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The Source Provinces in the Black Sea

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Introduction

Marine sediments are an association from the authochtonic components (solutions, gases, biochemical solid substances and organism), formed under specific conditions of the sedimentation media and allochtonic components (runoff of the rivers, eroded material, aeolian drift), transformed under the influence of the postsedimentical factors. During the last decades as a result of human activity with allochtonic components an enormous quantity of pollution (heavy metals, pesticides, oil products, radionuclides) have been introduced into the Black Sea basin.

Source provinces in the Black Sea

Solid discharges of the rivers are very important in the processes of sedimentation and pollution. The Black Sea basin covers an area (1 875 000 km^2) of asymmetric form (fig. 1). The rivers, running to the Black Sea are about 500. Data on the rivers with sediment discharge more than 100 000 t/a are presented in table 1 (from J a o s h v i l i, 2000).

The total river discharge in the Black Sea is distributed irregular. It represents 353.30 km^3 of water annually (R e s h e t n i k o v, 1992), a 75 % of which coming from the Northwestern part of the sea with basin area 1 500 000 km^2. At the present time the main sources of terrigenous material on the shelf in the northwest of the Black Sea are the Danube (length 2 860 km, sediment load $53.9 \cdot 10^6$ t/a), Dnieper (length 2 285 km, sediment load $2.1 \cdot 10^6$ t/a), Dniester (length 1 328 km, sediment load $2.5 \cdot 10^6$ t/a) and South Bug rivers (length 857 km, sediment load $1.2 \cdot 10^6$ t/a). These rivers have a typical plain features.

The Northern part of the Black Sea is arid and covers a basin area of the Crimea peninsula. The runoff of small rivers of Crimea is only 0.343 km^3/a, <0.1 % of the total river discharge in the Black Sea (D e d k o v, M o z j e r i n, 1984). The Alma river is the largest transporting agent of solids with 44 300 t/a.

The main rivers which flow into the Azov Sea are Don (basin area 422 000 km^2, runoff 28 km^3/a, sediment load $7.8 \cdot 10^6$ t/a) and Kuban (basin area 63 500 km^2, runoff 12.8 km^3/a, sediment load $8.4 \cdot 10^6$ t/a).

In the Northeastern part of the Black Sea, located in Russia, the total number of river runoff is 6.5 km^3/a (J a o s h v i l i, 2000). The main rivers are Mzimta, Shakhe, Sochi.

The source provinces of the Georgian rivers (Rioni, Bzibi, Kodori, Inguri) in the Eastern part of the Black Sea are Caucasus snow and glaciers. The total amount of water input here is 45.5 km^3/a. The total volume of river sediments represents 11 100 m^3/a, of which 4 400 m^3/a stay in the coastal zone and 6 700 m^3/a discharge into deeper parts of the sea (J a o s h v i l i, 2000).

The total runoff discharge into the Southern part of the Black Sea is 40 km^3/a (A l g a n et al., 2000). Watershed area in

