CHAPTER 1B GENERAL OCEANOGRAPHIC PROPERTIES: GEOGRAPHY, GEOLOGY AND GEOCHEMISTRY

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1B.1 Geographic position and physiography

The Black Sea is one of the largest almost enclosed seas in the world: its area is about 420 thousands km^2, the maximum water depth 2.212 m, the total water volume of about 534,000 km^3.The Black Sea is placed in the southeastern part of the Europe between 40° 54? 40? and 46° 34? 30? northern latitudes, 27 27? and 41? 46? 30? eastern longitudes. The sea is roughly oval-shaped. The maximum extent of the sea in the east-west direction is about 1175 km, while the shortest distance is of some 260 km between the southernmost tip of the Crimea and the Cape Kerempe on the Turkish coast (Fig. 1B.1). The Black Sea is connected to the Mediterranean Sea to the west and to the Sea of Azov to the north. The connection with the Mediterranean Sea is limited to the Istanbul-Canakkale (Bosporus-Dardanelles) straits. The Istanbul Strait is a rather narrow (0.76 ? 3.6 km large) and shallow strait (presently 32 ? 34 m at the sill) restricting the two-way water exchange between the Black and Mediterranean Seas. The other connection, with the Sea of Azov is realized by the Strait of Kerch.

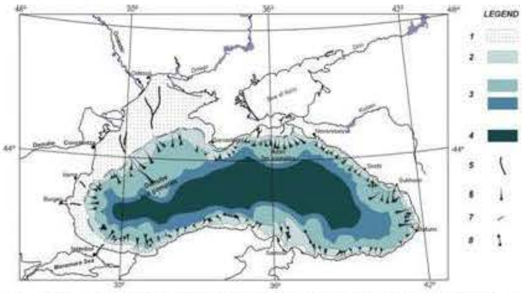

Fig. 1B.1. Geomorphologic zoning of the Black Sea (after Ross et al.,1974, Panin and Ion, 1997).

Legend; 1, continental shelf; 2, continental slope; 3, basin apron: 3 a - deep sea fan complexes; 3 b - lower apron; 4, deep sea (abyssal) plain; 5, paleo-channels on the continental shelf filled up with Holocene and recent fine grained sediments; 6, main submarine valleys - canyons; 7, paleo-cliffs near the shelf break; 8, fracture zones expressed in the bottom morphology.

The Black Sea is surrounded by high folded mountain chains represented by the Balkanides-Pontides belts to the south-west and south, by the Great and Little Caucasus to the east and by the Crimea Mountains to the north. There are low-standing plateaux and the Danube delta lowland only in the west and north-west. On the opposite eastern side there is the Kolkhida lowland of smaller extent. Consequently the relief energy is much higher on the eastern and southern costs than on the northwestern shore.

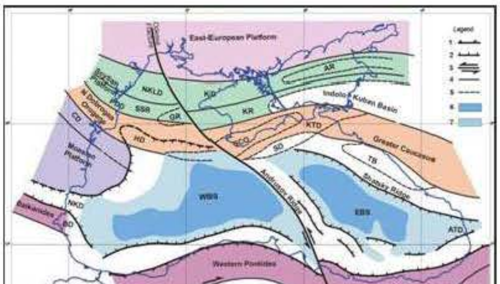

Fig. 1B.2. Tectonic sketch of the Black Sea Region (after Dinu et al., 2003; Panin et al., 1994).

Legend: 1, Orogene overthrust front; 2, Gravitational faults of the rift; 3, Major strike-slip faults; 4, Major faults; 5, Limits of depressions and/or ridges; 6, Zone without granitic crust; 7, Thinned crust. Explanation of abbreviations:? I. Platform regions: East European, Scytian, Moesian: II. Orogenic regions: North Dobrogea Orogene, Greater Caucasus, South Crimea Orogene ? SCO, Balkanides, Western and Eastern Pontides; III. Depressions and ridges: PDD ? Pre-Dobrogean Depression; NKLD ? North Kilia Depression; KD ? Karkinit Depression; HD ? Histria Depression; SD ? Sorokin Depression; KTD ? Kerci-Taman Depression; NKD ? Nijne-Kamchilsk Depression; BD ? Burgas Depression; ATD ? Adjaro-Trialet Depression; TB ? Tuapse Basin; SSR ? Suvorov-Snake Island Ridge; KR ? Krymskyi Ridge; AR ? Azov Ridge; GR ? Bubkin Ridge; IV. WBS ? Western Black Sea; V. EBS ? Eastern Black Sea;

The Black Sea basin can be divided into four physiographic provinces: the shelf representing about 29.9% of the total area of the sea, the basin slope - about 27.3% of the total area, the basin apron, with 30.6%, and the abyssal plain - 12.2% (Fig. 1B.1). One of the most prominent physiographic features is the very large shallow (less than 200 m deep) continental shelf within the northwestern Black Sea (about 25 % of the total area of the sea). The Crimean, Caucasian and southern coastal zones are bordered by very narrow shelves and often intersected by the submarine canyons.

