THE TEXTURAL CHARACTER OF THE LITTORAL SEDIMENTS BETWEEN SFÂNTU GHEORGHE AND GURA PORTIȚA

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Abstract. This paper is based on grain size analyses performed on 250 sediment samples collected with the Van Veen grab from water depths of 0 to 20 meters in the littoral area of the Black Sea situated between Sfântu Gheorghe village and Gura Portiţa. As a result of analyzing the distribution of the types of depth sediments, it has been noted that along the entire length of the area under study littoral sediments consisting of well-sorted sands with skewness levels ranging from –0.41 to 0.60 are to be found between 0 and 7 meters. At water depths between 7 and 20 meters there are frequent sediments consisting of clayey silt, followed by clay, poorly sorted and with skewness values ranging from 0.10 to 0.85. The percentage of sand in the composition of sediments (closely connected to the average diameter of the particles) decreases in a linear fashion with depth, suggesting a possible direction of transport of the sand particles from the littoral area out towards the open sea. By interpreting the grain size parameters it was noted that sandy sediments tended to move from North to South, East of Sakhalin Island. South of Sakhalin Island it is impossible to estimate in which direction sediment is being transported based on the sizes of the sand grains. This is due to the presence of organogenous particles resulted from shells, whose larger dimensions upset the normal distribution of textural parameters.

Key words: littoral sands, clayey silt, textural parameters, bimodal character, sediment transport

INTRODUCTION

The Black Sea littoral area situated South of the mouth of Sf. Gheorghe distributary is considered to be a highly complex area whose evolution has major implications for the entire Romanian littoral. Situated at the junction between the Danube and the Black Sea, this area exemplifies how hydrotechnical improvements in the fluvial and marine domain can contribute to increasing levels of coastal erosion.

The area South of Sf. Gheorghe distributary has been the subject of an impressive number of studies of sedimentology, littoral dynamics, geomorphology, hydrology and hydrodynamics.

The present paper is an attempt to identify the sedimentation and transport processes of sediments, as far as possible based on the interpretation of grain size distribution and the textural parameters of the various types of littoral sediments.

The zone under study is the littoral area situated between Sfântu Gheorghe village and Gura Portiţa, from the shoreline to a water depth of approximately 20 meters.

Before the increase in anthropogenic activities, especially the construction of dams on the Danube and the adaptation of the Sulina distributary for the use of marine ships, the Romanian littoral beaches were in a stable state of equilibrium and even growth in some sectors. They received fluvial sediments discharged by the Danube into the sea through the three distributaries, and these sediments were transported Southwards by long-shore currents. After the rectification of the Sulina distributary and the building of jetties to protect the shipping canal, the sediments transported by Chilia and Sulina distributaries were no longer deposited on the littoral, sediments transported by Sf. Gheorghe distributary were the only available source.

The Southern circulation of the sediments of Sf. Gheorghe distributary was redirected through the East of Sakhalin Island after the North of the island was connected to the mainland, thus more likely to be lost out at sea. The sand passing the Southern tip of Sakhalin Island contributes to the building of the island platform and is not able to feed the beaches farther South since the shoreline orientation changes abruptly (Panin, N., Jipa, D., 1999). For this reason most of the shoreline South of Sf. Gheorghe, including the Sakhalin Island which seems to get closer to the shore, is continually retreating(PANIN *et al*., 1974-1994). The only exceptions consist of a few sectors, more precisely the sector facing Sakhalin Island and the Periteasca sector, where growth occurs to the detriment of neighbouring Southern sectors.

METHODS

The paper is based on the grain size analysis of approximately 250 samples of littoral sediments collected in August 2005, in the course of the Contract 4-174/15.11.2004 - Programme CERES, and other themes of the "National Institute of Marine Geology and Geo-ecology".

The sample locations are situated in the littoral area between Sf. Gheorghe and Portita (Fig.1) at water depths ranging from 0 meters (the swash area) to 25 meters. The sediment samples were taken by means of the Van Veen grab, their location being determined with GPS–type equipment.

Grain size analyses were made through the combined method of dry sieving for sand and gravel fractions and pipetting for clayey and silty fractions. A set of 18 sieves ranging from 4Φ to –2Φ (0,063 mm to 4,00 mm) was used for the dry sieving and the pipetting was performed for the dimension interval between 4Φ and < 10Φ (0,063mm and - <0,001mm).

