Biostratigraphy and radiocarbon data of Upper Quaternary sediments from western part of Black Sea

Vladimir L. Shopov¹, Elisaveta D. Bozilova², Juliana R. Atanasova²

¹ Geological Institute of Bulgarian Academy of Sciences, 1113 Sofia
² University of Sofia, Biological Faculty, 1040 Sofia

(Received 30. 06. 1991; accepted 15. 11. 1991)

Abstract. The results of the stratigraphical and pollen-analytical investigation of shelf and deep sea sediments from the Bulgarian sector of the Black Sea are presented.

The sediments referred to the complex pollen zone I belong to the New Euxinian Regional Stage (upper substage). They were deposited during a regression of the sea under the conditions of dry and cold climate typical of the Black Sea region during Late Glacial time. The sediments referred to the complex pollen zone II belong to the Holocene or Chernomorian Regional Stage. The age of the sediments was confirmed by several radiocarbon dates which fit the biostratigraphic evidence.

Introduction

The Upper Quaternary sediments of the Bulgarian Black Sea sector are well studied in respect to their stratigraphy and lithological content. On the other hand the information about their absolute age from radiocarbon dating is still scarce. In the publication of Димитров (1982) are reviewed the results of Купцов et al. (1979) and Николаев et al. (1980) about the absolute age of the Quaternary shelf sediments in front of the Bulgarian coast. The lack of similar information from the deep sea part have stimulated the present investigation which included stratigraphical description, pollen analysis, determination of coccoliths and radiocarbon dating of cores from the western part of the Black Sea (Fig. 1).

Material

The location of the cores are from the whole bathimetric profile of the Black Sea floor — outer shelf (XK-120, depth 94 m), middle (XK-71, depth 520 m) and lower parts of
the continental slope (XK-55, depth 1430 m), continental rise at the transition to the abyssal plain (E-26, depth 2260 m) (Fig. 2).

Stratigraphical description

The stratigraphy of the sediments from the shelf is presented according to the lithobistratigraphical scheme suggested by Khristchev, Shopov (1978). In this scheme several informal lithostratigraphic units are distinguished among the shelf sediments on the basis of macroscopically discernible features marked with letter indexes from the Latin alphabet.

Core XK-120 is located at the transitional zone between the shelf and deep sea sediments. Two lithostratigraphic units are established.

Unit D (0,0-0,32 m) comprises grey-green soft plastic clay mud with many shells of the molluscs Modiolus phaseolinus (P h i l.), Abra alba pontica (M i l.), Spisula subtruncata triangula (R e n.), Hydrobia ventrosa (M t g.), Mytilus galloprovincialis L m k., Cardium edule lamarcki R e e v e, Dreissena polymorpha (P a l l.) and others.

Unit L (0,32-0,60 m) comprises grey soft plastic to hard plastic clay muds with rare black spots of hydrotroilite or organic substance and fragments of shells of the molluscs Dreissena polymorpha (P a l l.), Dreissena rostriformis distincta A n d r u s., Micromelania caspia lincta M i l., Monodacna caspia caspia (E i c h w.), Theodoxus pallasi L i n d h. and others.

The stratigraphy of the deep Black Sea sediments is solved on a lithostratigraphic principle by marking among them real geological bodies — lithostratigraphic units in a similar way like with the shelf sediments because of the complete absence of fossil organisms. A р х а н г е л ь с к и й, С т р а х о в (1938), D e g e n s, R o s s (1974), R o s s, Н е р г о с н ы й et al. (1978) worked out in general the lithostratigraphy of the deep Black Sea sediments. Following the cited above authors Х р и с ч е в et al. (1988) suggested a more detailed scheme of the lithostratigraphic division of the deep sea sediments of the western part of the Black Sea. According to this scheme informal lithostratigraphic units can be distinguished (from top to bottom) — coccolith muds
Fig. 2. Lithostratigraphic description of the cores
1 - grey-green soft-plastic clay muds containing shells of molluscs (unit D); 2 - grey soft-plastic clay muds (unit L); 3 - grey-green muds with coccolith layers (unit 1a); 4 - Coccolith clay muds with sapropel layers (unit la-b); 5 - sapropel clay muds (unit 1b); 6 - sapropel muds with lesser amount of sapropel substance (unit 1b-c); 7 - light-grey carbonate muds type "Seecreide" (packet 1 of unit 1c); 8 - grey clay muds with bands of dark pigmentation (packet 2 of unit 1c); 9 - thick black muds (packet 3 of unit 1c); 10 - various banded muds - yellow, brown, grey-green (packet 4 of unit 1c); 11 - samples for radiocarbon dating