1B.2. Geology of the Black Sea

Geologists consider the Black Sea a back-arc marginal extensional basin, which originated from the northward subduction of the Neo-Tethys along the southern margin of the Eurasian plate under a Cretaceous-Early Tertiary volcanic arc (Letouzey et al., 1977; Dercourt et al., 1986; Zonenshain and Le Pichon, 1986) as a result of the northward movement of the Arabic plate (Fig. 1B.2).

Since about 120 million years ago, the area has been a marine basin, with extremely dynamic development and large sediment accumulation of about 13 km of bottom sediment thickness in the central part of the basin. There are two extensional sub-basins with different geological history (Fig. 1B.2): (1) the Western Black Sea Basin, which was opened by the rifting of the Moesian Platform some 110 Ma ago (Late Barremian) followed by major subsidence and probable oceanic crust formation about 90 Ma ago (Cenomanian) (Astyushkov, 1992; Finetti et al., 1988; G?r?r, 1988) and (2) the Eastern Black Sea Basin, with rifting beginning probably in the Late Palaeocene (about 55 Ma ago), and extension and probable oceanic crust generation in the Middle Eocene (ca.45 Ma ago) (Robinson et al., 1995).

1B.3. Water and sediment supply from rivers

The Black Sea has an extremely large drainage basin of more than 2 million km^2, collecting the water from almost all the European countries, except the westernmost ones. The northwestern Black Sea receives the discharge of the largest rivers in the Black Sea drainage area ? the Danube River with a mean water discharge of about 200 km^3/yr and the Ukrainian rivers Dniepr, Southern Bug and Dniestr contributing with about 65 km^3/yr (Table 1B.1). Presently the influence of the Danube River is predominant for the sedimentation on the northwestern Black Sea shelf area.

The Danube influence extends far southward up to the Bosporus region, as well as down to the deep sea floor. Presently the other three tributaries of the north-western Black Sea (Dniestr, Dniepr and Southern Bug) are not significant suppliers of sediments because they are discharging their sedimentary load into lagoons separated from the sea by beach barriers.

Table 1B.1. Fluvial water and sediment discharge into the Black Sea. *Data from Balkas et al. (1990); ** multiannual mean discharge before damming the River Danube after Bondar (1991); Panin (1996).

Rivers	Length (Km)	Drainage basin Area? (Km2)	Water discharge (Km3/yr)	Sediment discharge (Mt/yr)
I. North-Western Black Sea				
Danube	2,860	817,000	190.7	51.70**
Dniestr	1,360	72,100	9.8	2.50*
Dniepr	2,285	503,000	52.6	2.12*
Southern Bug	806	63,700	2.6	0.53*
Sub-total I:	1,455,800	255.7	56.85	
II. Sea of Azov				
Don	1,870	442,500	29.5	6.40*
Kuban	870	57,900	13.4	8.40*
Sub-total II:	500,400	42.9	14.80	
III. Caucasian coast rivers	41.0*	29.00*		
IV. Anatolian coast rivers	29.7	51.00*		
V. Bulgarian coast rivers	3.0*	0.50*		
TOTAL:	372.3	152.15		

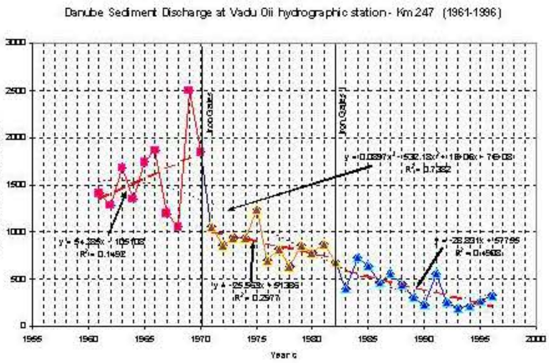

Fig. 1B.3. The decreasing trend of the Danube River sediment discharge after damming (Iron Gates I barrage in 1970, Iron Gates II barrage in 1983).

