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LITHOSTRATIGRAPHIC AND SPATIAL RELATIONSHIPS OF THE UPPER QUATERNARY SEDIMENTS ON THE BOUNDARY SHELF-CONTINENTAL SLOPE IN THE BULGARIAN SECTOR OF THE BLACK SEA

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Abstract

The region of the Bulgarian sector in the western part of the Black Sea has been investigated, more specifically the continental shelf in front of the Bulgarian coast and part of the Western Black Sea depression. This investigation focuses on the Upper Quaternary sediments, which is related to the economic exploitation of the shelf. In the last decade, a lot of telecommunication companies and firms, searching for oil and gas and the hydrotechnical construction, need up-to-date geological information exactly on the upper part of the Quaternary section and the top distribution of the types of bottom sediments, which allows for collection of large factual material.

The paper represents the spatial relations of the Upper Quaternary lithostratigraphic units on the boundary shelf-continental slope in the Bulgarian Black Sea zone. The results obtained are a new touch to the knowledge about the Bulgarian Black Sea shelf and the Quaternary lithostratigraphy.

Key words: marine geology, lithology, stratigraphy, Upper Quaternary sediments, Black Sea shelf and deep zone

Introduction. The paper represents the spatial relations of the Upper Quaternary lithostratigraphic units on the boundary shelf-continental slope in the Bulgarian Black Sea zone. The results obtained are a new touch to the knowledge about the Bulgarian Black Sea shelf and the Quaternary lithostratigraphy.

Data and methods. As a result of research on representative geological sections, analysis of the horizontal and vertical changeability of the lithostratigraphic units of the shelf and the deep zone, an attempt has been made to identify some regional dependencies in the lithofacial transition between the shelf and the front of the continental slope. For that purpose a representative factual material has been used, consisting of more than 1800 geological sections with strategic geomorphological location and spatial positioning. This research is carried out as a part of the project: "Geological map of the Bulgarian sector of the Black Sea M 1 : 500 000" – Ministry of Environment and Waters, 2010. The region of the Bulgarian sector in the western part of the Black Sea has been investigated, more specifically the continental shelf in front of the Bulgarian coast and part of the Western Black Sea depression. Three summarized geological sections of strategic importance have been interpreted: those of the northern shelf, A–A and B–B; and that of the southern, C–C (Fig. 1).



Fig. 1. Spatial relations of the Upper Quaternary lithostratigraphic units on the boundary shelfcontinental slope in the Bulgarian Black Sea zone: A-A Section of the North Bulgarian Black Sea Shelf (north of cape Kaliakra); **B–B** Section of the Bulgarian Black Sea Shelf (traverse of cape Emine); C-C Section of the South Bulgarian Black Sea Shelf (traverse of Strandja depression). Lithostratigraphic units on the shelf: Upper Pleistocenian (Neweuxinian) lithostratigraphic units: N – "Lumachelle", shells accumulation; L – grey, soft plastic clay muds, containing shells from *Dreissena*; NL - variety of light grey silts, containing shell detrit from Dreissena. Holocenian lithostratigraphic units: C – grey black, roquefort type of silts, containing cavities filled with gas, also known as "gas-pockets"; \mathbf{H} – grey-greenish muds, "roquefort" type, with gas turbation texture, containing cavities with saturated gas; \mathbf{B} – grass green, plastic silts; \mathbf{D} – greenish-grey, soft-plastic muds with layers of shells; \mathbf{A} – variety of the upper part of unit D, strongly watered; \mathbf{K} – olive-green, soft-plastic muds, containing shells from Mytilus galloprovincialis; $\mathbf{K_1}$ – variety, containing shells from Modiolus and Cardium; \mathbf{O} – shells accumulation, specific only of the North shelf – north of cape Kaliakra. Lithostratigraphic units on the continental slope: Pleistocenian (Neweuxinian) lithostratigraphic units: 1c - lutit; Holocenian lithostratigraphic units: 1b - sapropel packet; 1a - recent mud with Cocolithpphoridae

Discussion. The theoretical basis of the stratigraphy of the marine Quaternary lithostratigraphic units in the western sector of the Black Sea was already established in the classical works of ANDRUSOV [¹]. As more facts were gathered, the succeeding research-workers [²] laid the foundations of the Quaternary stratigraphic terminology of the Black Sea and corrected the scheme of Andrusov. NEVESSKAYA [³] developed a detailed biostratigraphic scheme of the Black Sea on the basis of the changes in the molluscan fauna, as a consequence of the climatic influence of the Mediterranean basin. The long-term researches of FEODOROV [⁴] play a major role in the exploration of the Quaternary stratigraphy of the Black Sea basin.