(unit 1a), sapropel muds (unit 1b) and terrigenous pelitic muds or lutite (unit 1c). The transitions between the three principal facies of the sediments are distinguished and separated as lithostratigraphic units with a lower rank (1a-b, 1b-c) but not everywhere. The sediments of unit 1b usually possess trinomial structure and those of unit 1c are usually divided into four packets depending on the lithological content. The main lithostratigraphic units and their lithofacies are mapable and well defined in space.
The sediments of the upper parts of the deep sea cores XK-71 (0.0—0.36 m), XK-55 (0.0—0.23 m) and E-26 (0.0—0.22 m) are in the range of unit Ia with thickness in the different parts of the Western Black Sea depression varying from 0.0 m to 0.4 m (Fig. 2). They are grey-green muds saturated in the upper part with water and distinctly laminated by white coccolith layers.

The next intervals of cores XK-71 (0.36—0.43 m) and E-26 (0.22—0.28 m) belong to the transitional unit Ia-b. The sediments of unit Ia cover those of unit Ib. At normal occurrence the lower boundary of unit Ia is delimited with different degrees of distinctness. It is included in a thin transitional interval where an alternation of coccolith and sapropel muds in different proportions is observed. This boundary is more difficult to be distinguished in lithofacies with a considerable quantity of terrigenous material.

The area of development of unit Ia coincides with that of unit Ib. Unit Ia is laterally limited and is connected with the shelf sediments with the same age. The transitional zone is usually narrow and situated in the upper part of the continental slope.

The next intervals of cores XK-71 (0.43—1.02 m), XK-55 (0.23—0.65 m) and E-26 (0.28—0.78 m) belong to the lithostratigraphic unit Ib. The most characteristic feature of the units is the enrichment in organic substance. The unit usually possesses trinomial structure: (a) lighter green and friable sapropel muds with a marker coccolith layer in its upper part, (b) thick rubber like saproel with aragonite laminae and banded sapropel, (c) grey-green muds with less amount of organic substance. The coccolith layer is well developed and serves as a good stratigraphic marker. The thickness of the unit varies between 0.25 and 0.65 m, quite often between 0.3 m and 0.5 m.

The sediments of the last packet of unit Ib are transitional to the New Euxinian terrigenous muds of unit Ic. This packet could be separated from unit Ib as an independent lithostratigraphic unit Ib-c and includes the intervals from cores XK-71 (1.02—1.09 m), XK-55 (0.65—0.74 m) and E-26 (0.78—0.96 m).

The next interval of cores XK-71 (1.09—1.91 m), XK-55 (0.74—2.00 m) and E-26 (0.96—2.55 m) belongs to unit Ic. The characteristic feature is the presence of terrigenous material with a predominance of pelitomorphic varieties of the muds — lutites. The content of organic substance, as well as the carbonate biogenic component is considerably restricted. The presence of iron monosulphides in some places gives the black colour of the muds (hydrotroilite muds). The sediments of the unit could be divided into four packets dependent on the variations in their lithological content.

The sediments of carbonate muds type "Seekreide" — packet 1, are present in the section of the cores XK-55 (0.74—0.85 m) and E-26 (1.25—1.72 m). The next packet 2 includes light blue-grey clay muds with stripes of darker pigmentation. The stratigraphic position of these two packets could be exchanged because of a local hiatus. Packet 2 is present in the sections of cores XK-71 (1.09—1.91 m), XK-55 (0.55—1.43 m), E-26 (0.96—1.25 m). The sediments of packet 3 are banded clay muds from dark-grey to black and thick black muds (hydrotroilite pigmentation). They are present in cores XK-55 (1.43—1.80 m) and E-26 (1.72—2.07 m). The sediments of packet 4 are found in the lowermost part — different banded muds, yellow-pink brown, grey-green, dark-grey clay muds with single silty and sandy layers. These sediments are present in sections of the cores XK-55 (1.80—2.07 m) and E-26 (2.07—2.55 m).