After the damming of the Danube River at Iron Gates I and II, the river sediment discharge diminished by almost 40-45 % (Fig. 1B.3), and the real sediment load brought by the Danube into the Black Sea is not larger than 30-40 million t/yr, of which only 10-12 % is sandy material and contributes to the littoral sedimentary budget of the delta front zone.

1B.4. Sedimentary systems of the Black Sea

The sedimentary systems in the Black Sea have been strongly influenced by the sea level changes driven by the processes of global glaciation and deglaciation. The surrounding relief and the physiography of the basin play also a very important role in defining the sedimentary systems. The eastern and southern parts of the sea are characterized by high relief energy and narrow continental shelf; this facilitates the direct transfer of sediments from the continent to the deep sea and determines a coarser grain size of these sediments. The western and north-western parts of the Black Sea have wide shelf and lower relief. Instead here the largest rivers are supplying important quantities of sediments, much finer (mainly silty-clay sediments).

North-western continental shelf: On the north-western Black Sea shelf area, the dispersal pattern of the Danube sediment supply indicates the existence of two main areas with different depositional processes (Panin et al., 1998): the Danube sediment-fed internal shelf and the sediment starving, external shelf (Fig. 1B.4).

Generally speaking, on the continental shelf the following sedimentary facies can be recognised (Shcherbakov and Babak, 1979):

Modiolus Mud: The *Modiolus* Mud is located at the top of the sedimentary sequence between 50 to 125 m of water depth. It is a light coloured mud, very rich in *Modiolus phaseolinus* coquinas whose thickness does not normally exceed 30 cm.

Mytilus Mud: The Mytilus (*Mytilus galloprovincialis*) mud is present from the shelf break till the depth of 50 to 40 m; further it is covered by the*Modiolus* Mud

Dreissena Mud: Around 130 m of water depth the surficial sediment is made of shells of*Dreissena*. Landward, this unit is covered by the *Mytilus Mud* and by the *Modiolus Mud*. The *Dreissena Mud* is outcropping only at the top of the continental slope.

The vertical transition in between *Dreissena Mud* to *Mytilus Mud* corresponds to the change from fresh/brackish to marine conditions in the Black Sea.

Internal, Danube sediment - fed shelf: The sediment-fed area in the neighbourhood of the Danube Delta includes the delta front unit (about 1,300 km^2) and towards off-shore, at the base of the delta front to 50-60 m depth, the prodelta covering an area of more than 6,000 km^2. Its southern boundary is more difficult to define on account of the strong southward drift of fine grained sediment load discharged into the sea by the Danube, which is stumping the prodelta limit.

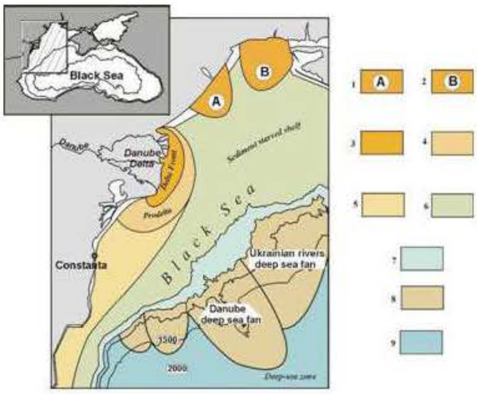

Fig. 1B.4. Main sedimentary environments in the northwestern Black Sea (after Panin et al., 1998).

Legend: 1-2, Areas under the influence of the Ukrainian rivers? sediment discharge (A ? Dniester and B ? Dnieper); 3, Danube Delta Front area; 4, Danube Prodelta area; 5-6, Western Black Sea continental shelf areas (5, under the influence of the Danube-borne sediment drift; 6, sediment starved area); 7, Shelf break and uppermost continental slope zone; 8, Deep-sea fans area; 9, Deep-sea floor area.

Out of the area defined as the prodelta unit, the internal, western zone of the Romanian shelf stands out as the shallow marine area (less than 50 -60 m water depth), which receives clay and siltic sediments, supplied by the Danube River. Moving as a suspended load, the sediment flux goes beyond the area in front of the Danube Delta but does not reach the eastern, external shelf zone. Under the influence of the dominant currents, the "clayey-silty" sediment flux moves southward toward the Bulgarian shelf, keeping within the western shelf area, close to the shoreline and finally discharging the sediment load in the deep-sea zone within the pre-Bosporus region.

