Distribution of heavy minerals in surficial bottom sediments of the Nida–Klaipėda mapping area in the Baltic Sea

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This work is based on the data obtained by the X-ray mineralogical semi-quantitative analysis of a heavy fraction extracted from surficial bottom sediments of the mapping area. The amounts of heavy minerals and the dependence of their distribution on the sea bottom relief, lithological type of sediments and possible sources of matter supply are described.

Keywords: XRD analysis, heavy minerals, almandine, tremolite, magnetite, ilmenite, zircon, rutile, epidote, Baltic Sea

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INTRODUCTION

The south-eastern part of the Baltic Sea is one of the most interesting areas of this shallow closed basin, because here the processes of recent sedimentation are mainly influenced by coast abrasion. Besides, there are also some other sources of clastic matter supply to this part of the Baltic Sea (Блажчишин, Усонис, 1970).

The south-eastern part of the Baltic Sea includes the shallow zone near the coasts of Vistula Spit, Sambian Peninsula and Kuršių Nerija (Curonian Spit) and the deep zone – the north-eastern part of Gdansk Depression. The Nida–Klaipėda area of mapping studied by us belongs to the part of Kuršiai–Sambian Plateau and is located in the most south-eastern part of the Baltic Sea at the coasts of Lithuania (Figs. 1 and 2). It is a shallow zone which geomorphologically consists of Kuršiai and Sambian elevations separated by the Kuršiai Depression. The Kuršiai Elevation is the main sea district of the Nida–Klaipėda mapping area.

Orographically, a great part of drainage area of the south-eastern part of the Baltic Sea is represented by a slightly hillocky plain formed by glacial and aqueoglacial accumulation processes. Rivers of this region belong to the basins of two large arteries: the Vistula and the Nemunas. According to the available data (Блажчишин, Усонис, 1970), the surface run-off of solid material for all rivers of the drainage area makes 4 mill. t/year, the most part of which remains in the Vistula and Kuršių Marios lagoons, where these rivers fall, respectively, and only about 1 mill. t/year of this material gets into the sea.

In the near-shore zone the distribution of sediments is controlled by the dynamics of the coastal processes: in the accumulation subzone finer sediments accumulate, meanwhile in the abrasional subzone only coarser sediments are redeposited almost *in situ*, when finer ones are removed and transported farther by waves and currents flowing along the sea coasts.

The abrasional coasts of the Sambian Peninsula, formed of Pleistocene moraines and intermorainic

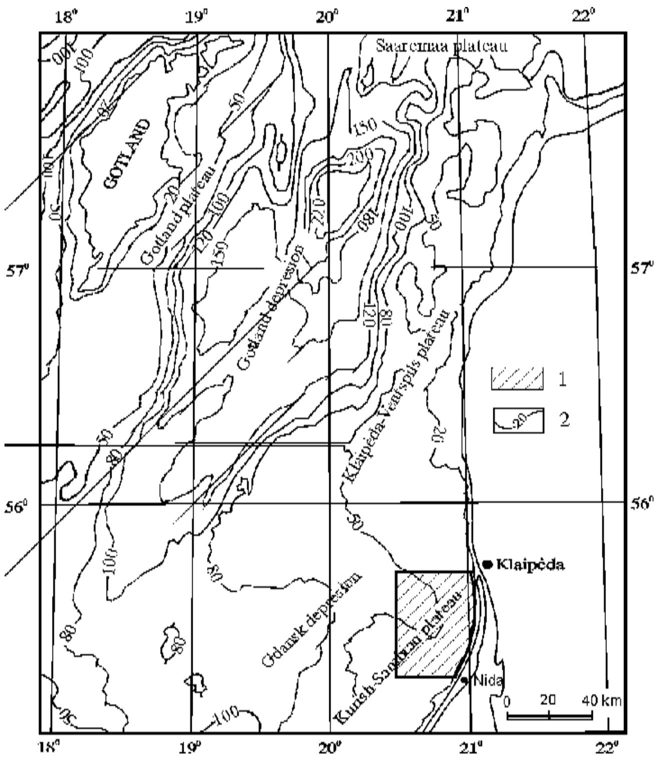

Fig. 1. Situation map: *1* – Nida–Klaipėda mapping area, *2* – isobathic line, m
1 pav. Situacinis žemėlapis: *1* – Nidos–Klaipėdos nuotraukos plotas, *2* – izobata m

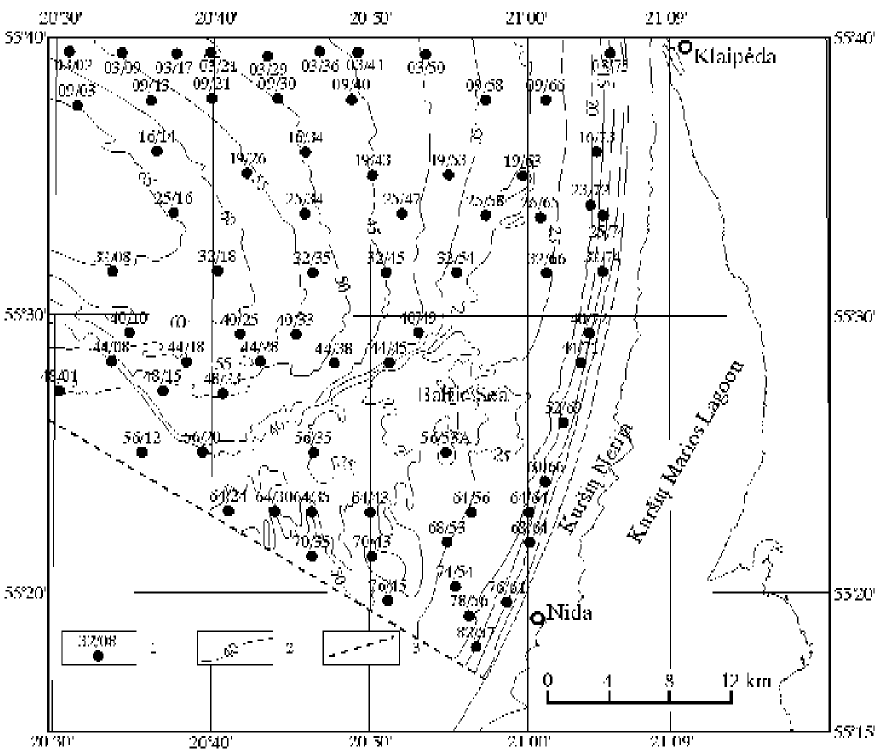

Fig. 2. Location of stations where deposits were sampled for mineralogical analysis: *1* – station, *2* – isobathic line, m, *3* – frontier between Lithuania and Russia
2 pav. Faktinės medžiagos žemėlapis: *1* – stotis, *2* – izobata m, *3* – Lietuvos–Rusijos siena

deposits, as well as of Paleogene sandy-aleuritic rocks in some places are another source of material. Besides, the foot of the Kuršių Nerija Spit is washed out during storms. Supply of solid material by coast abrasion processes is about 0.5 mill. t/year (Блажчишин, Усонис, 1970).

A great amount of clastic material is thrown out to the sea from an amber quarry in Sambian Peninsula (settlement Palvininkai (Yantarnyj), where the Paleogene amber-bearing deposits are washed out, and barren rock is removed to the sea. So, the contribution of the quarry is about 1.5 mill. t/year (Блажчишин, Усонис, 1970).