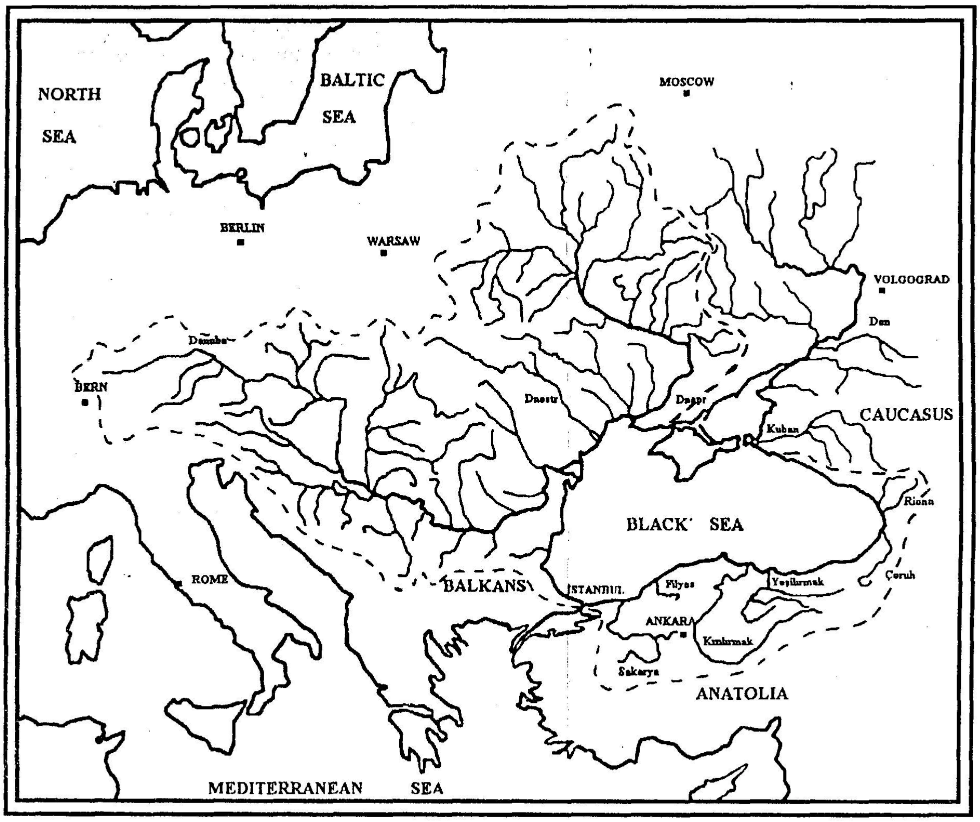

Fig. 1. Drainage areas of the Black Sea (from M u l l e r, S t o f f e r s, 1974)

Turkey is 260 000 km^2. The main Anatolian rivers are Kyzylyrmak (length 1 355 km), Sakarya (length 824 km), Yesshilyrmak (length 519 km) and Filyos (length 228 km) (table 1).

The Western part of the Black Sea covers a watershed area 4 590 km^2 in Romania (without Danube river) and 16 930 km^2 in Bulgaria. The total runoff discharge of the Romanian rivers is 0.12 km^3/a with sediment load less than 100 000 t/a. The main Bulgarian rivers running direct to the Black Sea are Kamchya (length 245 km), Veleka (length 147 km) and Rezovska (length 112 km). The total amount of the sediment load is 780 600 t/a (D i m i t r o v et al., 2000).

Source provinces in the Bulgarian Black Sea region

The large diversity of geological formations constituting the Bulgarian coast of the Black Sea explains the assorted composition of beach and shelf deposits. The main structural elements (e.g., deep faults) intersect the shelf and the coast and divide the region into four main geological provinces: Eastern Moesian Plate, Lower Kamchya Depression, Stara Planina and Sredna Gora zones.

The Southern source province covers an area limited by Turkey towards the south, the Northern Transbalkan deep faults towards the north, and the Strandja mountain range towards the west. It is located within the Sredna Gora zone which consists mainly of a Senonian volcano-sedimentary complex. This complex is composed of various lithologics, including andesite, trachyandesite, tuff, tuffite, agglomerate and various dyke rocks, and is

