total number of pollen grains counted in every sample is bewteen 250 and 500. The number of dinoflagellate cysts and some acritarchs was also counted. The Steppe-Forest Index (*SFI*) and the Marine Influence Index (*MII*) were also calculated and graphically presented (after T r a v e r s e, 1978).

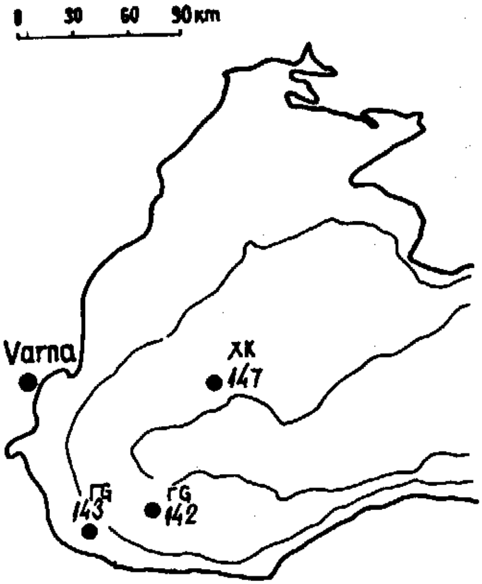

Fig.1. Location of the cores

$$SFI = \frac{\text{Chenopodiaceae} + \textit{Artemisia}}{\text{Chenopodiaceae} + \textit{Artemisia} + \textit{AP}}$$

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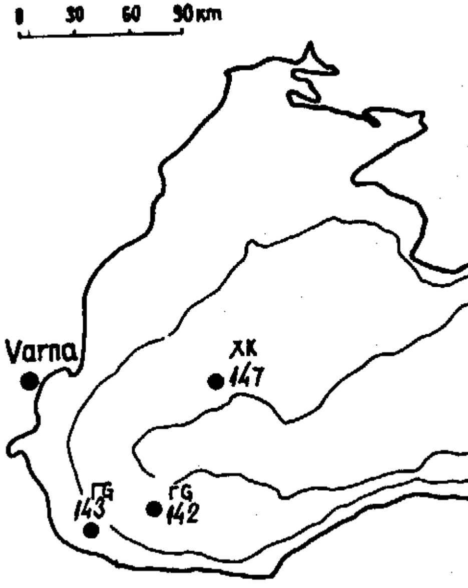

Fig.1. Location of the cores

$$SFI = \frac{\text{Chenopodiaceae} + \textit{Artemisia}}{\text{Chenopodiaceae} + \textit{Artemisia} + AP}$$

$$MII = \frac{\text{Dinoflagellatae + Acritarchs}}{\text{Dinoflagellatae + Acritarchs} + TP}$$

where *AP* is the pollen sum of all tree taxa and *TP* – the total pollen sum.

The curves of the SFI provide useful information for the ecological conditions in the investigated area while the dominant type of the dinoflagellate cysts and the values of the MII are important for the changes in the Black Sea basin.

The percentage values of the pollen taxa are calculated on the basis of *AP+NAP* pollen sum (arboreal plus non-arboreal plants, excluding local components and dinoflagellate cysts) and pollen diagrams are constructed. Pollen types with values less than 1% are indicated with dots or mentioned in the text. The pollen diagrams are divided into horizontal pollen assemblage zones (*PAZ*). The local pollen zones are compared with the climatic subdivision of the Holocene (Blytt - Sernander, 1876-1908) and the regional stratigraphical scheme for the bulgarian shelf (Khrischev, Shopov, 1978) (Fig.6).

Results. Core G-143 was taken from the shelf zone at the water depth 90 m with latitude 41° 58' 5'' N and longitude 28° 29' 1'' E. The capacity of the core is 86 cm, lithological composition: 20-52 cm clay with molluscan remains, 52-86 cm clayish-terrigenic material with molluscan remains (Fig.2).

Core G-142 was taken from the lower part of the continental slope at the water depth 1500 m with latitude 42° 01' 8'' N and longitude 29° 02' 5'' E. The capacity of the core is 120 cm, lithological composition: 7,5-31 cm cocolithic clay, 31-105 cm sapropelic clay, 105-115 cm carbonic clay, 115-120 cm clayish silt (Fig.3).