Transportation of sediments along the coasts of the South Baltic Region is possible by the current flowing from the North Sea.

Besides, the transportation, differentiation and sedimentation of suspended matter in the near-shore zone occur under conditions of constant swell. During heavy storms, rolling of bottom sediments and their displacement occur to a depth of 20–30 m (Dolotov, 1982).

According to literary sources (Блажчишин, 1998), two regions of recent sedimentation exist in the Baltic Sea: a narrow shallow near-shore zone and a deep offshore zone. They are separated by a wide belt of no sedimentation and of prevailing erosion of sea bottom. This belt without recent sedimentation preliminarily is subdivided into some zones on the grounds or median values which fix probably the coastal lines of separate phases of the Baltic Sea development (Repečka, 2000).

On the grounds of a characteristic mineral distribution in bottom sediments of the Baltic Sea and according to the established complexes of matter supply, there were established three mineralogical macro provinces: pre-Cambrian, Paleozoic and Meso-Kainozoic (Блажчишин, 1976).

The Meso-Kainozoic mineralogical macro province, which is located in the south-eastern and southern parts of the Baltic Sea, consists of the Sambian-Vistula and South Baltic mineralogical provinces. The Nida–Klaipėda area of the Baltic Sea belongs to the northern part of the Sambian-Vistula province and is named the

Nemunas subprovince. According to the literary data (Блажчишин, 1976), accumulation of increased concentrations of amphiboles is characteristic of the Nemunas subprovince. The mineral complex of the Nemunas subprovince represents mainly the relict deposits of the old Nemunas valley and less the recent river drift, the main mass of which is deposited in the Kuršių Marios Lagoon.

MATERIAL AND METHODS

A lot of samples of bottom sediments from the Nida–Klaipėda area of the Baltic Sea have been collected during the marine expedition in 1998. Seventy two samples of surficial bottom sediments (interval 0–1 cm from the surface of the sea bottom) from the stations distributed more or less at the same distance from one another in the area were selected for analysis (Fig. 2).

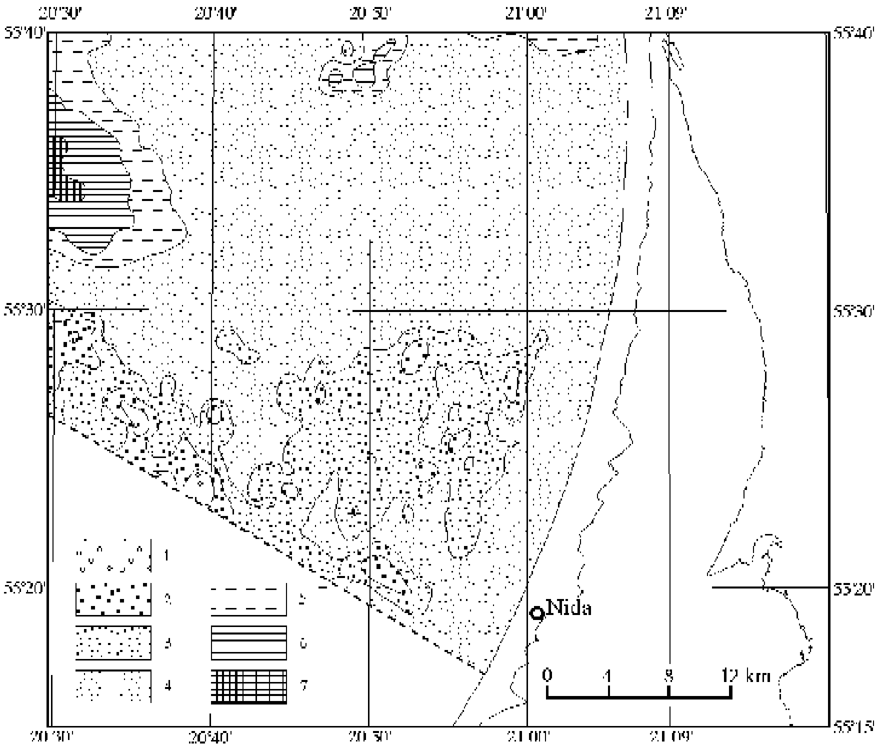

Fig. 3. Lithological scheme of bottom sediments: *1* – gravel, *2* – coarse sand, *3* – medium sand, 4 – fine sand, *5* – coarse aleurite, *6* – fine aleuritic mud, *7* – aleuritic-pellitic mud

3 pav. Litologinės dugno nuosėdų sudėties schema: *1* – žvirgždas, *2* – rupus smėlis, *3* – vidutinis smėlis, *4* – smulkus smėlis, *5* – rupus aleuritas, *6* – smulkus aleuritinis dumblas, *7* – aleuritinis-pelitinis dumblas

The first work was the grain size analysis, which was carried out by elutriation and dry sieving methods, using a set of 19 sieves and a Fritsch shaker. Then the median (*Md*) and sorting coefficients (S_o) were calculated. The results of this kind of analysis proved that the most part of samples belonged to the group of fine sand (Fig. 3, Table).

Table. **Concentration (per cent) of heavy minerals in the fine sand fraction (0.25–0.1 mm) of bottom sediments**
Lentelė. **Dugno nuosėdų smulkaus smėlio frakcijos (0,25–0,1 mm) sunkiųjų mineralų koncentracija %**

No.	Station	Depth, m	Sed. type	Median, mm	S_o, (Trask)	Heavy minerals, %						
						Tr	Alm	Rt	Ep	Ilm	Mag	Zrn
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	03/02	56.6	CA	0.092	1.21	36.9	6.6	13.7	23.1	9.9	3.0	3.0
2	03/09	53.8	FS	0.105	1.18	24.9	11.1	25.3	20.0	3.0	8.2	3.0
3	03/17	50.9	FS	0.113	1.17	30.1	8.5	19.1	23.2	9.4	3.0	<3.0
4	03/21	49.1	FS	0.124	1.19	16.5	15.4	15.3	25.1	9.2	8.0	<3.0
5	03/29	47.8	FS	0.129	1.22	15.1	19.7	16.5	23.6	10.0	6.9	3.0
6	03/36	45.3	FS	0.148	1.32	16.8	20.5	12.6	24.7	6.5	8.4	<3.0
7	03/41	43.5	FS	0.119	2.48	45.5	10.2	9.8	17.7	7.2	3.0	<3.0
8	03/50	38.9	FS	0.124	1.18	27.8	13.3	9.2	25.1	8.1	6.1	<3.0
9	03/75	6.7	FS	0.121	1.14	21.9	10.2	19.2	23.9	7.2	7.2	3.0
10	09/03	63.1	CA	0.080	1.21	27.2	6.9	10.6	33.2	5.2	5.2	4.8
11	09/13	56.6	FS	0.107	1.15	22.2	16.6	15.8	35.2	3.0	3.0	3.0
12	09/21	52.0	FS	0.124	1.26	24.4	11.2	14.8	23.9	7.2	8.0	<3.0
13	09/30	49.3	FS	0.123	1.20	16.5	17.6	17.0	24.4	7.7	6.5	3.0
14	09/40	49.3	FS	0.197	1.75	16.5	29.8	8.7	20.5	8.0	5.7	3.0
15	09/58	33.3	FS	0.114	1.20	16.2	17.9	10.9	32.7	6.3	8.0	<3.0
16	09/66	27.5	FS	0.111	1.33	19.4	16.2	8.1	45.9	3.0	3.0	<3.0
17	16/14	61.4	FS	0.104	1.17	12.3	23.9	15.9	37.7	3.0	3.0	3.0