Table 1. Main rivers of the Black Sea

№	Rivers	Coast	Basin area, 1000 km^2	Water flow, km^3/a	Sediment Load	
					1000 m^3/a	1000 t/a
1	Danube	NW	817.0	198.00	31 680	53 867
2	Kyzylyrmak	S	78.6	5.74	13 500	23 000
3	Yesilyrmak	S	36.1	5.30	11 200	19 000
4	Sakarya	S	56.5	4.54	5 200	8 800
5	Chorokhi	E	20.0	8.43	4 920	8 440
6	Rioni	E	13.4	13.38	3 755	6 410
7	Filyos	S	13.2	2.85	2 500	4 200
8	Inguri	E	4.1	5.21	1 500	2 700
9	Dniester	NW	72.1	11.60	1 500	2 500
10	Dnieper	NW	505.8	49.20	1 250	2 100
11	Kodori	E	2.0	4.17	754	1 295
12	South Bug	NW	63.7	4.40	700	1 200
13	Bzibi	E	1.5	3.79	445	767
14	Kamchya	W	5.4	0.61	272	462
15	Gumitsa	E	0.6	1.05	153	264
16	Mzimta	NE	0.8	1.56	158	258
17	Supsa	E	1.1	1.58	143	246
18	Shakhe	NE	0.6	1.16	124	211
19	Khobi	E	1.3	1.59	121	207
20	Psou	E	0.4	0.61	91	158
21	Natanebi	E	0.7	0.77	85	147
22	Ingul	NW	9.7	0.60	75	126
23	Sharsukho	NE	0.3	0.22	63	113
24	Tuapse	NE	0.4	0.40	65	111
25	Sochi	NE	0.3	0.51	60	101
Total of the Black Sea basin			1 874.9	353.30	84 456	143 854

covered with Neogene and Quaternary sediments.

The Laramian intrusive masses are concentrated in a strip, occupying the coast and the adjacent land at the south of Burgas where Rosen's and Vurlybriag's intrusions are located.

The length of the eroded coast, formed by volcano-sedimentary complex (fig. 2) between Burgas and river Rezovska is 99.0 km. Erosion's average yearly rate is 0.01 m/a (P e y c h e v, 1998).

The Lower and Middle Sarmatian sediments of Crimean – Caucasian type are represented by clay, marl, sandstone and limestone relatively resistant to erosion, which compose the jutting capes between the towns of Nessebar and Pomorie.

Erosion's highest rates on the Bulgarian coast (1.05 m/a) are measured in Pliocene and Pleistocene aleurolities and clays in region Burgas – Pomorie. The length of the eroded coast in region is 9.8 km. Between Pomorie and Nessebar eroded coast is formed by Sarmatian limestone. Coast's length is 8.0 km and erosion's average rate is 0.09 m/a.

The coast between Nessebar and cape Emine is formed by the Emine bent with geological structure consisting of sandstones, argylites, sandish limestones. The length of eroded coast is 12.8 km. Erosion's average yearly rate is 0.08 m/a.