Core XK-147 was taken from the lower part of the continental slope at the water depth 1425 m with latitude 43° 19' 5'' N and longitude 31° 06' 0'' E. The capacity of the sediments is 101 cm, lithological composition: 2-20 cm carbonic clay, 20-40 cm sapropelic clay, 40-56 cm sapropel, 56-65 cm carbonic clay, 65-72 cm clayish silt, 72-85 cm diatomit clay, 85-101 cm clayish silt with hydrolithic bands (Fig.4).

Pollen diagrams. *Pollen diagram from core G-143 (Fig.2).* The diagram is divided into two pollen assemblage zones – I and II, the second one composed of subzones IIa,b and IIc,d.

PAZ I (86-55 cm, pollen spectra *1-4*). The arboreal pollen (*AP*) dominates which is mainly due to the higher percentage value of *Pinus diploxylon*-type 18-35%. In spectrum *1* *Corylus* reaches 13 %. Pollen of *Quercus robur*-type is constantly present with 11% while *Tilia, Ulmus, Carpinus belutus, Abies* and *Picea* do not exceed 1-2%. Pollen of *Betula* reaches 4% in spectrum *4*. Single pollen grains of *Quercus cerris*-type, *Fagus, Acer, Salix* are determined as well as two pollen grains of *Carya* and *Myrica*.

Among the herb elements the participation of *Artemisia* pollen is most significant in spectrum 1-33% and subsequently the pollen curve declines to 18%. Pollen of Chenopodiaceae is constantly present with 10-12%, Poaceae 1-3%, *Achillea/Aster*-type 2%, *Taraxacum*-type 1-2%. Single pollen grains of *Cirsium, Filipendula, Sanguisorba minor*, Caryophyllaceae, Lamiaceae are counted.

The Polypodiaceae curve does not exceed 5% in this zone. The presence of Typha/Sparganium-type and Cyperaceae is insignificant.

The dinoflagellate cysts from *Spiniferites cruciformis* type characteristic for lower water salinity show a maximum of 15%. while those from *Spiniferites ramosus* and *Lingulodium machaerophorum* type are with insignificant participation.

PAZ II (55-20 cm, pollen spectra *5-9*). The *AP* curve increases up to 70% in spectrum 5 due to *Quercus robur*-type up to 30%, *Corylus* 9%, *Carpinus betulus* 14%, *Fagus* 4%. The increase in the participation of *Betula, Ulmus* and *Tilia* is not so sharp while *Alnus* pollen curve reaches 7%. With low percentage values or single pollen curves are present *Salix, Quercus cerris*-type, *Carpinus orientalis, Fraxinus ornus, Fraxinus excelsior, Ericaceae Juniperus, Picea, Abies, Castanea, Juglans, Vitis*. The pollen curve of *Pinus diploxylon*-type quickly declines at the beginning of the zone.

Artemisia and Chenopodiaceae pollen participation is considerable ccompared to Poaceae, *Achillea/Aster*-type, *Taraxacum*-type, single pollen grains of Ranunculaceae, *Thalictrum, Adonis*, Rubiaceae, Apiaceae, Plumbaginaceae, Caryophyllaceae, *Filipendula* are also found.

Spores of Polypodiaceae and grains of *Typha/Sparganium*-type and Cyperaceae are also present. In subzones II*a,b* and II*c,d* is registered some decrease in the presence of arboreal taxa with the exception of *Alnus* pollen curve. The dinoflagellate cysts in this zone are from *Spiniferites ramosus* type and *Liingulodinus machaerophorum*, typical for higher water salinity. Acritarchs are also found.

Pollen diagram from core G-142 (Fig.3). The diagrams is divided into two pollen assemblage zones — I and II.

PAZ I (20-115 cm, pollen spectra *1-2*). The non-arboreal pollen prevails over the arboreal. The pollen curve of Chenopodiaceae shows its maximal value of 40%. *Artemisia* pollen reaches 25% in the spectrum *2*, the same is marked for the pollen curves of *Achillea/Aster*-type and *Taraxacum*-type respectively 7,6 and 6,6%. Single pollen grains of *Cirsium*, *Echinops*, Lamiaceae Rubiaceae, Brassicaceae, Caryophyllaceae, Poaceae are also determined.

Among the tree taxa in this zone the largest quantities of pollen are determined from *Pinus* 18-20% while the deciduous components are underepresented — *Quercus robur*-type 8%, *Betula* 4%, *Ulmus* 2%, *Corylus* 1%. Single pollen grains are found from *Carpinus betulus*, *Fagus*, *Alnus*.

The quantity of Polypodiaceae spores and grains of Cyperaceae is insignificant. The dinoflagellate cysts from *Spiniferites cruciformis* type are predominant.