Table (continyed)
Lentelė (tęsinys)

1	2	3	4	5	6	7	8	9	10	11	12	13
18	16/34	49.0	FS	0.131	1.23	24.1	11.7	17.9	24.1	12.2	3.0	3.0
19	16/73	15.9	FS	0.113	1.20	33.6	9.4	12.6	23.8	10.9	3.0	3.0
20	19/26	55.0	FS	0.124	1.21	31.7	12.0	16.3	20.9	9.3	3.0	<3.0
21	19/43	44.0	FS	0.125	1.21	21.8	14.3	15.0	26.1	9.1	3.0	<3.0
22	19/53	36.6	FS	0.128	1.22	15.1	10.3	5.8	36.6	5.8	3.0	<3.0
23	19/63	35.1	FS	0.108	1.17	32.0	16.7	12.3	18.6	10.7	3.0	<3.0
24	23/72	17.8	FS	0.114	1.29	33.0	16.0	11.4	20.5	9.5	3.0	3.0
25	25/16	64.1	FS	0.103	1.18	18.4	33.3	17.9	10.4	10.1	3.0	3.0
26	25/34	50.9	FS	0.140	1.27	22.5	25.6	10.8	30.9	3.0	3.0	<3.0
27	25/47	40.6	FS	0.122	1.20	10.0	12.8	17.7	32.7	3.0	11.6	3.0
28	25/58	30.8	FS	0.138	1.24	41.9	11.9	10.8	18.6	6.9	3.0	<3.0
29	25/65	27.6	FS	0.123	1.34	42.3	15.5	12.3	14.2	6.0	3.0	3.0
30	25/74	9.6	FS	0.132	1.17	27.0	18.3	6.8	19.8	3.0	11.5	6.7
31	32/08	64.4	FS	0.104	1.22	20.5	17.0	14.8	21.3	8.1	8.0	3.0
32	32/18	63.6	FS	0.099	1.27	27.0	13.8	17.4	18.4	13.6	3.0	<3.0
33	32/35	52.6	FS	0.149	1.39	32.1	8.4	14.0	26.9	8.8	3.0	3.0
34	32/45	43.4	FS	0.140	1.29	27.5	8.3	15.1	30.6	8.8	3.0	3.0
35	32/54	32.2	FS	0.146	1.25	34.4	12.5	13.5	22.0	8.0	3.0	<3.0
36	32/66	26.7	FS	0.202	1.37	16.2	38.6	8.6	17.0	3.8	5.1	3.0
37	32/74	8.0	FS	0.131	1.18	27.1	8.5	23.6	20.4	10.7	3.0	3.0
38	40/10	56.6	FS	0.156	1.20	37.8	10.6	14.6	16.7	10.3	3.0	3.0
39	40/25	57.6	FS	0.142	1.18	37.8	6.9	19.7	17.9	8.0	3.0	<3.0
40	40/33	53.9	FS	0.129	1.16	18.5	14.0	11.6	27.4	10.7	7.5	3.0
41	40/49	36.7	FS	0.232	1.35	36.4	19.3	9.3	19.3	5.9	3.0	3.0
42	40/72	9.2	FS	0.136	1.18	30.3	24.2	11.9	23.8	3.0	3.0	3.0
43	44/08	42.1	MS	0.275	1.28	24.3	16.2	9.0	29.8	5.4	5.0	3.0
44	44/18	54.2	FS	0.152	1.21	39.0	8.5	15.4	19.4	7.8	3.0	<3.0
45	44/28	61.8	MS	0.302	1.73	24.6	21.0	10.2	18.8	7.1	8.3	<3.0
46	44/38	47.2	FS	0.138	1.14	22.3	13.3	13.2	21.6	12.4	6.9	3.0
47	44/45	24.0	MS	0.332	1.35	25.1	21.9	14.4	21.8	7.1	3.0	3.0
48	44/71	8.9	FS	0.137	1.18	35.6	17.5	8.9	28.0	3.0	3.0	3.0
49	48/01	39.3	CS	0.517	1.41	20.5	29.8	8.7	15.3	10.3	5.3	3.0
50	48/15	49.9	FS	0.157	1.17	21.4	10.5	13.2	26.2	10.3	8.2	<3.0
51	48/23	52.1	FS	0.139	1.15	21.4	12.0	9.2	30.7	8.2	8.1	3.0
52	52/69	9.9	FS	0.120	1.17	32.0	17.8	11.7	17.9	5.6	3.9	3.0
53	56/12	36.8	CS	0.803	2.07	27.1	22.5	14.0	15.1	11.5	3.0	3.0
54	56/20	36.0	FS	0.249	1.24	29.3	25.6	10.3	17.7	6.8	3.0	<3.0
55	56/35	33.0	MS	0.335	1.31	32.7	18.0	12.1	19.6	7.9	3.0	<3.0
56	56/53	34.2	FS	0.117	1.24	43.7	10.3	9.3	16.2	10.5	3.0	3.0
57	60/66	12.1	FS	0.118	1.16	37.0	6.3	17.9	22.3	6.4	3.0	3.0
58	64/24	29.8	CS	0.636	1.54	10.3	38.0	10.2	20.5	5.9	4.7	3.0
59	64/30	31.0	FS	0.184	1.21	40.2	16.5	7.1	26.3	3.0	3.0	<3.0
60	64/35	32.0	FS	0.183	1.25	20.3	13.2	10.2	34.4	12.3	3.0	<3.0
61	64/43	31.6	MS	0.390	1.35	18.6	23.0	9.0	23.4	8.7	7.3	<3.0
62	64/56	24.2	MS	0.361	1.27	20.5	29.7	11.7	21.4	6.9	3.0	3.0
63	64/64	14.7	FS	0.109	1.21	27.2	6.6	18.8	22.8	14.8	3.0	3.0
64	68/53	32.9	MS	0.354	1.11	47.9	9.6	13.4	10.1	9.1	3.0	3.0
65	68/64	8.3	FS	0.149	1.17	43.5	6.9	13.5	20.5	5.9	3.0	3.0
66	70/35	26.8	MS	0.353	1.45	14.4	37.7	7.9	18.3	6.5	4.9	<3.0
67	70/43	26.6	CS	0.597	1.47	25.5	22.7	17.4	19.1	5.5	3.0	<3.0
68	74/54	25.6	FS	0.129	1.26	40.7	8.4	11.1	20.2	9.7	3.0	<3.0
69	76/45	28.2	FS	0.188	1.25	16.8	22.2	8.1	27.9	8.2	6.6	<3.0
70	76/61	6.5	FS	0.149	1.18	25.2	16.3	12.6	35.9	3.0	3.0	3.0
71	78/56	22.7	FS	0.114	1.24	27.4	6.8	16.3	29.5	10.4	3.0	<3.0
72	82/57	12.8	FS	0.115	1.15	35.6	9.6	12.9	24.5	8.0	3.0	3.0

Note: CS – coarse sand, MS – medium sand, FS – fine sand, CA – coarse aleurite. Tr – tremolite, Alm – almandine, Rt – rutile, Ep – epidote, Ilm – ilmenite, Mag – magnetite, Zrn – zircon.
Pastaba: CS – rupus smėlis, MS – vidutinis smėlis, FS – smulkus smėlis, CA – rupus aleuritas, Tr – tremolitas, Alm – almandinas, Rt – rutilas, Ep – epidotas, Ilm – ilmenitas, Mag – magnetitas, Zrn – cirkonas.