External, sediment starving shelf: Situated outside the area covered by the Danube fed sediment flux the external, eastern part of the continental shelf represents an area practically deprived of clastic material (Fig. 1B.5). Within this sediment starving shelf area, the condensed sediment accumulation is of biogenic origin, producing an organic thin cover on relict sediments or concentrations of shells. The Danubian sediments seldom reach the shelf area north or northwest of the Danube mouths. Dniester and Dniepr, the main rivers north of Danube Delta, are themselves, as already mentioned, not significant suppliers of sediment for the north-western Black Sea shelf. Consequently, the sediment starving status characterizes almost all of the whole Black Sea continental shelf west of the Crimean Peninsula.

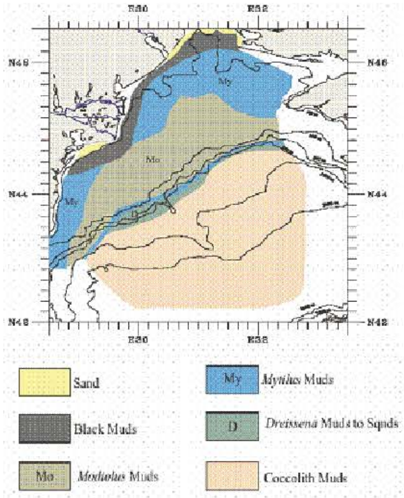

Fig. 1B.5. Repartition of litho-stratigraphic units on the sea floor in the NW Black Sea (from S. Radan, unpublished data).

Deep sea zone of the western Black Sea: During the Upper Quaternary, in correlation with the sea-level fluctuations of this period, very large accumulations of sediments were formed in the deep-sea zone of the north-western Black Sea, mainly on the continental slope and apron areas. This accumulation is represented by two distinct but interfingering fans: the Danube fan fed by the River Danube during fan accretion and the Dniepr fan built up by the Ukrainian rivers Dniepr, Dniestr and Bug. Eight seismic sequences have been identified within each of these fans (Wong et al., 1994, 1997). While the lowermost two consist mainly of mass transport-related deposits, the six upper sequences comprise typical fan facies associations, corresponding mainly to the low stands of the sea level related to the glacials.

The interpretation of seismic sequences show that the Danube and Dniepr fans were accreted during the past 480 k.yr (sequences 3 to 8). Average deposition rates for the fan sequences range from 2.4 to 7.2 m/k.yr and the volume of material deposited within a sea level cycle lies between 4,300 km? and 9,590 km?.

Within the deep-sea zone of the Black Sea, the existing accumulation of recent sediments is represented by coccolith ooze overlying sapropelic or organogen sediments (Ross et al., 1970) highlighting the domination of the organic component over the detrital one. Ross and Degens (1974) have defined the following succession of the upper sediment layers:

Unit I ? coccolith ooze (0 - 3,000 yrs BP) : micro laminated carbonated? sediment with*Emiliana huxleyi*

Unit II ? sapropel beds (3,000 - 7,000 yrs BP) ? micro laminated sediment very rich in organic matter (sapropel)

Unit III ? banded lutite (7,000 - 25,000 yrs BP) ? banded lutites ? turbidites.

These units correspond to the Arkhangelskiy and Strakhov?s (1938) stratigraphic units: (1) recent deposits; (2) Old Black Sea beds, and (3) Neoeuxinian deposits (Tables 1B.2 and 1.3).

Very seldom and locally spread gravitationally transported material and mainly hemipelagic sediments occur within the slope, apron and abyssal zones, during this high stand sea level. ?

1B.5. Past environmental and sea level changes in the Black Sea

Large-scale sea level changes and consequently drastic reshaping of land morphology, large accumulation of sediments in the deep part of the sea and modifications of environmental settings occurred all along the Black Sea geologic history. The Quaternary was especially characterised by very spectacular changes, which have been driven by the global glaciations and deglaciations.

During these changes the Black Sea level behaviour was influenced by the restricted connection with the Mediterranean Sea by the Bosporus ? Dardanelles Straits. When the general sea level lowered below the Bosporus sill, the further variations of the Black Sea level followed specific regional conditions, without being necessarily coupled to the ocean level changes. One of the main consequences of the lowstands was the interruption of the Mediterranean water into the Black Sea, which became an almost freshwater giant lake.