The textural parameters (mean size-M, sorting σ, and skewness Sk) were calculated by means of the logarithmic graphical measures according to FOLK and WARD (1957) and their interpretation was made in the course of one longitudinal and four transversal shore profiles.

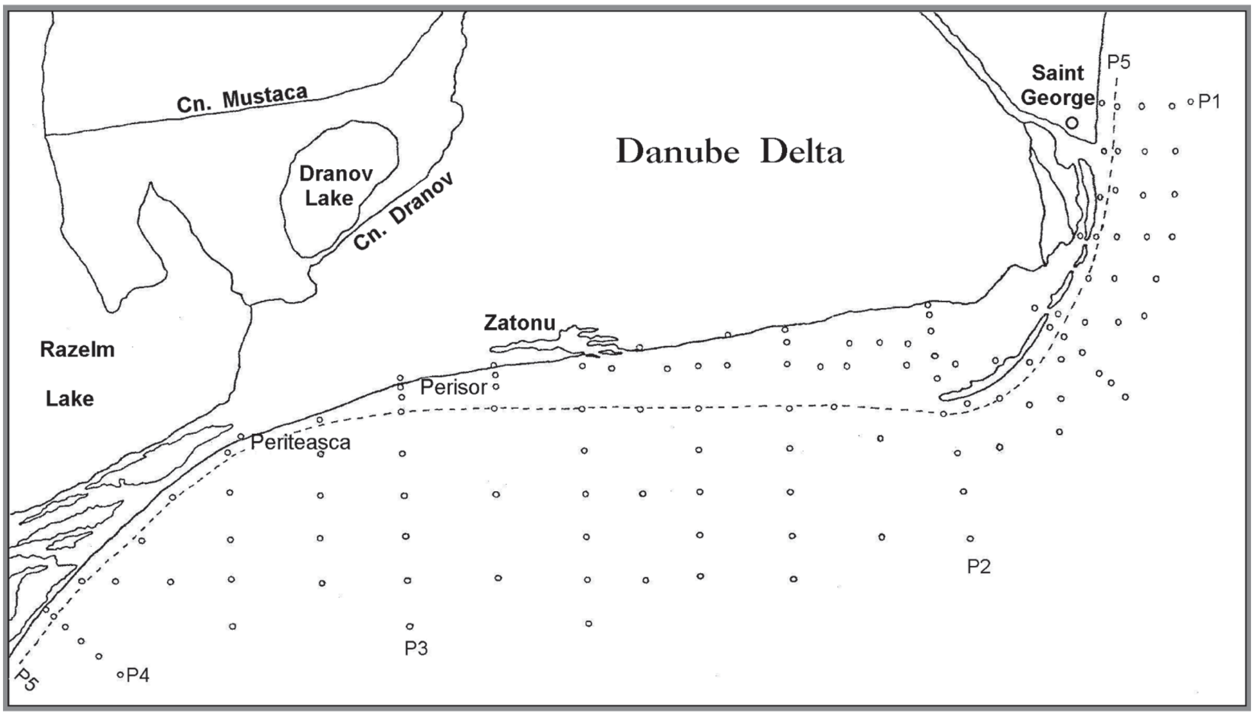

Fig. 1 The study area, the sampling sites, and location of profiles in the study area

The unimodal or polymodal distribution character was determined by means of histograms.

The dimensional criterion (the Wentworth scale 1922), the lithological criterion (the Shepard diagram 1954), the distribution character and the relative values of textural parameters were taken into account in the classification of sediments.

RESULTS

Textural types

The littoral sector under study is characterized by a relatively uniform distribution of types of sediments, being in complete accord with environmental conditions dependent on the area's geomorphology and the hydrodynamic factors controlling the way sediments are deposited and transported.

According to Shepard's classification, which is widely used in specialized Romanian literature, the littoral sediments in the area mainly fall in the sand and clayey sand categories, followed by silty sand, silt and silty clay.

Since Shepard's classification is too general to allow for a more detailed textural study, in the present paper, a more complex classification has been used consisting of a compilation of more recent papers (Parrado, J.M., Achab, M., - 1999) and using, apart from the dimensional criterion, other criteria such as the unimodal or polymodal distribution character, the relative values of the textural parameters (mean, standard deviation, skewness) and the genetic criterion.