The fraction of fine sand (0.25–0.1 mm) as the most representative in the area under investigation was chosen for mineralogical analysis. With the help of Tule heavy liquid (specific weight 2.9) this fraction of sediments was subdivided into two subfractions: light and heavy. The light subfraction was not analysed by us, because, as far as was known from previous works, it consisted mainly of quartz (85–90%) and feldspar (about 10–15%). The mineralogical composition of the heavy subfraction was most interesting and most informative, so it was studied by XRD semi-quantitative mineralogical method worked out by the authors (Šimkevičius, Apanavičiūtė, 1999), using literary sources (Зевин, Завьялова, 1974 and oth.).

The mineralogical XRD analysis of the heavy subfraction shows that the following 7 heavy minerals may be defined in the analysed samples: zircon, ilmenite, rutile, magnetite, almandine, tremolite and epidote, *i.e.*, all minerals the concentration of which makes approximately more than 3% of sample content. In the case when some of these 7 minerals were "invisible" in a diffractogram, it was accepted that their concentration was <3%.

Most of the results obtained by mineralogical XRD analysis correspond with the data found in literary sources (Stauskaitė, 1962; Dolotov, 1982 and oth.).

DISCUSSION

A simple and monotonous composition of heavy subfraction depends on the following limited sources of terrigenous material transported to the comparatively small area of investigation:

1) abrasional coast of Sambian Peninsula and submarine slope of coast (glacial and aqueoglacial Quaternary deposits and terrigenous glauconitic Paleogene rocks);

2) glacial and intermorainic Pleistocene deposits occurring on the bottom of the Baltic Sea in the areas of sea bottom elevations (Kuršiai, Sambian, etc.).

Diverse concentrations of each individual mineral described below depend on the mineralogical composition of source rocks, bottom relief, hydrodynamics, as well as on their own properties (form, specific weight, etc.).

According to literary sources, placers of titaniferous minerals (zircon, ilmenite and rutile) most often rest against the edges of ancient platforms. On the one hand, it is explained by the fact that in ancient platforms metamorphic, magmatic and sedimentary rocks containing these minerals are found. On the other hand, ancient platforms, particularly shields, are elevated places where a crust of weathering has been formed. They were washed out permanently, and their minerals were transported to younger formations. Repeated redepositions of minerals derived from older rocks in younger ones resulted in an increase of the concentration of heavy minerals in the latter. All these three titaniferous minerals are highly resistant to mechanical influence, and at it is owing to this property that they could be transported by water currents at a distance of hundreds of kilometers from denudation or abrasion areas. Thus, in our case, in the course of geological evolution most part of zircon, rutile and ilmenite could be transported to the Nida–Klaipėda area from the Baltic Shield by glaciers in the form of tills which later were washed out and the minerals distributed by waves and currents.

It is established by geologists that the main rocks containing titaniferous minerals are as follows: gabbro, gabbro-norite, gabbro-anorthosite for ilmenite, amphibolites and gneisses for rutile, granite and sienite for zircon.

Distribution of zircon

Zircon is one of the main minerals found in beaches and in near-shore zones. However, almost everywhere in the study area, in the so-called Nemunas subzone of amphiboles the concentrations of zircon are very low – about 3%. In the area of the Baltic Sea under investigation, slightly increased amounts of zircon are distributed in two almost parallel lines of plots oriented in the N–S direction (Fig. 4, Table). The eastern, nearshore line is related with the active processes of hydrodynamic differentiation of material washed out from the coast, as well as of the terrigenous material transported north-eastwards from the Sambian Peninsula by the nearshore current. The highest concentration of zircon (up to 6.7%) is found in fine sand of this nearshore zone.

The western line of increased zircon concentration (up to 4.8%) is related with coarse aleurite in the western part of the study area. There are two versions explaining such a distribution of zircon. One of them, according to Ž. Gelumbauskaitė and co-authors (Гелумбаускайте и др., 1991), is that 9–10 thousand years ago after the maximum transgression of the Yoldia Sea there had been a shallow nearshore zone of this sea, where minerals with a heavy hydraulic weight accumulated. Though at present the depth of the sea reaches here 50–60 m, the accumulation processes are absent, and the surficial bottom sediments found here are the ancient nearshore sediments of the Yoldia Sea.

Another version is that at present the current washes out fine lighter matter of bottom sediments, while heavy minerals, including zircon, remain "*in*

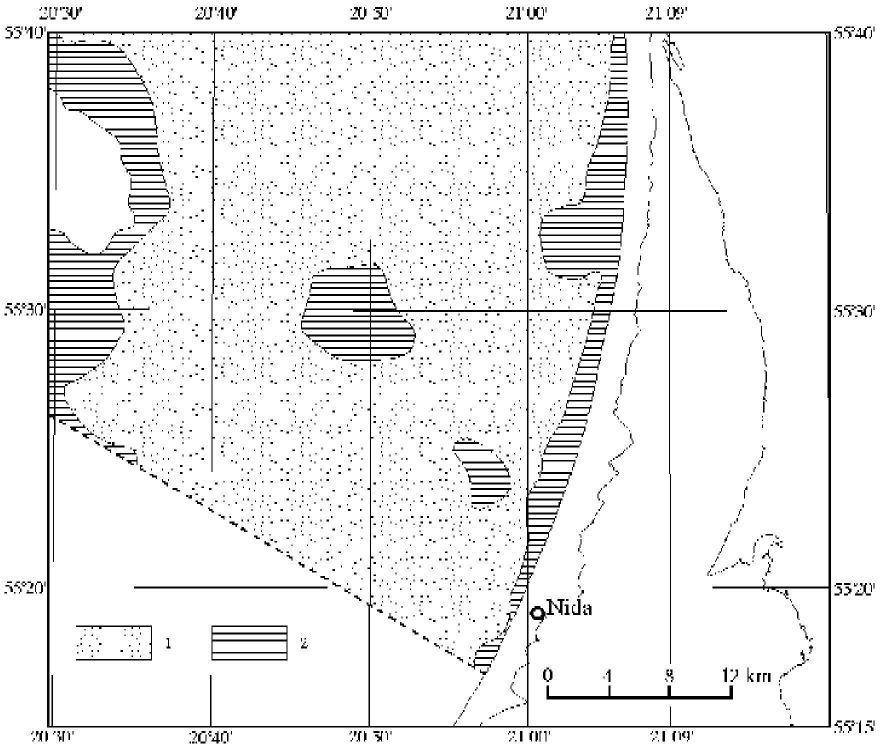

Fig. 4. Map of areal distribution of zircon concentration (%): *1* – 0–3, *2* – >3
4 pav. Cirkono koncentracijos (%) pasiskirstymo žemėlapis: *1* – 0–3, *2* – >3

situ”. Besides, in this place the lithological composition of bottom sediments changes: fine sand is replaced by coarse aleurite and fine aleuritic mud.

Analysis of zircon concentrations compared with the sorting of bottom sediments (Table) shows a connection between them: concentrations of zircon are higher in better sorted sediments.

From a geomorphological standpoint, increased zircon amounts concentrate in abrasional-accumulative and alluvial-accumulative zones. The facts described above confirm it: largest amounts of zircon get into the sea during abrasion of the coasts of Sambian Peninsula and Kuršių Nerija Spit, as well as of the submarine slope of the Kuršiai-Sambian Plateau. Probably they are transported a little by the southern current, but remain in the near-shore zone.