The main glacial periods of the Quaternary in Europe (Danube, G?nz, Mindel, Riss and W?rm) corresponded to the regressive phases of the Black Sea, with lowstands of the water level down to ?120 m. As mentioned above, the regressions represent phases of isolation of the Black Sea from the Mediterranean Sea and the World Ocean. Only the connection with the Caspian Sea could sometimes continue through Manytch valley. Correspondingly, during regressions, under fresh water conditions, the particularities of fauna assemblages had a pronounced Caspian character. On the contrary, during the interglacials, the water level rose to levels close to the present level; the Black Sea was reconnected to the Mediterranean Sea, and the environmental conditions as well as the fauna characteristics underwent marine Mediterranean influences.

For example, during the Karangatian phase (since 125 ka BP to ~ 65 ka BP) of the Black Sea, which corresponds to the warm Riss-W?rmian (Mikulinian) interglacial (Fig. 1B.6), the water level exceeded the present-day level by 8 to 12 m. The saline Mediterranean water penetrated through the Bosporus, and the Black Sea became saline (30 to 37?), with a steno- and eury-haline marine Mediterranean type fauna (Nevesskaya, 1970). The sea covered the lowlands in the coastal zone.

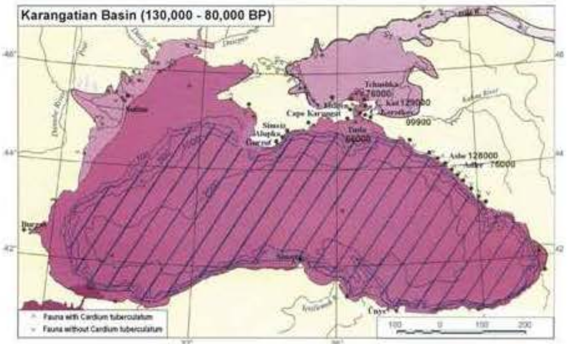

Fig. 1B.6. Plaeo-geographic reconstruction of the Black Sea during the Karangatian phase (Riss-W?rmian or Mikulinian interglacial) (after Tchepalyga, 2002).

The last Upper W?rmian glaciation (Late Valdai, Ostashkovian) corresponds to the Neoeuxinian phase of the Black Sea. This is a very low-stand phase, down to -110 - 130 m. The shoreline moved far away from the present-day position, especially in the north-western part of the Black Sea, and large areas of the continental shelf were exposed (Fig. 1B.7). The hydrographic network, especially the large rivers as Palaeo-Danube and Palaeo-Dniepr, incised up to 90 m the exposed areas. The Neoeuxinian basin, during the glacial maximum (~19 ? 16 ka BP) was completely isolated from the Mediterranean Sea, and, correspondingly, the water became brackish and even fresh (3-7? and even less), well oxygenated, without H_2S contamination. The fauna was brackish to fresh water type with Caspian influence.

At about 16 - 15 ka BP, the postglacial warming and the ice caps melting started. As the supply of the melting water from the glaciers through the Dniepr and the Dniestr rivers, as well as the Danube river to the Black Sea was very direct and important, the Neoeuxinian sea-level rose very quickly, reaching and overpassing at ~ 12 ka BP the Bosporus sill altitude. The majority of scientists, who studied the Black Sea, believe that in this phase it was a large fresh-water outflow through the Bosporus-Dardanelles straits towards the Mediterranean (Aegean) Sea. Kvasov calculated (1975) that the fresh water outflow discharge was of about 190 km^3/year.

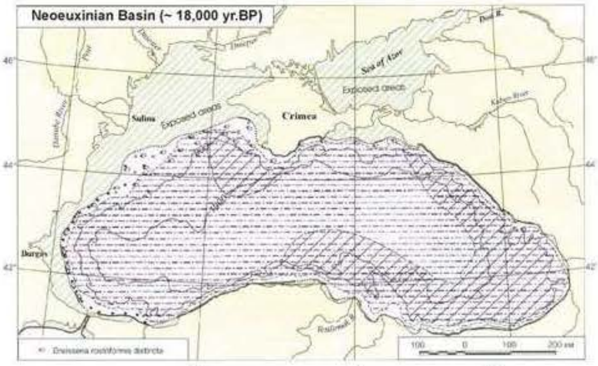

Fig. 1B.7. Palaeo-geographic reconstruction of the Black Sea during the Neoeuxinian phase (

Upper W?rmian) (after Tchepalyga, 2002).

At the beginning of the Holocene, some 9-7.5 ka BP, when the Mediterranean and the Black Seas have reached the same level (close to the present day one), the two-way water exchange was established, and the process of transformation of the Black Sea in an anoxic brackish sea started. During the last 3 ka BP, a number of smaller oscillations of the water level have been recorded (?Phanagorian regression?, ?Nymphaean? transgression, a lowering of 1-2 m in the X-th century AD, a slow rising continuing even today).