PAZ II (115-7,5 cm, pollen spectra *4-7*). The AP is prevailing in this zone. Comparatively high is the participation of *Quercus robur*-type with 37%, *Carpinus betulus* 13-15%, *Corylus* 13%, while the pollen curves of *Fagus*, *Ulmus*, *Tilia* do not change. *Alnus* pollen reaches 10%. The pollen curve of *Pinus diploxylon*-type is around 24%, *Picea*, *Abies* and Ericaceae — 1%. Single pollen grains are determined from *Quercus cerris*-type, *Carpinus orientalis*, *Salix*, *Vitis*, *Hedera*, *Humulus/Cannabis*-type, *Viburnum* etc.

The herbs are represented mainly by *Artemisia* with 15%, Chenopodiaceae 4%, *Achillea/Aster*-type and single grains of *Taraxacum*-type, *Centaurea jacea*-type, *Centaurea scabiosa*-type, Poaceae, Caryophyllaceae, Lamiaceae, Rubiaceae, Brassicaceae, *Sanguisorba minor*, Ranunculaceae, *Thalictrum*.

Spores of Polypodiaceae and pollen of Cyperaceae, *Lythrum*, *Typha/Sparganium*-type are determined. Maximal values are registered for the dinoflagellate cysts from *Spiniferites ramosus* type and *Lingulodinium machaerophorum*. Acritarchs are also present.

Pollen diagram from core XK-147 (Fig.4). The diagram is divided into two pollen assemblage zones I and II. The second zone which is related to Holocene is subdivided into subzones II*a*, II*b*, II*c* and II*d* — compared to Preboreal-Boreal, Atlantic, Subboreal, Subatlantic (After Blytt-Sernander scheme). The first zone is also presented by two subzones I*d* and I*e* compared to interstadial and stadial period of Lateglacial.

PAZ I (101-71 cm, pollen spectra *1-6*). Subzone I*d* (101-91 cm, pollen spectra *1-3*). The total *AP* curve reaches a maximum of 57% due to the presence of high precentage values of *Pinus diploxylon*-type with 53% (sprectrum *2*). Pollen of *Quercus robur*-type with 8% and *Betula* 2% as well as signle grains of *Corylus*, *Tilia*, *Salix*, *Juniperus*, *Abies*, *Ephedra* are found.

The pollen curves of *Artemisia* and Chenopodiaceae rise up to 29% an 22%. Pollen of Poaceae, *Achillea/Aster*-type, *Centaurea jacea*-type, *Taraxacum*-type, Brassicaceae, Caryophyllaceae, *Adonis*, *Agrimonia*-type, Apiaceae is also determined.

Dinoflagellate cysts from *Spiniferites cruciformis*-type and *Tectatodinium psilatum* are present, characteristic for water with lower salinity.

Subzone I*e* (91-71 cm, pollen spectra *4-6*). The *AP* curve declines to minimal values of 12-15%. *Pinus diploxylon*-type pollen does not exceed 13%, *Quercus robur*-type 8%, *Betula*, *Corylus*, *Quercus cerris*-type 1%

High values are established for *Artemisia* — 56% (spectrum *5*) and Chenopodiaceae — 27 % (spectrum *6*). The quantity of Poaceae and Brassicaceae pollen is low and a whole group of herb taxa like *Centaurea jacea*-type, *Agromonia*-type, *Plantago lanceolata*, Ranunculaceae, *Thalictrum*, Lamiaceae, Asteraceae are present with less than 1 %. Single spores of Polypodiaceae and some dinoflagellate cysts are found.

The absence of pollen in the sediments

The absence of pollen in the sediments from the interval 61-56 cm arises some difficulties to delimit the boundary between PAZ I and II. The boundary is placed at level 61 cm below the sharp increase of arboreal taxa in the next pollen spectrum (56 cm).

PAZ II (71-2 cm, pollen spectrum *7-19*). Subzone II*a* (71-51 cm, pollen spectra *7-8*). The most characteristic feature is the rise of *Corylus* and *Quercus robur*-type pollen respectively to 26% and 18%. Constant is the presence of *Ulmus*, *Tilia*, *Alnus*, *Fagus*, *Carpinus betulus*, *Abies* pollen and single grains of *Picea*, *Fraxinus excelsior*, *Hedera*. The pollen curves of *Artemisia* and Chenopodiaceae decline. The pollen taxa are also established — *Achillea/Aster*-type, *Taraxacum*-type, Poaceae, *Filipendula*, Rubiaceae, Apiaceae, *Plantago*, Cyperaceae and spores of Polypodiaceae, There is a change in the type of dinoflagellate cysts marked by the increase of *Lingulodinium machaeorophorum* type, *Spiniferites ramosus* type and acritarchs *Cymatiosphara* sp., distributed in water with higher salinity.