Four types of grain size distribution have been identified, characterizing different sedimentation environments, as follows:

- Type I consists of sediments whose composition includes over 85% fine sand, with a unimodal distribution character (Fig. 2), the neighbouring fractions of very fine and fine sands, according to the Wentworth scale, being very well represented. They are moderately to well-sorted and present fine skewness. They are to be found in a wave-affected littoral energetic environment in the proximity of the shoreline at water depths ranging from 0 to approximately 7 meters.
- Type II consists of over 98% sand and shell fragments and has a bimodal character. The first mode consists of organogenous particles larger than 1mm and the second mode of fine sand. They are well-sorted and present coarse skewness. The sediments belonging to this type are characteristic of the area situated close to the coastline, and found in water depths of under 1m to the berm.
- Type III contains sediments consisting of over 40% sand, over 20% silt (the silty sand class according to Shepard) followed by clay; they are bimodal or slightly bimodal with a well represented mode consisting of fine, very fine sand or coarse silt and a less developed second mode consisting of fine clay. The sediments belonging to this type are poorly-sorted, present fine skewness and mark the passage from littoral sands to the muddy sediments of greater depths.
- Type IV contains sediments composed mainly of silt and clay followed by sand, whose distributions have a bi-modal character (two well represented distanced fractions or groups of fractions), the first mode consisting of medium or coarse silt and the second of fine clay. The samples are very poorly-sorted and present very fine skewness. In Shepard's diagram these sediments fall into the clayey silt or silty clay categories. The sediments belonging to this type are distributed at depths ranging from 7-6 meters to 20-25 meters.

The sediments included in type II (bimodal coarse sands) only appear in the sites on the shoreline and for this reason they could not be displayed on the map with the grain size distribution of sediments.

Type III sediments were only found in a few sites and their expansion over the whole area under study can only be assumed without clear proof, due to the limited number of sampling sites. These sediments seem to be distributed along the entire length of the studied area, and mark the transition from littoral sands to clayey silts at greater depths.

Analyses of the spatial distribution of the various types of sediments show that sediments consisting of sand are prevalently distributed in the littoral area, where the fine sands are most stable given the existent movement energy. Nearer the shoreline, where the environment energy reaches maximum values, coarser sands are more stable.

Sediments with a higher content of silt and clay components (clayey silt according to Shepard) are more stable at depths of over 8 meters where environment energy is lower. The sand percentage in the composition of sediments (in close correlation with the average diameter of the particles) shows an almost linear decrease, suggesting transport of sand particles from the littoral area out towards the open sea (Fig. 3).

The polymodal character of the distributions is an indicator of different sources or different sediment transport processes. Thus, sediments found near the shoreline are bimodal because their composition includes fine quartz sand occurring in lower percentages every year, and organogenous particles (from mollusc shells) whose dimensions are similar to those of coarse sand or gravel. The bimodal character of sediments to be found at greater depths is determined by the presence of coarser particles transported through dragging, or organogenous particles, some produced *in situ*, and finer material resulting from suspension or having a biogenic nature.

Textural parameters

In order to determine the variation tendencies of textural parameters, 4 shoreline transversal profiles were chosen in such a way as to cover the entire surface (Profile 1 North of Sf. Gheorghe, Profile 2 South of Sakhalin, Profile 3 Perişor, Profile 4 Gura Portița), as well as a longitudinal profile, between Sf. Gheorghe and Gura Portița (Fig. 3). The longitudinal profile was placed in the littoral sands area at a depth of approximately 4 meters, with the purpose of establishing a correlation between the value of textural parameters and the transport of sediments parallel with the shoreline. The variation of each textural parameter according to depth and grain size distribution was studied in the case of each profile (Fig. 5-9).

Mean – MΦ displays values ranging from 2.8 Φ to 4 Φ, in the case of the fine sandy sediments predominating in the littoral area, reaching 4.5 Φ in the case of clayey sands and decreasing in the swash area where they can amount to 2.4 Φ. In the clayey silt area the mean is higher, reaching the maximum value of 8 Φ.

Sorting σ The standard deviation σ, an indicator or the degree of sorting, has lower values in the case of littoral sands, ranging from 0.25 Φ to 0.35 Φ, which situates them in the field of very well-sorted sediments.