In the late nineties, a new hypothesis was formulated by Ryan et al. (1997). They considered that, when the deglaciation started during a short episode, the level of the Black Sea was high enough, and the fresh Pontic water flowed towards the Aegean Sea. At about 12 k.yr BP, the retreat of the ice-sheet front determined the reorienting towards the North Sea, for the limited period of time of melt-water supply. The Black Sea, without the inflow of the ice-melting water during the Younger Dries cooling (~11 ka BP) until 9 ka BP, under more arid and windy climate, experienced a new lowering of the level (down to -156 m). At the same time, the Mediterranean Sea continued to rise, reaching by 7.5 K.yr BP the height of the Bosporus sill, and generating a massive input of salt water into the Black Sea basin. The flux was several hundred times greater than the world?s largest waterfall, and it caused a rise of the level of the Black Sea, some 30 to 60 cm per day topping up the basin in few years time. More recent interpretation concludes that a deeper Bosporus sill (~ -85 m) could lead to another scenario of mixing of Black Sea and Mediterranean waters (Major et al., 2002).

This new hypothesis is still under debate; numerous data from the straits of Bosporus and Dardanelles, Marmara and Aegean Seas and the Danube Delta do not entirely support the Ryan?s hypothesis. These data indicates that the ?classical? scenario of Black Sea water outflow is rather credible. There are also some hydraulic incompatibilities for accepting a catastrophic flooding event in the Black Sea as well as a different time scale for reaching the present day salinity of the Black Sea waters (Myers et al., 2003). The scenario proposed by the EU ?Assemblage? project (Lericolais et al., 2006) after an extensive study of the western Black Sea is synthesized as shown in Fig. 1B.8.

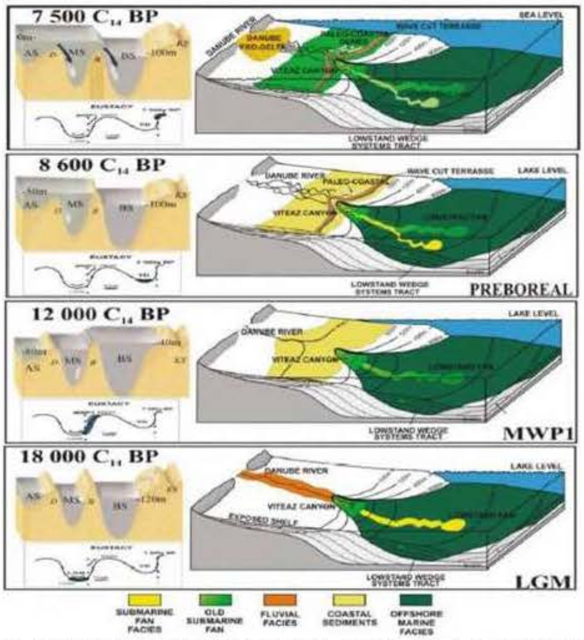

Fig. 1B.8. The scenario of the Black Sea water level fluctuation since the Last Glacial Maximum (after Lericolais et al., 2006, Final Report of the EU project ? Assemblage?)

The water brought to the Black Sea after the Melt Water Pulse 1A (MWP1A) at approximately 12,500 C14 BP (14,500 yr cal. BP) (Bard et al., 1990) was supposed to be sufficiently important that the water level rose up to between -40 m to -20 m, where the *Dreissena* layers were deposited. This water level would have brought the level of the Black Sea high enough for making possible an inflow of Mediterranean water with marine species of dinoflagellates (Popescu, 2004), and an outflow of Pontic waters towards Mediterranean Sea. Palynological studies show that during the Younger Dryas a cool and drier climate prevailed. The Younger Dryas climatic event had lowered the Black Sea water-level and cut again the connection with the Mediterranean Sea. Around 7.5 kyr BP, the Black Sea water level suddenly changed because of a quite abrupt flooding of the Black Sea by Mediterranean waters, as supposed by Ryan et al. (1997, 2003) supported with dinoflagellate cyst records (Popescu, 2004).

Table 1B.2. Stratigraphy and correlations of Upper Quaternary phases for the coastal and inner shelf zones (with slight modification from Fedorov, 1978).