Subzone II*b* (51-31 cm, pollen spectra *9-12*). The *AP* curve reaches 83% and almost all tree taxa are represented with high percentage values: *Pinus diploxylon*-type 27%, *Quercus robur*-type 17%, *Carpinus betulus* 17%, *Corylus* 9%, together with *Ulmus*, *Tilia*, *Fagus*, *Alnus*, *Betula*, *Quercus cerris*-type. In addition pollen grains of *Abies*, *Picea*, *Salix*, *Fraxinus ornus*, *Fraxinus excelsior*, *Pinus haploxylon*-type, *Juglans*, *Juniperus*, *Ephedra* are determined. The percentage values of *Artemisia*, Chenopodiaceae, Poaceae, *Achillea/Aster*-type are low, the variety of herb pollen taxa is great: *Taraxacum*-type, *Centaurea jacea*-type, *Centaurea cyanus*, Ranunculaceae, *Thalictrum*, Apiaceae, Rubiaceae, Lamiaceae, *Sanguisorba minor*, *Agrimonia*-type, *Rumex*, *Plantago*, *Filipendula*.

The absolute maximum of dinoflagellate cysts from *Lingulodinium machaeorophorum*-type — 44% is registered in spectrum *12*. The presence of Spiniferites ramosus type and the acritarchs *Cymatiosphaera* sp. is considerable.

Subzone II*c* (31-21 cm, pollen spectra *13-15*). The pollen curves of *Pinus diploxylon*-type, *Carpinus betulus*, *Quercus robur*-type, *Betula*, *Ulmus*, *Tilia* decline. *Alnus* pollen curve rises up to 12%. Single pollen grains of *Abies*, *Picea*, *Juniperus*, *Carpinus orientalis*, *Juglans*, *Humulus/Cannabis*, *Vitis* are determined.

In spectrum *14* is marked an increase in the participation of Chenopodiaceae and *Artemisia*. Among the rest of the herb taxa pollen grains of *Achillea/Aster*-type, Poaceae, Apiaceae, Rubiaceae, Ranunculaceae, *Thalictrum*, *Sanguisorba minor*, Lamiaceae, *Helianthemum*, *Centaurea jacea*-type are found.

Subzone II*d* (21-2 cm, pollen spectra *16-19*). The *AP* curve fluctuates around 57-65%, *Quercus robur*-type 10-13%, *Pinus diploxylon*-type around 16-21%, *Alnus* up to 18%, *Carpinus betulus* 8%, *Corylus* 4%. Rather low are the percentage values of *Fagus*, *Ulmus*, *Tilia*, *Quercus cerris*-type, *Carpinus orientalis*, *Betula*, *Pinus haploxylon*-type. Single grains of *Juniperus*, *Picea*, *Abies*, *Salix*, *Juglans*, *Celtis* are counted. The variety of herb pollen taxa is great. The maximal value of *Artemisia* 27%, Chenopodiaceae 8% and the presence of *Achillea/Aster*-type, Poaceae, Apiaceae, *Plantago lanceolata*, *Filipendula*, Rubiaceae etc. should be pointed out.

The quantity of dinoflagellate cysts is also very small.

Discussion. The results from the pollen analysis and the high values of the SFI (Fig.5) indicate that the sediments in PAZ I were accumulated during cold and dry climate characteristic for Lateglacial time (New-Euxinian). Along the Black Sea coast were distributed steppe xerothermic plant communities dominated by *Artemisia* and Chenopodiaceae species with representatives from Asteraceae (*Achillea*, *Aster*, *Taraxacum*, *Cirsium*, *Centaurea*, *Echinops*), Poaceae, Rubiaceae, Ranunculaceae (*Thalictrum*, *Adonis*). In these plant communities participated also shrubs of *Juniperus* and *Ephedra*. The pollen spectra suggest also the existence of stands of deciduous trees, mainly oak species, *Ulmus* (elm), *Tilia* (lime), *Corylus* (hazel) etc. along the river valleys. In the southern coastal area these groups were more numerous and rich in composition. Similar vegetation type for the Western part of the Black Sea during Lateglacial has already been described by

Koreneva, Kartashova (1978) and Filipova et al. (1983).