The following conclusions are drawn, based on the brief survey of the stratigraphic schemes, discussed in the previous paragraph with respect to their relevance to the Bulgarian shelf:

a) bathymetric factor limit – the scheme of Feodorov is based upon an analysis of coastal terraces, while the scheme of Nevesskaya refers to the continental shelf, which makes both of the schemes inapplicable to the whole sector of the Bulgarian shelf;

b) regional limit – the cited schemes are only relevant to the Russian and Ukrainian coast and shelf sectors;

c) nomenclature deficiency – terms such as "horizons" and "layers" are used, which do not comply with the requirements of the International Commission on Stratigraphy.

The stratigraphy of the Quaternary sediments in the Bulgarian continental shelf is a result of long-term research. Between 1975–1990 there were various Bulgarian-Soviet marine scientific expeditions the results of which are issued in numerous articles, compendiums and monographs [$^{5-8}$]. The stratigraphy and the genesis of sediments in the continental shelf and the deep-sea zone of the Bulgarian sector of the Black Sea are clarified in a series of publications issued by Bulgarian scientists.

The scheme of KHRISCHEV and SHOPOV [^{9, 10}], who explore the sediments in the peripheral sector of the South Bulgarian continental shelf is a major contribution to the stratigraphy of the Bulgarian sector of the Black Sea continental shelf. According to this scheme unofficial lithostratigraphic units and biostratigraphic sectors are distinguished and the relations between them are analyzed.

The stratigraphic scheme, which is relevant to the features of the Bulgarian continental shelf, is issued by SHOPOV $[^{11, 12}]$. The chronostratigraphic scheme of the regional levels and sublevels of the Bulgarian Black Sea continental shelf is adopted and used during the geological explorations in the last decades.

The correlation scheme suggested in this article represents the spatial relations between the Upper Quaternary lithostratigraphic units and the biostratigraphic zones at the border between the shelf and the continental slope in the Bulgarian sector of the Black Sea depression (Table 1).

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Lithostratigraphic units on the shelf: Upper Pleistocene (Neweuxinian) lithostratigraphic units. Unit N – "Lumachelle". The Neoeuxinian sediments are defined by shell accumulation "lumachelle" with clay matrix of overlying muds. The biogenic component of the unit is represented by mollusks (*Bivalvia and Gastropoda*) as g. Dreissena rostriformis distincta Andrus, which is a dominatinig taxon. The shells and fragments of g. Dreissena rostriformis tschaudae Andrus., Didacna sp. in "lumachelle" are black, indicating anoxic environment, strongly reworked and redeposited. The eastern boundary of distribution coincides with the shelf edge. The western boundary is not clear because it is always covered by younger Holocene deposits. The lower boundary, determined in the sections on the outer south Bulgarian Black sea shelf [¹³], is sharp, washing surface with round quartz grains and pebbles, overlaying Tschaudinian (Lower Pleistocene) clays. The shell accumulations of unit N are correlated with accumulative forms of the type of coastal or barrier bars, formed by low sea level and the smallest rates of sedimentation.

Table 1

The correlation scheme suggested in this article represents the spatial relations between the Upper Quaternary lithostratigraphic units and the biostratigraphic zones at the border between the shelf and the continental slope in the Bulgarian sector of the Black Sea depression

System	Series	Regional stages	Substages	Shelf	Deep basin
				inner outer	
				Lithostratigraphic]
				and	
				biostratigraphic units	
QUARTERNER	Holocene	Black Sea	New Black Sea	B /K/ § D /K/	1 <i>a</i>
				2 E	
				Zone Sp. triangulata – M. phaseolinus	
				C H	
			Old Black Sea	Zone M. galloprovincialis	11
				C H	10
				Zone H. ventrosa – M. caspia	
	Pleistocen e	New e u xinian	upper	Zone Dr. polymorpha - Dr. distincta)	
				N § NL	1
			lower	Barren zone Hiatus	- 1c

Unit L – light grey, soft plastic clay muds, containing shells from g. Dreissena. The sediments of the unit are determined in the peripheral zone of the shelf, in the coastal accumulative bars. In the upper part of continental slope they are deposited over the unit Ic. The upper boundary is usually clear due to the sharp lithological contact with Holocene deposits. The intervals with hydrotroilite spots, irregularly clustered are very typical in the lower part of the units.