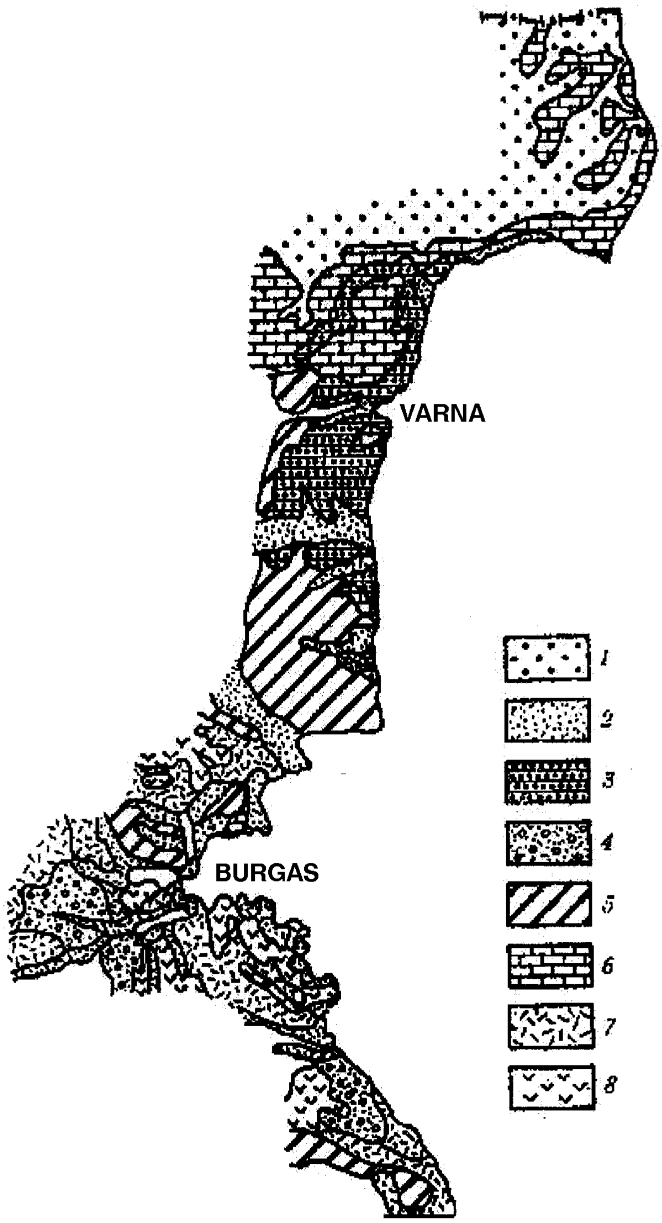

Fig. 2. Lithologic scheme of Bulgarian Black Sea coast (from, Popov, Mishev, 1974)

1. loess **2. Clay and sand**
3. Sandstone **4. Conglomerate**
5. Flysh **6. Limnestone**
7. Volcano-sedimentary rocks **8. Magmatic rocks**

In the process of wave reworking, beach sands in some sectors have been enriched in heavy minerals, more particularly in magnetite. The composition of the heavy-mineral fraction is determined by the lithological composition of the sources rocks.

The Central source province is located between the capes of Emine and Varna Bay eastward, the TransBalkan deep faults southward, and the Varna lowland northward (fig. 2). The folds of the eastern Balkans can be traced at the seaside. The Low-Kamchya river depression is a transitional tectonic zone between the Alpine system of the East Stara Planina mountain and the Moesian plate.

Upper Cretaceous to Paleocene sedimentary rocks – represented by an alternation of limestone and quartz sandstone with clayey-calcareous sandstone and clayey limestone – constitute the lithological structure of the province. The Emine flysch, presented mainly by clayey-limy sandstone and clayey-sandy limestone is typical of the region. Sediments of Paleocene (Eocene) and Neogene (Chokrakian, Karaganian, and Konkian) are constituted by sandstone, sandy-clayey limestone and limestone facies in the Varna depression.

The large river valleys (Kamchya, Shkorpilovska, Dvoinitsa) are refilled with Quaternary alluvium of significant thickness.

The beaches of the central source province are formed near the mouths of the big rivers.

The length of the eroded coast between cape Emine and cape Galata is 29.5 km. Erosion's average yearly is 0.12 m/a.

The Northern source province covers the northern part of the Moesian plate. It is delimited in the south by the latitude crossing the Varna Bay and in the north by the Romanian frontier (fig. 2). The lithological structure of the province is rather uniform. The Neogene carbonate complex, Pleistocene loess and indurate loess in the north are the predominant rocks. The Sarmatian Complex is represented mainly by an alternation of limestone, silty clays and clayey sandstone.

The coast between Varna and Shabla is formed by Neogene carbonate complex. The length of the eroded coast in Varna Bay is 3.5 km and erosion's rate is 0.20 m/a. The length of the eroded coast between Varna and Kavarna is 24.9 km and erosion's rate is 0.15 m/a. The length of the eroded coast between Kavarna and Shabla is 36.8 km and erosion's rate is 0.05 m/a. The region cape Shabla – cape Sivriburun is formed by clear brown loess, locally passing into siet clays. The length of the eroded coast is 12.5 km. Erosion's rate is 0.30 m/a, but separate cases cliff's destruction is 1-2 m/a (P e y c h e v, 1998).

From Bulgarian coast about 575 300 t/a of eroded material is transported into the sea.