In subzone I*d* (core XK-147) (Fig.4) is observed a sharp increase in *Pinus diploxylon* pollen curve with some *Quercus robur*-type, *Betula* and single grains of *Tilia* and *Corylus*. We suggest that these sediments were deposited during the warmer and moister period — an interstadial of Lateglacial, when a certain enlargement in the speading of *Pinus nigra* had occurred. Such an interstadial was delimited by Божилова и др. (1979) for the coastal area. The find of *Picea* and *Abies* pollen in Lateglacial sediments is most probably a result of long distance transport. In the case of *Picea* (spruce) according to Поп (1957) this tree had some of its refugia in the Carpathian mountains and this possibility for long distance transport is rather acceptable because the northern winds are prevailing along the coast. Concerning *Abies* (fir) reliable evidence for the preservation during the end of Lateglacial in the coastal mountains in Northern Turkey was provided by Bottema (1986) from were its pollen grains were transported.

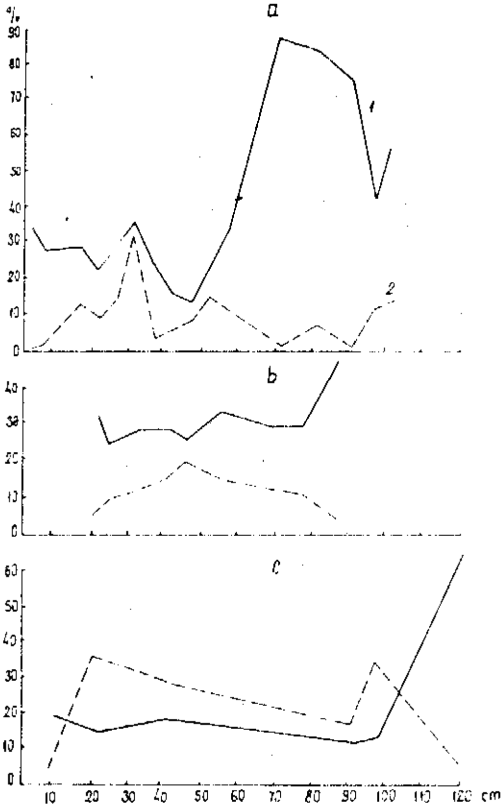

Fig.5. Steppe-forest index, marine influence
1 - steppe-forest index SFI; *2* - marine-influence index MII

The pollen grains of *Carya* and *Myrica* are redeposited which is proved by their corroded structure and outer appearance.

The dinoflagellate cysts from *Spiniferites cruciformis* and *Tectatodium psilatum*-type indicate lower water salinity. The MII for this period is rather low (Fig.5). These data testify to a regression phase of the sea which coincide with conclusions of Degens, Hecky (1973) for the decrease in the water salinity twice (7%-10%). between 17 000 — 9300 B.P.

The sediments from PAZ II in all diagrams are related to Holocene time. Only in the diagram from core HK-147 (Fig.4) it was possible to delimit several stages of the Holocene sediments. In the other two diagrams (Fig.2, 3) the capacity of these sediments does not allow more detailed division. The pollen data and the lowering of the SFI (Fig.5) indicate an improvement of the climate during Holocene and vast distribution of all deciduous trees along the coast.

The subzone II*a* could be compared with early Holocene — Preboreal-Boreal (10 300-8000 B.p.). Part of the sediments in this period are defined as Bugaski-Vitjazevian layers (Khrischev, Shopov, 1978). The vegetation is characterized with the spreading of oak forests with *Ulmus*, *Tilia*, *Alnus*, *Acer*, together with enlargement of *Carpinus betulus* (hornbeam) communities. It is worth to mention the participation of *Fagus* (beech) pollen in the pollen spectra of early Holocene in contrast to diagram from other parts of the country. In our case the debate runs over *Fagus orientalis*, wich species was preserved during the last glaciation in some areas of Southeastern Bulgaria (Bozilova, Tonkov, 1985; Божилова, 1986).

The next subzone II*b* could be compared with Atlantic time (8000-5000 B.P.). The continuing amelioration of the climate stimulated the enlargement of the forest vegetation in Eastern Bulgaria. The composition of the dominant oak forests has become richer. Though *Fraxinus excelsior* is presented with suggested as derived from analysis of surface pollen samples. In Atlantic time *Carpinus betulus* has probably formed pure communities on the northern slopes of the plateaus as it was earlier established for the area of Lake Varna (Б о ж и л о в а, Ф и л и п о в а, 1975). The find of *Vitus*, *Humulus/Cannabis* and *Hedera* pollen is also an indication for the existence of optimal climatic conditions. *Juglans* and *Castanea* were also present in these coastal forests. The herbaceous vegetation by that time though rich in composition has been restricted in distribution.