Distribution of ilmenite

Ilmenite, like zircon, is a one of main titaniferous minerals of the near-shore zone. Increased concentrations of this mineral (up to 10–15%) are distributed along the coast of Kuršių Nerija Spit of the Nida–Klaipėda area and mostly in the southern half of the aquatory studied, at a distance of 10–20 miles from the coast, in the form of separate small plots (Fig. 5). It is a result of active hydrodynamic processes when during strong storms the near-shore zone and the most elevated areas of the Kuršiai-Sambian Plateau are washed out and the matter is transported by waves to the sea, where heavy minerals are distributed in an orderly fashion depending on their hydraulic weight. In this case, such a distribution of ilmenite may be related with its quite large hydraulic weight, owing to which the mineral precipitates near its source. Prevailing concentrations in the area are 6–10%.

From a geomorphological standpoint, the maximum amount of ilmenite is concentrated by a conti-

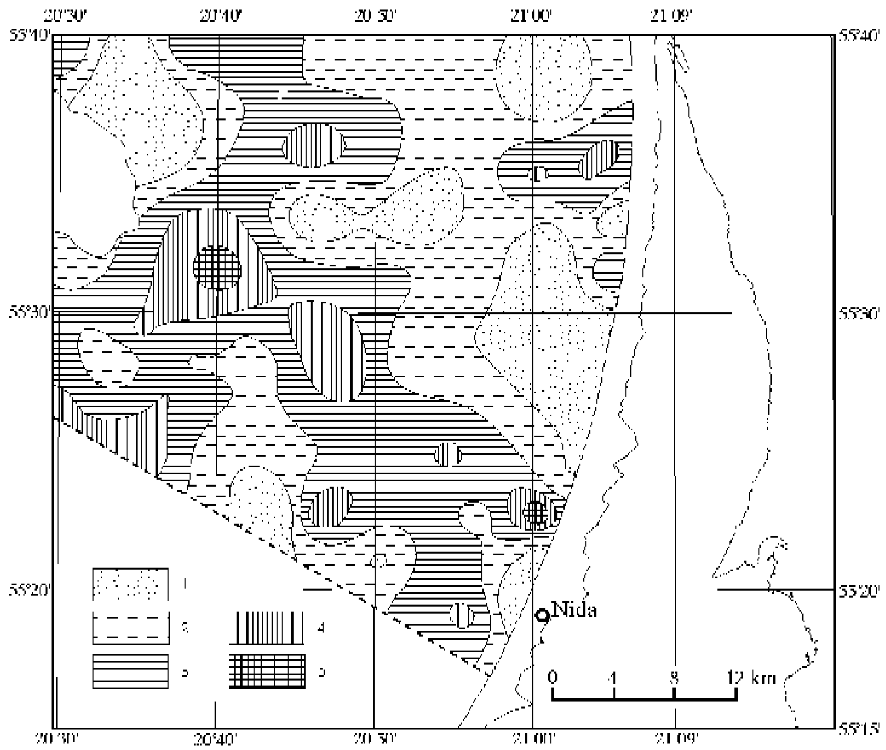

Fig. 5. Ilmenite concentration (%): *1* – 4–6; *2* – 6–8; *3* – 8–10; *4* – 10–12; *5* – >12
5 pav. Ilmenito koncentracija %: 1 – 4–6, *2* – 6–8, *3* – 8–10, *4* – 10–12, *5* – >12

nuous belt in the Pronemunas delta and its old valley, *i.e.*, in alluvial deposits. Here the concentration of ilmenite reaches even 13.6% (sample 32/18, Table).

Lithologically, largest amounts of ilmenite accumulate in coarse aleurite (average 9.6%) in sediments of alluvial-accumulative genesis and in coarse sand (average 8.0%) related with abrasional processes. The ilmenite distribution does not depend on the degree of sediment sorting.

Distribution of rutile

Rutile is the third titaniferous mineral widespread in nearshore zone and beach. This mineral is found everywhere in the study area in prevailing amounts 10–15%. An increase of its concentration to more than 15% (even up to 25%) is observed in the northwestern part of the area studied, in the field of coarse aleurite – fine sand distribution and in separate small plots along the coast of Kuršių Nerija Spit (Figs. 3 and 6). The least amounts are found in the southern part of the area, where the medium and coarse sand predominates (Table).

Geomorphologically, it is obvious that the largest amount of rutile is concentrated in the alluvial-accumulative plain. Its distribution resembles a little the zircon distribution (Figs. 4 and 6). Thus, the increase of rutile amount at a depth of 50–60 m of the sea may be related with coast fragments of the Yoldia Sea. The distribution of rutile in the nearshore zone of the Yoldia Sea, as well as of the present Baltic Sea may be explained by a high hydraulic weight of these minerals, which determined the short distance of their transportation.

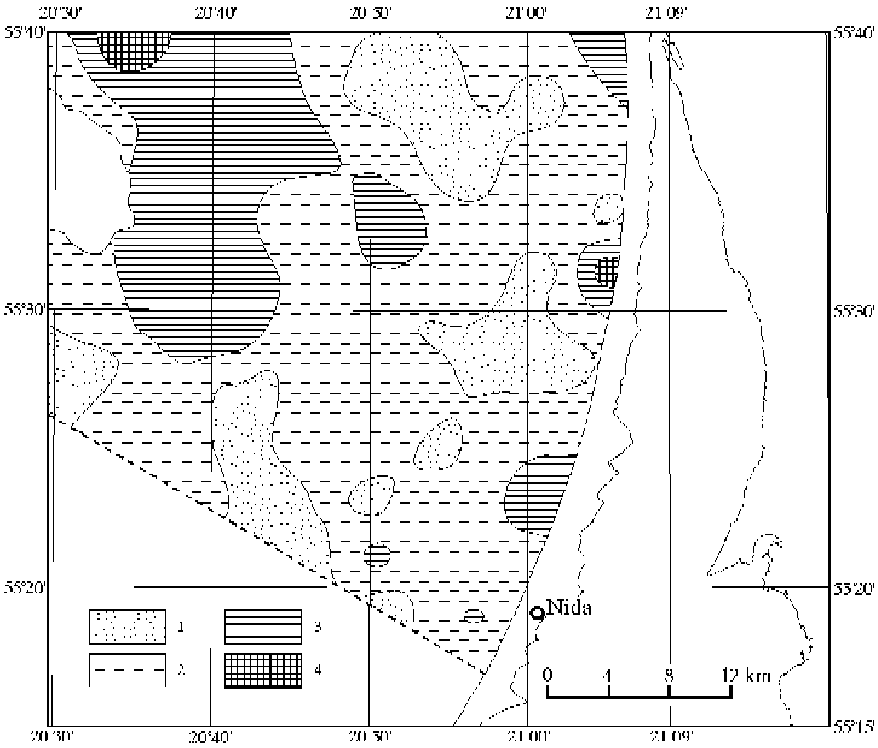

Fig. 6. Rutile concentration (%): *1* – 5–10; *2* – 10–15; *3* – 15–20; *4* – >20
6 pav. Rutilo koncentracija %: *1* – 5–10, *2* – 10–15, *3* – 15–20, *4* – >20

Distribution of magnetite

Magnetite is a mineral placers of which are formed near its source rocks. Its distribution is uneven –