The intensity of the transported sediment material, depend on geological and climatic factors. The coastal zone ensure exchange of terrigenous material on the land to the deep – water sea zones as the sediments, coming from lithosphere tansform by means of mechanical desintegration and hydrodynamic differentiation. Division into detached morphodynamic systems of the Bulgarian Black Sea coast is done (P e y c h e v, A n d r e e v a, 1998). On the table 2 are represented the positive items of the balance of the sediment material for different morphodynamic systems.

Until now the aeolian drift from Bulgarian coastal accumulative forms is not investigate. The aeolian drift is calculated at 15 100 t/a by analogy of results, received for coasts of Ukraine (V y k h o v a n e t s, 1999), with estimate of the length of the Bulgarian beaches.

The total amount of sediment originating from coastal erosion, river transport and aeolian drift is 1 371 000 t/a (table 2), of which 215 000 t/a are beach-forming and 1 156 000 t/a are marine sediments.

The alluvium coming from the river are suspended load and bed load. Sediments are divided into coastal and marine ones: beach-forming sediments are coarser than 0.25 mm on the deeper pebble shores, and coarser than 0.1 mm on sandy shores.

Conclusion

To sum up the total river solid discharge in the Black Sea represents $84.5 \cdot 10^6$ m^3/a. According to J a o s h v i l i (2000) about $51.6 \cdot 10^6$ m^3/a of sediments are marine, which take part in the present process of sedimentation.

The total volume of sediments, originating from the Black Sea coastal erosion is about $27 \cdot 10^6$ m^3/a (S h u i s k y, 1986). The aeolian

Table 2. Sediment material from Bulgarian Black Sea coast

№	Morphodynamic system	Length of coast-line, km	Coefficient of indentity	Mean submarine slope	Erosion mass of active cliffs, ·1000 t/a	Solid discharge of rivers ·1000 t/a	Aeolian drift ·1000 t/a	Total
1	c. Sivriburun – c. Shabla	24	1.09	0.010	61.0	0	1.6	62.6
2	c. Shabla – c. Kaliakra	26	1.13	0.020	56.6	0	0	56.6
3	c. Kaliakra – c. St. George	50	1.70	0.019	126.5	43.4	1.6	171.5
4	c. St. George – c. Galata	15	1.67	0.013	24.2	0	0.5	24.7
5	c. Galata – c. Emine	61	1.13	0.013	103.6	524.3	3.7	631.6
6	c. Emine – Nessebar	24	1.62	0.014	28.5	37.4	0.9	66.8
7	Nessebar – Pomorie	22	1.57	0.010	12.4	13.4	1.5	27.3
8	Pomorie – Sozopol	60	3.98	0.009	139.4	4.7	2.8	146.9
9	Sozopol – c. Maslen nos	29	2.13	0.024	6.9	23.6	0.8	31.3
10	c. Maslen nos – c. Emberler	21	2.11	0.017	4.5	34.0	0.7	39.2
11	c. Emberler – r. Rezovska	46	1.60	0.027	11.7	99.8	1.0	112.5
Total		378	1.90	0.016	575.3	780.6	15.1	1371.0

drift from coastal accumulative form is estimated about $4 \cdot 10^6$ m^3/a (S h u i s k y, 1986).

The total amount of sediment material, which transported on the land to the Black Sea is about 0.12 km^3/a.

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Подхранващи провинции на Черно море

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(Резюме)

Подхранващите провинции на Черно море обхващат площ от 1 875 000 km^2 и имат асиметрична форма. Определени са водосборните площи, водните количества и твърдите оттоци на черноморските реки, като са приведени данни за 25 реки, твърдият отток на които надхвърля 100 000 t/a. Оценено е подхранването със седиментен материал в резултат на бреговата абразия на клифовете и от еоловия транспорт. Общото количество на твърдото вещество, транспортирано от сушата към Черно море, е около 0.12 km^3/a.

Българското Черноморско крайбрежие е разделено на 11 морфодинамични системи, като за всяка от тях са представени позитивните компоненти в баланса на седиментния материал.