The sediments deposited in Atlantic and Subboreal are defined as Kalamitski (K h r i s c h e v, S h o p o v, 1978) (Fig.6). During the second half of Subboreal (subzone IIc) the deciduous forests had retreated to some extent and an increase in *Carpinus orientalis* had been observed. These communities of oriental hornbeam are cosidered of secondary origin as a result of anthropogenic activity.

At the end of the Subboreal and the beginning of Subatlantic the observed increase of *Alnus* pollen could be explained with the formation of the recent longoz forests along the rivers running into Black Sea (Б о ж и л о в а, 1986). The upper sediments described as Dzemetinski layers were deposited in Subatlantic time, i.e., since 3000 B.P.

In Holocene sediments from the three cores pollen from *Pinus haploxylon*-type, *Picea* and *Abies* originates from a long distance transport, while the considerable participation of *Pinus diploxylon*-type is mainly due to *Pinus nigra*. The overepresentation of Pinaceae pollen in marine pollen diagrams is the main difference from the coastal pollen diagrams (B e u g, 1977). In the sediments dominant are the dinoflagellate cysts from *Lingulodinium machaerophorum*-type, *Spiniferites ramosus*-type and acritachs *Cymatiosphaera* sp., typical for water with higher salinity. The MII during Holocene (Fig.5) is high wich is an indication for increase in the water salinity as a cosequence of sea transgression (T r a v e r s e, 1978).

The pollen assemblage zones and subzones clearly reflect the general tendencies in vegetation development and climatic changes during Lateglacial and Holocene time along the coastal area (Fig.6). On the basis of the changes in the spore-pollen complexes and the type of dinoflagellate cysts the boundary Pleistocene/Holocene could be pointed out with great precision, which makes pollen analysis one of the most reliable biostratigraphic methods. Taking into consideration that the spore-pollen spectra from marine sediments reflect the changes in the terrestrial vegetation which are not synchronous with the changes in the paleoecological conditions of the basin, the boundary Lateglacial/Holocene is placed at 10 300 B.P. This age is generally accepted for continental deposits (B o z i l o v a, 1982) while the accepted age by K h r i s c h e v, S h o p o v (1978), Д и м и т р о в (1982) et al. for the boundary Pleistocene/Holocene for the bulgarian shelf is around 9000 B.P. (Fig.6).

Our data from cores 143 and 142 are compared to the results from the biostratigrapical investigations carried out by Ш о п о в (1984) for the same cores and from core 147 — with the diatom analysis (Final report on „Lithogenesis of the Quaternary sediments from the continental slope of the Bulgarian shore“) where a slight difference in the position of the boundary Pleistocene/Holocene is observed.

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Палинологические исследования западного сектора Черного моря

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(Резюме)

Основным методом реконструкции палеоэкологичеесских условий черноморского побережья во время четвертичного периода является спорово-пыльцевой анализ морских осадков. Сочетание его с анализами динофлагеллятных цист и другими биостратиграфическими и литостратиграфическими методами позволяет сделать выводы о колебаниях уровня моря во время четвертичного периода, дает возможность осуществить достоверное стратиграфическое разчленение осадков, а также и другие заключения.

В настоящей работе представлены результаты спорово-пыльцевого анализа и анализов динофлагеллятных цист, взятых с трех морских скважин северного и южного континентального склона и южного черноморского шельфа с континентальной окраины болгарского берега. Обособлены две комплексные пыльцевые зоны.

Отложение осадков комплексной пыльцевой зоны I происходило при сухом и холодном климате, и вероятнее всего, связано с поздним ледниковым периодом. Доказательством этому служит преобладание пыльцы травянистых видов, например, из рода *Artemisia* (полыни) и представители семейства Chenopodiaceae, а также высокие значения степно-горского индекса.

В осадках, отнесенных к комплексной пыльцевой зоне II, преобладает пыльца широколиственных древесных видов; степно-горский индекс значительно ниже, и ето дает основание отнести их к голоцену.

Граница между двумя комплексными пыльцевыми зонами ясно очертана повышением кривой древесных пыльцевых видов (*AP*) в начале комплексной пыльцевой зоны и сменой типов динофлагеллятных цист.

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