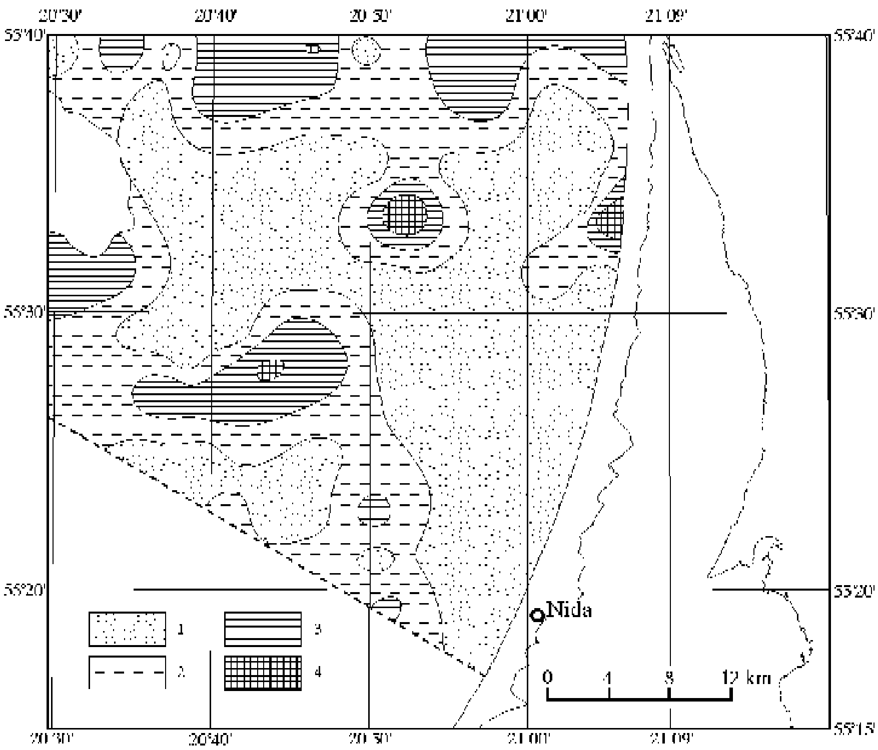

Fig. 7. Magnetite concentration (%): *1* – 2–4; *2* – 4–6; *3* – 6–8; *4* – >8
7 pav. Magnetito koncentracija %: *1* – 2–4, *2* – 4–6, *3* – 6–8, *4* – >8

small plots with its highest concentration (exceeding 8% and reaching up to 11.5%) are located in the northern and south-western parts of the study area (Fig. 7, Table). They are related a little with the present near-shore zone and mostly related with the delta and old valley of Pronemunas River which arose in the Littorina period, when the Kuršių Nerija Spit was already formed and the Pronemunas water fell into the Baltic Sea by the Klaipėda Strait. The present relief of the sea bottom reflects the location of the Pronemunas valley. The paleodelta of the Nemunas River, found in the southern part of area, is marked by a bent form of a 35 m isobathic line. Also, an increased (up to 11%) concentration of magnetite is found in the alluvial-accumulative plain at a depth exceeding 40 m. The increased amount of magnetite found in the northern part of the area may be related with the dumping zone, where the ground dug out during some works is transported by barges and buried in the sea.

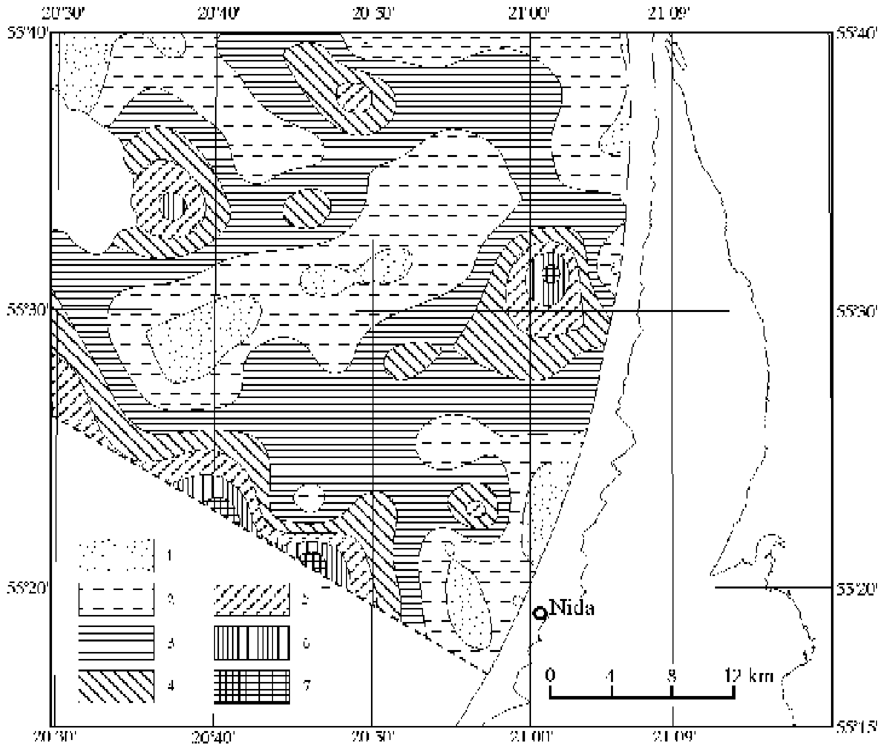

Fig. 8. Almandine concentration (%): *1* – 5–10; *2* – 10–15; *3* – 15–20; *4* – 20–25; *5* – 25–30; *6* – 30–35; *7* – >35

8 pav. Almandino koncentracija %: *1* – 5–10, *2* – 10–15, *3* – 15–20, *4* – 20–25, 5 – 25–30, *6* – 30–35, *7* – >35

The magnetite concentration depends on the lithologic types of sediments: its largest amount concentrates in fine and medium sand (4.6–4.7%) which form the Pronemunas paleodelta and old valley; the least amount is found in the relict Pleistocene deposits – coarse aleurite (Figs. 3 and 7).

The sorting of deposits has a strongest influence on the mode of magnetite distribution in them: in well and very well sorted sediments (S_0 = 1.2–1.3, according to Trask) of the Nida–Klaipėda area the highest concentrations of this mineral are found (Table).

Distribution of almandine

In the Nida–Klaipėda area almandine, the most widespread mineral of the group of garnets, is found everywhere. The concentration of this mineral ranges in a very wide interval (from 6 to 39%) in different parts of the study area. Owing to the medium hydraulic weight of almandine, in the near-shore zone where the depth reaches 20 m, concentrations of this mineral are not high (5–10%); only in some samples they increase up to 33% (sample 25/16) and 38% (sample 32/66) (Fig. 8, Table). Lithologically, highest concentrations of almandine (average 28.3%) are found in coarse sand and a little lower (average 22.1%) in medium sand (these two types of sediments are distributed in the south-western part of the area), meanwhile the least amount of almandine concentrates in coarse aleurite (9.1% in the north-western part) (Figs. 2 and 7). According to the degree of bottom sediment sorting, the largest amounts of almandine accumulate in worse sorted sediments (S_0 = 1.3–2.0) where the depth of the sea is more than 25 m. According to marine geologist A. I. Blazhchishin (Блажчишин, 1976), the largest amount of garnets is concentrated in relict Pleistocene sands found in the Upper Pleistocene morainic plains in the southern part of the Nida–Klaipėda area, where almandine is a product of washing out. In this part of the area the maximum amount of almandine is 35–40%. The increased amounts of almandine in the Pleistocene deposits may be related also with an influence of Paleogene deposits.