General scale		**Europe**		**?European Russia**	**Black Sea region**				
General stratigraphic scale		W and NW Black Sea	Northern Black Sea Crimea, Kerch, Taman	Eastern Black Sea Caucasus					
Holocene		Flandrian		Holocene	Black Sea Horizon	Nymphean	Terrace at 2 m; sands with Cardium edule L. etc.??	Terrace at 2 m; Sands with Cardium edule L. etc.??	Terrace at 2 m; sands with Cardium edule L. etc.??
						Phanagorian	Regression to ? 6 ? 8 m. Archeological layers V?I c. BC	Regression to ? 6 ? 8 m. Archeological layers V?I c. BC	Regression to ? 6 - 8 m. Archeological layers V?I c. BC
						New Black Sea	Terrace at +4 +5 m; sands and shells with Cardium edule L., Chlamys, Ostrea, Mytilus?	Terrace at +4 +5 m; sands and shells with Cardium edule L., Chlamys, Ostrea, Mytilus?	Terrace at +4 +5 m; sands and shells with Cardium edule L., Chlamys, Ostrea, Mytilus?
						Old Black Sea	Clayey sands with Cardium edule L. etc. at ?10 ?20? m water depth on shelf	Clayey sands with Cardium edule L. etc. at?? -10 -20 m water depth on shelf	Clayey sands with Cardium edule L. etc. at?? -10 -20 m water depth on shelf
Pleistocene	Upper	Grimaldian ? Würm (regression to -100 -130 m)		Ostashkovian	Neoeuxinian	Late?? Neoeuxinian	Würmian loess ; clays with Monodacna caspia Eichw., Dreissea polymorpha Pall.,at ?20 ?30 m water depth on shelf	Clays with Monodacna caspia Eichw., Dreissea polymorpha Pall., at ?20 ?30 m water depth on shelf	Clays with Monodacna caspia Eichw., Dreissea polymorpha Pall., at ?20 ?30 m water depth on shelf
				Mologo-Shekanian		Early? Neoeuxinian (Postkarangatian)	Regression to ?60 ? 80?? (-130) m.? Würmian loess. Deepening of the valleys incisions	Loesslike deposits; alluvial-deltaic sands, deepening of Kertch strait.	Regression ; deepening of the valleys incisions to ?60 ?80 m.

UA-439

General scale		Europe		?European Russia	Black Sea region					
				Kalininian						
		Neotyrrhenian (terrace at? 2-8 m above SL)		Mykulinian	Karangatian	Upper Karangatian	Terrace at +15 +16 m Shells and sands with Cardium tuberculatum L., Paphia senescens (Coc.) etc.	Terrace at? +8 +12 m (4?8 m Taman) Shells and clays with Cardium tuberculatum L., Paphia senescens (Coc.), Aporrhais pespelicani L. etc. At the base clays with? Paphia senescens (Coc.), Cerithium vulgatum Burg.	Terrace at +12 +15 m (Pshady valley), +25 +30 m (in Sochi region); Shells with Cardium tuberculatum L., Paphia senescens (Coc.), Aporrhais pespelicani L., Cerithium vulgatum Burg.etc.	
						Lower Karangatian				
	Middle	Regression (Riss II ?) Deepening of Bosporus to - 100 m		Moskovian	Upper Euxinian-Uzunlarian	Regression	Regression. Clayey loess-like deposits.	Clayey deposits with Limneea, Planorbis ; pebbles with Viviparus	Regression. Alluvial pebbles, terminal moraine at Amtkheli.	
		Eutyrrhenian (Tyrrhenian Ib) (terrace at 10-20 m)		Odyntzovian		Uzunlarian	Terrace at +35 +40 m (Bulgaria) Upper Babel layers, sands with Didacna nalivkini Wass. etc., Uppermost lagoonal clays	Clayey sands with Cardium edule L., Didacna nalivkini Wass. etc.	Terrace at +25 +30 m (Pshady) and +35 +37m (Pshady valley); pebbles, sands with Cardium edule L., Mactra stultorum L., Scrobicularia	
		Regression (Riss I ?)		Dneprian		Late Paleoeuxinian		Sands and clays with Didacna? nalivkini Wass., D.pontocaspia Pavl., Viviparus	Terrace at 40?43 m (Pshady valley); Sands, conglom., limstones with D.nalivkini Wass., D. subpiramidata Prav., at the base Balanus	
					Lower Euxinian-Uzunlarian	Regression	Regression	Regression	Regression, Dilluvium	
		Paleotyrrhenian (Tyrrhenian I-a) (terrace at 18-30 m)		Lykhvinian		Paleouzunlarian	Sands, clays with Didacna pallasi Prav., D.nalivkini Wass. Lower Babel layers. Lagoonal clays with Didacna pseudocrassa Pavl. etc.	Continental deposits within the Mandzhil terrace	Terrace at +45 +50 m (at Ashe, Makopse, Magri); pebbles with C.edule, Paphia sp., Chione gallina	
						Early Paleoeuxinian			Terrace at? +60 +65 m (Dzhubgy); sands, pebbles with Didacna baericrassa Pavl., D.pallassi Prav., C.edule L.	
	Lower	Mindel (Roman regression)		Okan	Regression		Alluvial sands with Viviparus and Tyraspol complex of mammalians	Top deposits with Archidiscodon sp.	Regression	
		Cromerian	Sicilian 2 Terrace? at 60 m	Dnestrian	Tchaudian	Upper Tchaudian	Shells, sands with Didacna pseudocrassa Pavl., D. tschaudae Andrus., D.rudis Nal. ;Terrace ? Large tables ? (Bolshye stoly)	Terrace +40 +55 m(at Pshady), +100 +105 m (at Pshady valley), ~+130 m (at Sochi) ; Congl.,sands with? D.pseudocrassa,????? D. Tschaudae, D.rudis		
			Sicilian 1 Terrace? at 100 m		Gurian ? Tchaudian	Lower Tchaudian	Clayey??? continental?? deposits Sands with Didacna baericrassa, D.parvula, V.pseudoachatinoides, Fagotia esperi	Sandy-clayey deposits of Guria with D. tschaudae, D. tschaudae guriana Livent., D.crassa guriensis Newesk., D. pleisto-pleura (Davit), D.pseudocrassa		
		Günz (regression)				Regression	Sands and clays with Archidiscodon meridionalis Nest. (late) within Nogaysk outcrop	Continental deposits with Taman complex of mammalian fauna	Deposits with Gurian-Tschaudian fauna	Break
Eopleistocene		Emilian-Calabrian		Morozovian-Nogayskian	Gurian		Gurian deposits	Clays with Didacna digressa Livent. etc.		