Unit NL – a variety of light grey silts, containing shell detritus from g. *Dreissena*. The variability is established only in the north shelf, north from c. Kaliakra.

Holocene lithostratigraphic units. Unit C – grey to black silts, containing cavities filled with gas, also known as "gas-pockets". The most characteristic feature is the texture, type of "roquefort", forming after extraction from the corer. The deposits of the unit are very homogenous and slightly watered. Sometimes, in the outer southern part of the shelf, localitites are observed, enriched in organic matter and hydrotroilite traces. The unit replaces unit H in lateral direction toward the shallow parts of the shelf. The upper boundary is related with transition to the greenish muds of unit D; the western boundary is situated in the littoral zone, where the unit coincides with Holocene sands. The lower boundary is not established.

Unit H – grey-green muds, "roquefort" type, with gas turbation texture, containing cavities with saturated gas; soft to medium plastic. A specific feature is "roquefort" gas bearing texture, forming after extraction from the corer. The terrigenous, sandy-silty component varies in a large range. Unit H is spread in the central area of the shelf in the zone of transition from inner to outer shelf. Its western boundary is determined by a gradual transition toward the muds of unit C and on the east it sinks under the oil-green mud of unit K. The lower boundary is not reached anywhere.

Unit B – grass-green, plastic muds. They are represented by light green, soft-plastic hydrogen sulphide muds, with very well-differentiated shell horizons. The lateral transitions DB or BD are typical. The unit is disclosed directly on the bottom surface. The lower boundary is not reached.

Unit D – greenish-grey, soft-plastic muds with layers of shells. The unit is characterized by considerable heterogeneity in terms of lithological composition. It is widespread in the shallower parts of the central region of the shelf. "Roquefort" muds type C or H connected with it through a gradual transition serve as padding. To the west, in the littoral zone, the muds of the unit turn to type B mud or are replaced by Holocene coastal sands. The eastern boundary is marked by a gradual lateral transition to type K green muds.

Unit A – a variety of the upper part of unit D, strongly watered.

Unit K – olive-green, soft-plastic muds, containing shells of g. Mytilus galloprovincialis. The unit contains a significant amount of shell detritus that is

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dispersed among the clay-terrigenous matrix. Unit K rests on different lithostratigraphic units: in the upper part of the continental slope – on unit L muds; in the area of peripheral swells – on lumachelle N; towards the coast – on the green "roquefort" muds of unit H. The lower boundary of K muds is a washing surface when placed on Neoeuxinian sediments and gradual one when it is upon type H muds. The upper boundary coincides with the seabed. On the west, K muds gradually turn laterally to B and D muds. On the east, in the upper part of the continental slope full pinch-out of the sediments occurs and/or gradual lateral combination with the sediments of deepwater units Ia and Ib.

Unit K_1 – a variety containing shells of g. Modiolus and g. Cardium.

Unit O – shell accumulation, specific to the northern shelf only, to the north of c. Kaliakra. The unit is a variation of the lithologic varieties D and K. A twomember structure of the unit is clearly fixed. Shells of g. *Modiolus* prevail in the upper part with binding mass of green-gray to bright mud. At the bottom shells of g. *Mytilus* are deposited which are included in olive green mud. The lithostratigraphic unit K has a wide-area distribution on the shelf, north of c. Kaliakra. The indexing of unit O as a variety of unit K is made by Shopov et al. [¹¹]. Its definitive feature is the abundance of shells – whole or detritus, which in its typical development impart an appearance of "lumachelle", or this is a case of condensed faunas.