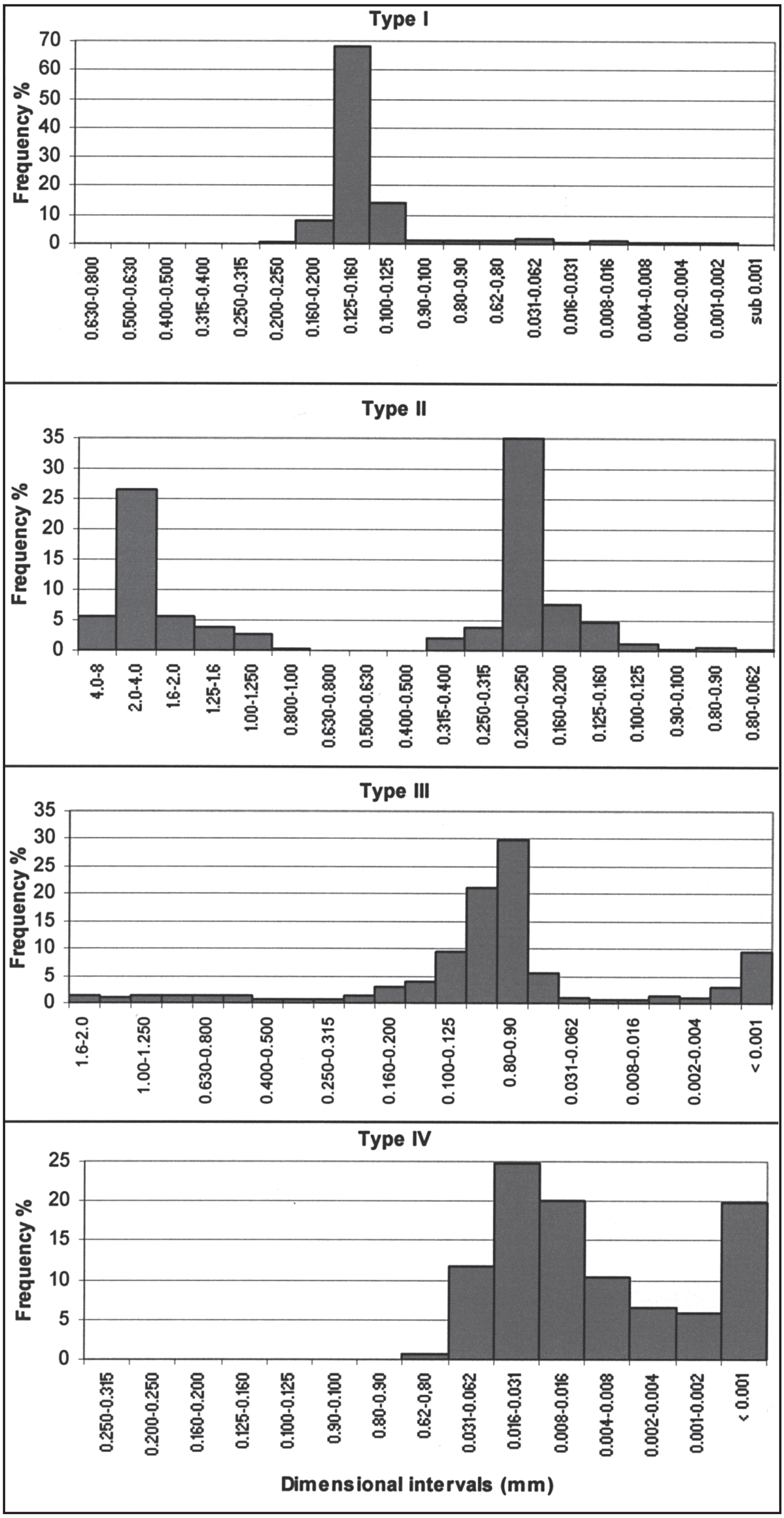

Fig. 2 Different grain size distribution found in the study area

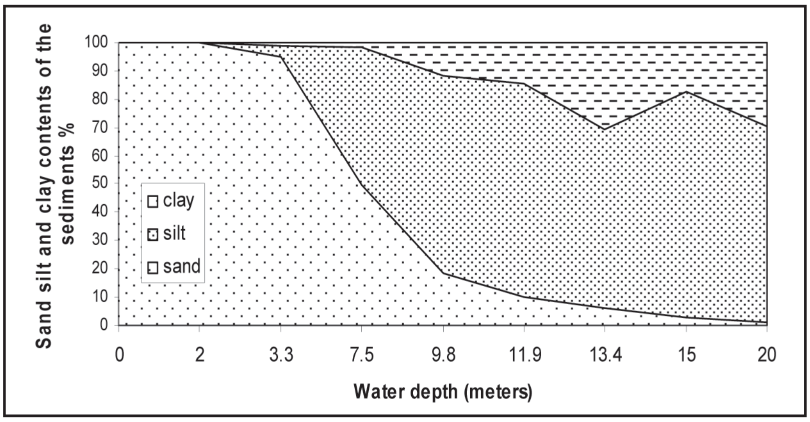

Fig. 3. Variation of percents of sand