Table 1B.3. Stratigraphy and correlations of Upper Quaternary phases for shelf and bathyal zones (with slight modification from Scherbakov et al., 1979)

Northern? Europe				BLACK SEA							
Stratigraphic subdivisions				Bathymetric zone 0-50 m		Bathymetric zone 50-200 m			Bathyal zone - northern part		Bathyal
				Layers	Molluscs	Horizon	Molluscs	Diatomaea	Horizon	Diatoms, molluscs	Horizon
Holocene	Upper		Subatlantic -?? 2,800 Sub-boreal -?? 4,800 Atlantic -?? 7,800 Boreal -?? 9,400	Dzhemetinian	Divaricella divaricata Gafrarium minimum Pitar rudis????????? Cardium papillosum	Phaseolinus muds	Modiolus phaseolinus	Coscinodiscus radiatus Thalassiosira excentrica Actinocyclus ehrenbergii Cyclotella kutzingiana Cyclotella aceolata	Cocolith ooze	Coscinodiscus radiatus Endictia oceanica Thalassiosira excentrica Asteromphalus robustus Rhizosolenia calcar avis	Cocolit ooze Unit 1
	Lower		Pre-boreal -?? 10,200	Neoeuxin	Monodacna caspia Dreissena polymorpha Dreissena polymorpha Viviparus fasciatus Unio sp.	8,550 ? 130 13,500? 1,500 17,760 ? 200	Monodacna caspia Dreissena rostriformis bugensis Dreissena rostriformis distincta Dreissena rostriformis distincta	Stephanodiscus astraea Melosira arenaria Diploneis domblitensis	Hydrotroilitic muds Terrigenous brown ? oxydated ? muds Clayey muds	Stephanodiscus astraea Fragments and young forms of : Dreissena rostriformis Monodacna caspia	Nannofi rich terrigen mud Lacustr phase
	Upper? Pleistocene	Würm? (Valdai)	Younger Dryas Aller?d Lower Dryass								
Tarkhankutian	Cardium edule Abra ovata Dreissena polymorpha		B?lling Gothiglacial Pomeranian Frankfurtian								
Middle	M-S.lg.		Brandenburgian -?? 25,000								
Post-Karangatian	Riss-Würm		Paudorf Arcy Gotweig -?? 40,000 -?? ~ 65,000 Eemian -?? ~125,000								

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