**Pollen analysis**

The samples for pollen analysis are prepared according to the acetolysis method (Fægri, Iversen, 1975) treated in advance with HF acid for elimination of the mineral components (Birks, Birks, 1980). The frequency of each pollen type (M) is presented in percentages of the pollen sum (P) which includes all arboreal (AP) and non-arboreal (NAP) pollen types.

\[
P = AP + NAP = 100\%
\]

\[
M\% = \frac{\text{number of pollen grains (M)}}{AP + NAP} \times 100
\]

62
The results are presented in the form of pollen diagrams (Fig. 3, 4, 5). Parallel with pollen analysis the dinoflagellate cysts are also counted and their participation is calculated as follows:

\[
\text{Dinoflagellate } \% = \frac{\text{number of dinoflagellate cysts}}{\text{AP} + \text{NAP}} \times 100
\]

The steppe-forest index (SFI) is calculated and graphically presented (Fig. 6) as well as the index of marine influence (MI) according to Traverse (1978):

\[
\text{SFI} = \frac{\text{Chenopodiaceae} + \text{Artemisia}}{\text{Chenopodiaceae} + \text{Artemisia} + \text{AP}} \times 100
\]

\[
\text{MI} \% = \frac{\text{Dinoflagellate} + \text{Acritarchs}}{\text{Dinoflagellate} + \text{Acritarchs} + \text{TP}} \times 100
\]

where TP is the sum of pollen types in a given sample.

The pollen analysis of the Black Sea sediments provides important information about the palaeoecological situation along the coast and the hydrological changes in the basin together with the dinoflagellate cysts and the values of the marine influence index (MI).

The complex pollen zone I is comparable with the Lateglacial while the complex pollen zone II with the Holocene. The subzones IIa, IIb and IIc, d (Figs 3, 4, 5) are respectively comparable with Preboreal and Boreal, Atlantic, Subboreal and Subatlantic time.

The predominance of Artemisia, Chenopodiaceae, Poaceae and other herb pollen, as well as the high values of the steppe-forest index (Fig. 6) shows that the sediments of the lithostratigraphic unit Ic related to the complex pollen zone I, were deposited under the conditions of dry and cold climate characteristic of the Late Pleistocene (New Euxinian). The xerophytic herb communities had their distribution maximum along the coast in the period 15000-10 000 y. B. P. The low percentage values of Quercus, Corylus, Tilia, Carpinus betulus (Figs 3, 4, 5) demonstrate that also groups of deciduous trees were preserved in favourable localities.

The predominance of the dinoflagellate cysts of Spiniferites cruciformis and Tectatodinium psilatum type living in low water salinity (Wall, Dale, 1974) and the low values of the marine index (Fig. 6) show a regressive marine phase (Traverse, 1978).

The abrupt increase of the tree taxa marks the boundary Late Pleistocene/Holocene. The pollen spectra of the complex pollen subzone IIa (sediments of unit Ib-c) indicate a period of quick expansion of the deciduous trees from their Lateglacial refugia. Mixed deciduous forests were distributed along the Bulgarian sea coast dominated by different Quercus species accompanied by Ulmus, Tilia, Carpinus betulus. Probably Corylus formed not only an undergrowth in these forests but also separate communities on open places, derived from its high pollen percentages (Figs 3, 4, 5). The content of the spectra related to the complex pollen zone IIb (sediments of unit Ib) is characterized by a maximal participation of deciduous tree pollen. Balanced oak forests along the sea coast composed by Quercus robur L., Q. frainetto Ten., Q. cerris L. and other oak species, as well as Ulmus, Tilia, Fraxinus, Corylus were widely distributed. The place occupied by Carpinus betulus and Fagus were also enlarged. The establishment of Hedera pollen which species is sensitive to air humidity indicates optimal climatic conditions (Iverson, 1944). The sediments related to this complex pollen subzone are rich in dinoflagellate cysts mainly Lingulodinium machaerophorum type (Figs 3, 4, 5). The values of the marine index are also high which characterizes an increased water salinity and rise of the sea level. The high productivity of the phytoplankton is connected with the "climatic optimum" in the Black Sea.
Fig. 3. Spore-pollen diagram from core XK-120
Fig. 4. Spore-pollen diagram from core XK-55

LITHOLOGY
POLLEN ASSEMBLAGE
ZONES (subzones)
POLLEN SPECTRA
DEPTH (cm)