Distribution of tremolite

Tremolite, a mineral of the amphibole group, is widespread in bottom sediments of the Baltic Sea,

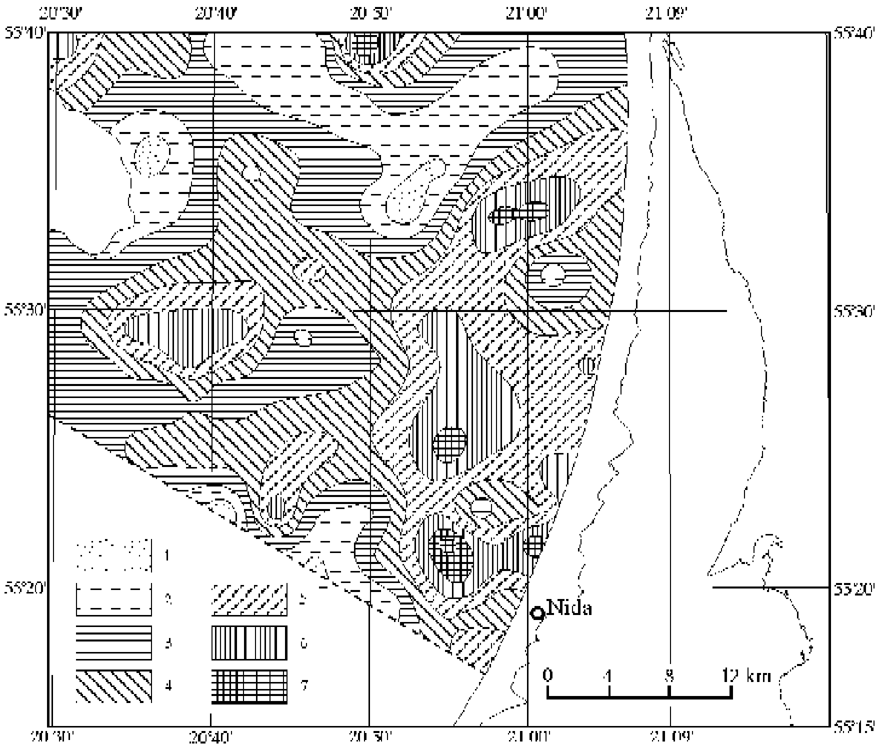

Fig. 9. Tremolite concentration (%): *1* – 10–15; *2* – 15–20; 3 – 20–25; *4* – 25–30; *5* – 30–35; *6* – 35–40; *7* – >40
9 pav. Tremolito koncentracija %: *1* – 10–15, *2* – 15–20, *3* – 20–25, *4* – 25–30, *5* – 30–35, *6* – 35–40, *7* – >40

particularly in the area called the Nemunas Subprovince and characterized by increased concentrations of amphiboles. Minerals of amphibole group are characterized by the lowermost hydraulic weight, thus they may be transported to large distances from their initial sources. However, according to the map of tremolite distribution (Fig. 9, Table), most of its amounts accumulate in the nearshore zone (mostly in the southeastern part: up to 44–48% in separate plots). Probably, part of this mineral got to this zone as a product of shore abrasion, another part was a product of abrasion of the Kuršiai-Sambian Plateau, and the third part was brought by the near-shore current from Sambian Peninsula. Increased amounts of tremolite (up to 38%) are also found in the Nemunas old valley. Conditionally, the least amounts of amphiboles are found in the alluvial-accumulative plain (up to 25%). The concentration of tremolite depends on the lithological composition of bottom sediments: the largest amounts (30.4–27.3%) are found in coarse aleurite and fine sand and the least ones (20.9%) in coarse sand. According to the values of sorting of bottom sediments (Table), the largest amounts of tremolite are concentrated in well- and medium-sorted sediments (S_0 = <1.2–1.4), while in those sorted worse (S_0 = = 1.5–2.0) the percentage of tremolite does not exceed 20%.

Distribution of epidote

Minerals of the epidote group are semi-resistant to weathering or they occupy the posi-

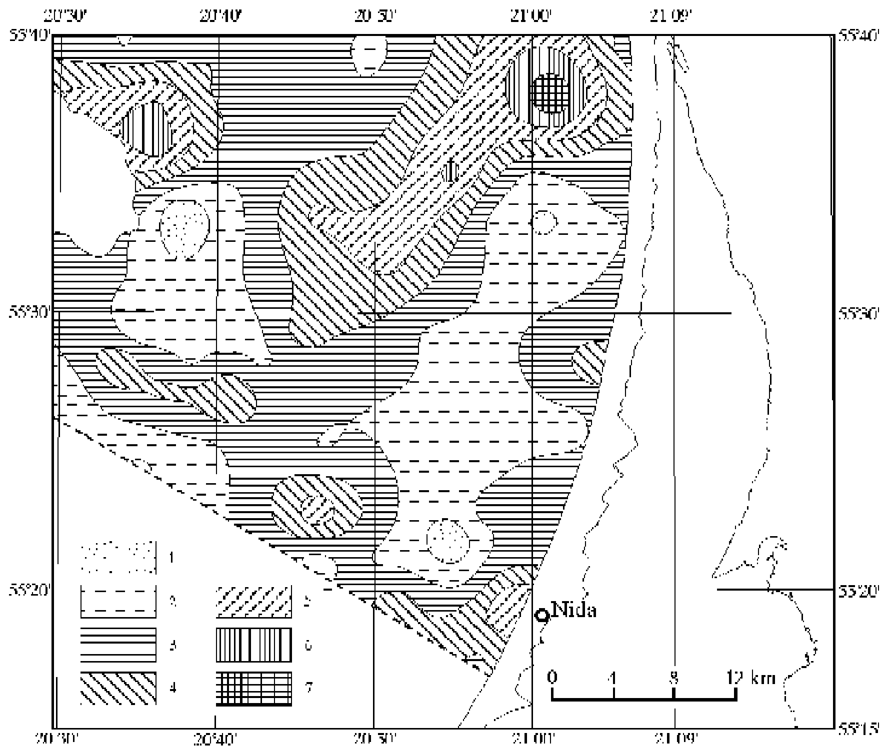

Fig. 10. Epidote concentration (%): *1* – 10–15; *2* – 15–20; *3* – 20–25; *4* – 25–30; *5* – 30–35; *6* – 35–40; *7* – >40
10 pav. Epidoto koncentracija %: *1* – 10-15, *2* – 15–20, *3* – 20–25, *4* – 25–30, *5* – 30–35, *6* – 35–40, *7* – >40

tion between amphiboles and other minerals described above. In the Nida–Klaipėda area of the Baltic Sea, the epidote group of minerals is represented by epidote. In the Kuršiai-Sambian Plateau the content of epidote ranges from 15 to 25%. In several separate small plots in the western, north- and south-eastern parts of the area, including the old delta of the Pronemunas River, the epidote content increases up to 30–35% and even to more than 40%, because it is related with sediments of alluvial-accumulation plain (Fig. 10, Table).

Lithologically, the largest amounts of epidote are concentrated in coarse aleurite (average 24.9%), a little less amounts are found in fine sand (24.3%), the least amounts are observed in coarse sand (17.5%). The percentage of epidote is related with the degree of sediment sorting. Its largest amounts are concentrated in well- and medium-sorted sediments (S_0 = <1.2–1.35, by Trask).