silt and clay with increase of water depth

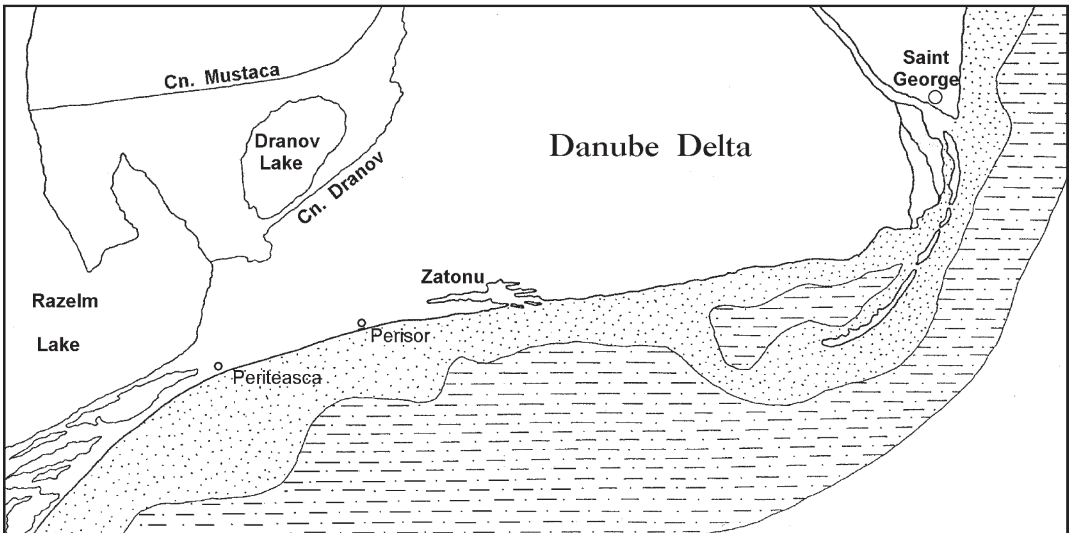

Fig. 4.The granulometric distribution of sediment in the littoral area between Sf. Gheorghe and Portita