APNAP

**Quercus rubra**

**Quercus cerris** t.

**Carpinus betulus**

**Carpinus orientalis** t.

**Corvilus**

**Ulmus**

**Tilia**

**Alnus**

**Fagus**

**Pinus diploxylon** t.

**Betula**

**Picea**, **Abies**

**Juniperus**

**Prunus excelsior** t. **Fr. ornus** t.

**Juglans**, **Castanea**

**Firacées**

**Ephedra distachia** t. **Rhamnus**

**Salix**, **Alnus**

**Humulus**, **Cannabis** t.

**Hedera**, **Vitis**

**Chenopodiaceae**

**Artemisia**

**Poaceae**

**Achillea/Aster** t.

**Taraxacum** t.

**Centaurea jacea** t. **Galium** t.

**Filipendula**, **Sanguisorba minor**

**Thalictrum**

**Ranunculaceae**

**Apludra**, **Sclerum quinamala** t.

**Brassicaceae**, **Lilium**

**T. Lanceolata** t. **Polus sylviculae**

**Rumex**

**Ceratia** t., **Viticium** t.

**Laminaria**

**Trapa**, **Sparagnum** t.

**Corylaceae**, **Polyglossaceae**

**Lingulodinium machaerophorum** t.

**Spiniferites cruciformis** t.

**Tectatodinium psiloptum** t.

**Cymatiosphaera** sp.

**Spiniferites ramusi** t.
Fig. 5. Spore-pollen diagram from core XK-71
The sediments related to the complex pollen subzone IIc, d (sediments of unit Ia) contain mainly pollen from tree taxa like *Quercus, Ulmus, Fagus, Carpinus*, but their participation is lower in comparison with the previous subzone. The presence of *Alnus* pollen is very characteristic which is in connection with the formation of the flooded longoz forests along the coast about 3000 B. P. at the end of Subboreal and the beginning of Subatlantic time (Bozilova, unpublished data). The composition of the dinoflagellate cysts (*Lingulodinium machaerophorum, Spiniferites ramosus* and acritarchs—*Cymatiopshaera* sp.) does not change but their percentage values are lower in comparison with the subzone IIb (Figs 3, 4).

Discussion

The necessity for the establishment of reliable criteria for the ecological conditions, the origin and the age of the different sediments was the reason for the application of the different methods of investigation.

The boundary Late Pleistocene/Holocene corresponds to radiocarbon age before 10000 B. P. (INQUA decision, 1969). Most of the biostratigraphers dealing with the continental deposits in Europe stick to this boundary. It is also accepted for the territory of Bulgaria and the Black Sea coast (Bozilova, 1982, and unpublished data). In accordance with the radiocarbon dating of the Black Sea shelf sediments (Любиев, 1982) this boundary is around 9000 B. P. because of the fact that the basin is half isolated from the system of the World Ocean and the effect of the global climatic events takes place with a certain delay.

The deep sea sediments of the lithostratigraphic unit Ic established in the cores XK-71, XK-55 and E-26 belong to the New Euxinian Regional Stage (upper substage). They are related to complex pollen zone I which pollen spectra are characterized by the predominance of herb pollen and high values of the steppe-forest index. The sediments were deposited in the conditions of dry and cold climate typical for the Lateglacial time. This is confirmed by the radiocarbon dating of the samples from packet 4 of unit Ic in core E-26 (2.39—2.55 m) — 11350 ± 205 B. P. (Lb. Hv 15162) (Table 1).

The lithostratigraphic unit Ib-c belongs to the lower part of the Chernomorian Regional Stage (lower substage). They are related to the complex pollen subzone IIc where is observed an abrupt increase of the steppe-forest index reflecting the quick distribution of the deciduous trees from their Lateglacial refugia. These sediments were
Table 1
Type of sediments, C-14 dates and the dominant taxa in the vegetation

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Core</th>
<th>Depth (in m)</th>
<th>Radiocarbon dates, (years B.P.)</th>
<th>Sediment types</th>
<th>The dominant taxa in the vegetation during the deposition of different type of sediments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hannover</td>
<td>XK-55</td>
<td>0.57-0.62</td>
<td>6135 ± 75</td>
<td>Sapropel mud</td>
<td>Quercus, Corylus Ulmus, Carpinus</td>
</tr>
<tr>
<td>Hannover</td>
<td>XK-71</td>
<td>0.99-1.02</td>
<td>6775 ± 350</td>
<td>Sapropel mud</td>
<td>Quercus, Corylus Ulmus, Alnus</td>
</tr>
<tr>
<td>Hannover</td>
<td>E-26</td>
<td>0.68-0.72</td>
<td>6370 ± 170</td>
<td>Sapropel mud</td>
<td>Detritus</td>
</tr>
<tr>
<td>Hannover</td>
<td>XK-120</td>
<td>0.55-0.60</td>
<td>15380 ± 540</td>
<td>Grey clay mud</td>
<td>Artemisia, Chenopodiaceae</td>
</tr>
</tbody>
</table>

deposited in a regime of improving climatic conditions at the beginning of early Holocene (9000—8000 B.P.).