CONCLUSIONS

The areal distribution of heavy minerals in the surficial sediments of the Nida–Klaipėda area of mapping in the Baltic Sea is related with a number of factors such as the mineral composition of source rocks, transportation of their fragments by waves and currents, lithological composition of sediments, shape and specific weight of minerals, bottom relief, etc.

The wave abrasion of sea coasts formed of Quaternary and Paleogene deposits and the distribution of material on the sea bottom by waves and currents are the main factors which determined a specific mineral composition in this part of the Baltic Sea named the Nemunas subprovince, characterized by increased amounts of amphiboles. Thus, the concentrations of other minerals, except the epidote and partly almandine, usually are low, not exceeding 10–15% of heavy fraction.

Increased concentrations of zircon, almandine and other minerals are found near the coast of Kuršių Nerija Spit and at a distance of 10–15 miles from the recent sea coast. Probably they indicate the presence of the ancient sea coast of the Yoldia Sea.

The highest concentrations of zircon, magnetite, tremolite and epidote are found in well- and medium-sorted sediments; almandine is related with worse-sorted ones, meanwhile ilmenite and rutile are indifferent to sediment sorting. Also, highest concentrations of heavy minerals depend on grain size of sediments where they accumulate. The highest concentrations of many of them (zircon, rutile, tremolite and epidote) are related with fine sand and coarse aleurite, of ilmenite – with coarse sand, of magnetite – with fine and medium sand, of almandine – with medium and coarse sand.

From the geomorphological standpoint, zircon is a mineral of abrasional- accumulative zones, ilmenite and magnetite are minerals of alluvial deposits of the Pronemunas old valley and delta, almandine is of morainic plains, and the rest (rutile, tremolite and epidote) are minerals of alluvial-accumulative zones.

ACKNOWLEDGEMENTS

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SUNKIŲJŲ MINERALŲ PASISKIRSTYMAS NIDOS–KLAIPĖDOS NUOTRAUKOS PLOTO PAVIRŠINĖSE BALTIJOS JŪROS DUGNO NUOSĖDOSE

S a n t r a u k a

Tirtajame Nidos–Klaipėdos nuotraukos plote rentgenofaziniu metodu atlikta 72 pavyzdžių smulkaus smėlio sunkiosios frakcijos (0,25–0,1 mm) mineraloginė analizė. Išaiškinti 7 sunkiųjų mineralų: cirkono, ilmenito, rutilo, magnetito, granato almandino, amfibolo tremolito ir epidoto procentiniai kiekiai ir jų koncentracijų pasiskirstymas plote, kurį lemia daugelis veiksnių, pradedant motininių uolienų mineraline sudėtimi, jų dalelių pernešimu bangomis bei povandeninėmis srovėmis ir baigiant tų dalelių nusodinimu, kuris priklauso nuo mineralų formos, jų lyginamojo svorio ir nuo jūros dugno reljefo.

Jūros bangų abraduojami krantai, sudaryti iš kvartero bei paleogeno nuogulų, yra pagrindiniai šios Baltijos jūros dalies dugno nuosėdų šaltiniai, lėmę specifinę jų mineralinę sudėtį. Kadangi ši Baltijos jūros dalis priklauso Nemuno mineraloginei subprovincijai, pasižyminčiai padidinta amfibolų koncentracija, be tremolito, kitų mineralų kiekiai, išskyrus epidotą ir iš dalies almandiną, yra nedideli – paprastai beveik neviršija 10–15%.

Padidėję cirkono, almandino ir kitų mineralų kiekiai, randami ne tik prie Kuršių Nerijos kranto, bet ir 10–15 jūros mylių atstumu nuo jo, galbūt parodo čia buvusią Joldijos jūros pakrantės ir kranto vietą.

Didžiausi cirkono, magnetito, tremolito ir epidoto kiekiai randami gerai ir vidutiniškai išrūšiuotose nuosėdose, almandinas susijęs su blogai išrūšiuotomis nuosėdomis, o ilmenitas ir rutilas yra indiferentiški nuosėdų išrūšiuotumo laipsniui. Be to, didžiausia sunkiųjų mineralų koncentracija priklauso nuo nuosėdų, kuriose jie randami, granuliometrinės sudėties. Cirkono, rutilo, tremolito ir epidoto padidėję kiekiai yra susiję su smulkiu smėliu ir stambiu aleuritu, ilmenito – su stambiu smėliu, magnetito – su smulkiu ir vidutiniu smėliu, o almandino – su vidutiniu ir stambiu smėliu.

Geomorfologiniu požiūriu cirkonas kaupiasi abrazinėje-akumuliacinėje zonoje, ilmenitas ir magnetitas yra Pronemuno senslėnio ir deltos aliuvio mineralai, almandino sankaupų randama moreninėje lygumoje, o rutilas, tremolitas ir epidotas yra susiję su aliuvinėmis-akumuliacinėmis zonomis.

Иолита Апанавичюте, Пятрас Шимкявичюс

РАСПРЕДЕЛЕНИЕ ТЯЖЕЛЫХ МИНЕРАЛОВ В ПОВЕРХНОСТНЫХ ДОННЫХ ОСАДКАХ БАЛТИЙСКОГО МОРЯ НА НИДА–КЛАЙПЕДСКОЙ ПЛОЩАДИ КАРТИРОВАНИЯ

Р е з ю м е

На исследованной Нида–Клайпедской площади картирования произведен минералогический рентгенофазовый анализ 72 образцов тяжелой фракции тонкозернистого песка (0,25–0,1 мм) донных осадков. Выявлено процентное содержание 7 тяжелых минералов – циркона, ильменита, рутила, магнентита, граната альмандина, амфибола тремолита и эпидота и распределение их концентрации на площади, которое зависит от многих факторов, начиная с минерального состава материнских пород, транспортировкой их частиц волнами и подводными течениями, и кончая осаждением этих частиц, которое своим чередом зависит от формы минералов, их удельного веса, а также от рельефа морского дна.

Абрадируемые морскими волнами берега, сложенные четвертичными и палеогеновыми отложениями, являются основными источниками донных осадков в этой части Балтийского моря. Поскольку эта часть Балтийского моря принадлежит Неманской минералогической субпровинции, характеризуемой повышенной концентрацией амфиболов, содержания других минералов, за исключением эпидота и частично алмандина, обычно почти не превышают 10–15%.

Увеличенные содержания циркона, алмандина и других минералов, установленные не только у берега Куршской косы, но и на расстоянии 10–15 морских миль от него, возможно, указывают на бывшую прибрежную часть и берег Иольдиевого моря.

Наибольшие концентрации циркона, магнетита, тремолита и эпидота содержатся в хорошо и средне сортированных осадках, алмандин связан с плохо сортированными осадками, а ильменит и рутил – индифферентны степени сортировки. Кроме того, распределение наибольших содержаний тяжелых минералов зависит от гранулометрического состава донных отложений. Увеличенные содержания циркона, рутила, тремолита и эпидота связаны с мелкозернистым песком и крупнозернистым алевритом, ильменита – с крупнозернистым песком, магнетита – с мелким и средним песком, а алмандина – со среднезернистым и крупным песком.

С геоморфологической точки зрения циркон образует повышенные концентрации в абразионно-аккумулятивной зоне, ильменит и магнетит – аллювиальные минералы старой долины и дельты р. Пронеман, алмандин накапливается на моренной равнине, а рутил, тремолит и эпидот связаны с аллювиально-аккумулятивными зонами.