Lithostratigraphic units on the continental slope: Pleistocene (Neweuxinian) lithostratigraphic units. Unit Ic – lutite (Neweuxinian regional stage). The unit is characterized by widespread development of terrigenous, clayey and fine-grained muds. In these sediments the content of organic matter and biogenic carbonate component is very limited. A specific feature is the presence of the so-called "hydrotroilite" muds – stratigraphically determined iron monosulfides, which colour muds in dark gray to black. Another specific feature is the presence of a packet of chemogenous calcareous mud, "seekreide" type [¹⁴], in the upper part of the unit. Sable stratigraphic sequence is established in the complete sections of the unit along the northwestern continental slope and the foot where the following four packets are defined (top-down):

- light gray, carbonate mud, "seekreide" type, unlayered;
- dove-gray, clayey muds;
- laminated muds: gray, dark gray to black, "hydrotroilite";
- variegated, pink-brown, oxidised, laminated muds ("chocolate").

Holocene lithostratigraphic units. Unit lb – sapropel (Holocene, Old Black Sea regional substage). A definitive feature of the unit is the essential part of organic matter, leading to the formation of sapropel-like muds. The unit section is characterized by a three-layer structure (top-down):

– oil green muds, loose deposits, sapropel-like and sapropelic muds with an upper boundary the first coccolith layer;

- thick, compact, rubber-like sapropel, often with aragonite laminas;

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– gray-green clayey muds, with lower content of organic matter (i.e. a transitional unit 1b - c).

According to VELEV et al. [¹⁵], Holocene sapropel-like deposits form a genetic sequence of four packets, including clay facies. Characteristic of the unit is the development of syn-sedimentary breccias, which are a product of deformation and landslide processes on the continental slope, or have seismogenic origin.

Spatial development of the individual lithofacies in the western Black Sea depression is represented by SHOPOV [¹⁶]. The age range of the unit lb is defined as the lower part of the Holocene – Middle Holocene.

Unit 1a – recent mud with Cocolithphoridae bf (Holocene, New Black Sea regional substage). The muds of the unit are defined as gray-green, fine-grained sediments, micro-laminated, sapropelic, high carbonated, coccolith. The unit is stratigraphically expressed in the northwestern part of the continental slope, the foot and abyssal plain [¹⁶]. The changes in the lithofacies in lateral direction are consequential. The terrigenous lithofacies are connected with the cone for export of clastic material in the depression from the Turkish coast. Another type of clay lithofacies is developed in the upper continental slope due to the import of terrigenous material from the edge of the shelf. Characteristic of the unit is the extensive development of syn-sedimentary breccias at the bottom of the slope. Specific facies of the unit are diatomaceous-coccolith muds developed in the upper part of the slope.

Unit 1a is Late Holocene in age.

Results. The lateral alternations of the lithostratigraphic units have been traced; a horizontal changeability has been identified within the unit itself, and at the same time, its spatial development at the border of the shelf and the deep zone; a correlation has been made between the given lithographic unit from the shelf and its even-aged analogue from the deep zone. Lithostratigraphic characterization of the Upper Quaternary sediments of the shelf and the deep zone is made. The stratigraphic mapping of the Upper Quaternary lithostratigraphic units of the shelf has the following features:

a) The lithostratigraphic units are separated on the basis of macroscopic diagnostic characteristics such as lithology, colour, smell and texture.

b) Division is made on slimy marine sediments (unlithified) which are distinguished by great lithological and facial changeability.

c) The top layer is not differentiated as a separate unit.

d) The lithostratigraphic units of the shelf are distinguished by regional limitation. On the one hand, most of the suggested strato-typical sections are defined in the north-western shelf of the Black Sea basin, the Russian coast and shelf, but they hardly correspond stratigraphicly with the even-aged sediments in our shelf. On the other hand, the stratigraphic correlation of the units of the Bulgarian shelf with the even-aged units of the Ukrainian and Romanian shelf is difficult, because despite the common regularities, several specific characteristics of the

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sediment genesis and the effect of regional factors are identified. In this sense, experience proves the need for continuous updating of the regional scheme of the Bulgarian shelf.

e) The Holocene sands in the coastal zone are not differentiated as a separate unit. These sediments are hardly suitable for stratigraphic mapping, due to the specific lithodynamic environment, and therefore differentiated as a single common undivided group of sediments.

f) All "horizons" and "layers" used by Russian authors for defining stratitypical sections or correlations in the given scheme are rated as regional levels whose sedimentary cycle closes between two consecutive regressions of the sea.

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