The deep sea sediments of lithostratigraphic unit Ib belong also to the Chernomorian Regional Stage (lower substage). They are related to the complex pollen subzone IIb which is characterized by maximal participation of deciduous tree pollen. The sediments are rich in saltwater dinoflagellate types and the value of the marine index is maximal. This fact indicates an increased salinity of the water, as well as a rise of the sea level. They reflect the conditions of the Mediterranean transgression in the region of the Black Sea during the climatic optimum 8000—5000 B.P. This is confirmed by the radiocarbon age of the samples from the sapropel muds in core XK-71 (0.99—1.02 m) — 6775 ± 350 B.P. (Lb. Hv 15165), core XK-55 (0.57—0.62 m) — 6135 ± 75 B.P. (Lb. Hv 15164) and core E-26 (0.68—0.75 m) — 6370 ± 170 B.P. (Lb. Hv 15163) (Table 1).

The deep sea sediments of units Ia and Ia-b are found in cores XK-71, XK-55, E-26 and belong to the Chernomorian Regional Stage (upper substage) according to the stratigraphical scheme suggested by Хрисчев et al. (1988). These sediments are related to the complex pollen subzone IIc, d. No radiocarbon dates are available for these sediments but the coccolith species and the predominance of deciduous tree pollen proves that they were deposited under the conditions of warm and humid climate characteristic of the Late Holocene since 3000 B.P. Billions of coccoliths among which the species Emiliania huxleyi (Lohmann) Hay & Moller, Braarudosphaera bigelowi (Gran & Braarud) Deflandre, Syracosphaera pirus Halldal & Markali, Syracosphaera mediterranea Lohmann were determined in these layers (Шопов, 1989).

Shelf sediments are established only in core XK-120. The sediments of lithostratigraphic unit L are related to the New Euxinian Regional Stage (upper substage). The molluscan fauna, the predominance of herb pollen and the high values of the steppe-forest index, undoubtedly prove that these sediments were deposited under the conditions of dry and cold climate characteristic of the Lateglacial. This is confirmed by the radiocarbon date 15380 ± 540 B.P. (Lb. Hv 15166) obtained from core XK-120 (0.55-0.60 m) (Table 1).

The sediments of lithostratigraphic unit D are included in the composition of the Chernomorian regional stage (Крисчев, Шопов, 1978). Radiocarbon dates are not available for them but the analyses of the molluscan fauna and the pollen content indicate their Holocene Age.

68
Acknowledgements

The authors express their gratitude to Prof. Dr. M. Geyh, C-14 und H-Laboratorium Niedersächsisches Landesamt für Bodenforschung, Hannover, Germany, for the determination of the radiocarbon age of the samples.

References

Архангельский, А. Д., Страхов, Н. М. 1938. Геологическое строение и история развития Черного моря. — М.—Л., АН СССР; 236 с.
Димитров, П. 1982. Радиоуглеродный датировк на динами утайки от българската черноморска шеф. — Океанология (CV), 9; 45—52.
Купцов, М. В., Зелдина, В. Б., Шимкус, К. М., Димитров, П. 1979. Определение абсолютного возраста. — In: "Геология и гидрология западной части Черного моря". С., БАН; 91—93.
Хрисчев, Хр., Василев, Е., Георгиев, В., Кожухаров, Е., Руккова, Н., Чочов, С., Шопов, В., Янкова, Д. 1988. Литостратиграфия и литофациональные особенности верхнечетвертичных глубоководных осадков Западночерноморской депрессии. — Geologica Balc., 18; 2; 5—17.
Шопов, В. Л. 1989. Холоценский колоны от дълбоководните карбонатни утайки на Черно море. — Сп. Вълг. геол. д 80, 30, 1; 46—51.