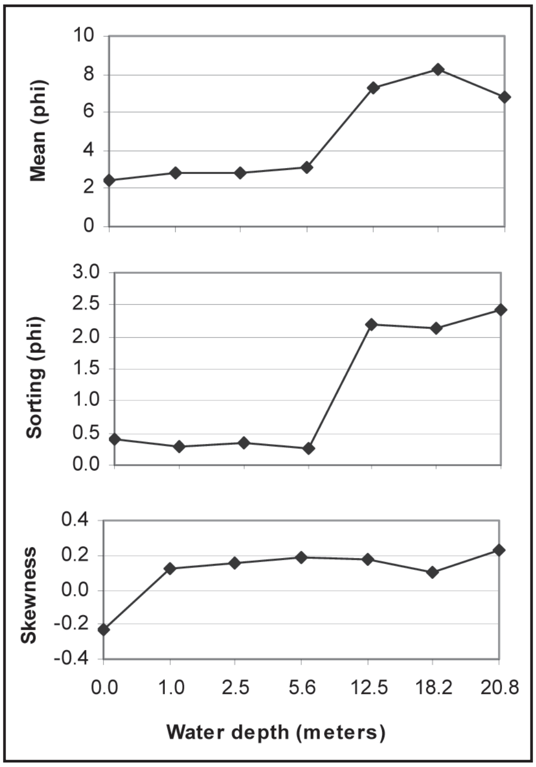

Fig. 5. Grain-size parameters variation *vs* depth at profile 1

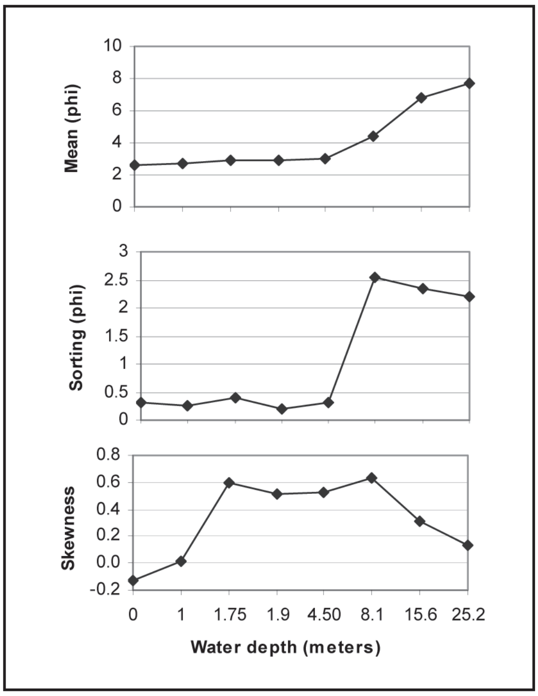

Fig. 6. Grain-size parameters variation *vs* depth at profile 2

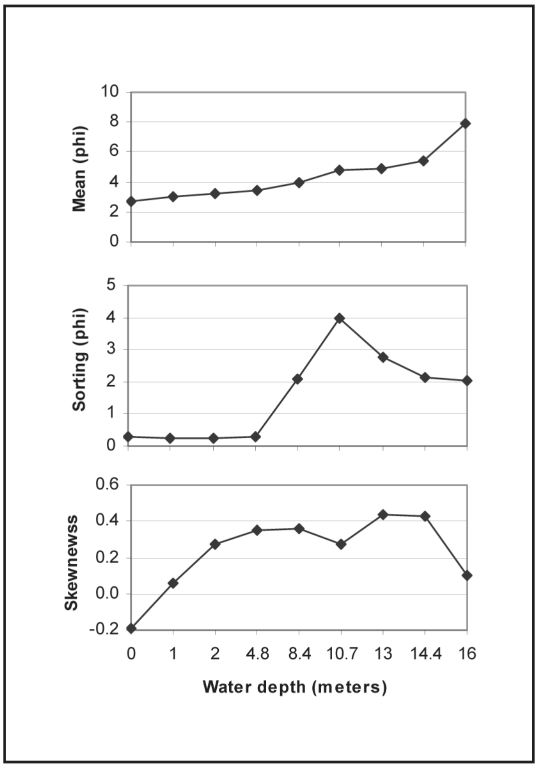

Fig. 7. Grain-size parameters variation *vs* depth at profile 3

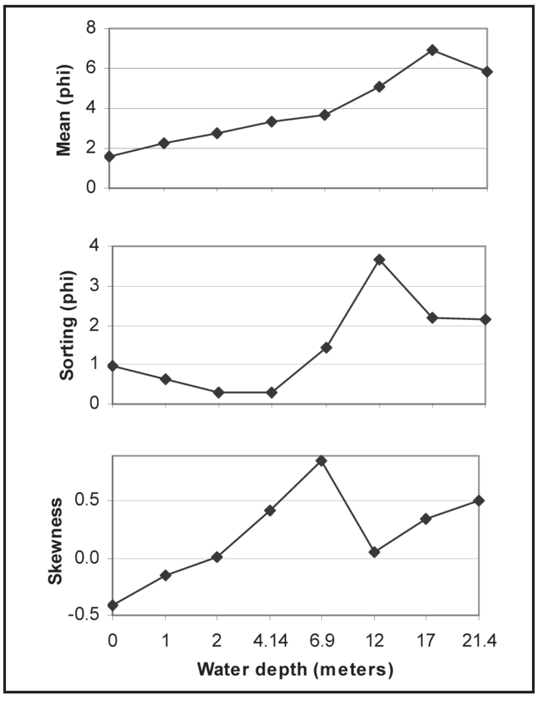

Fig. 8. Grain-size parameters variation *vs* depth at profile 4

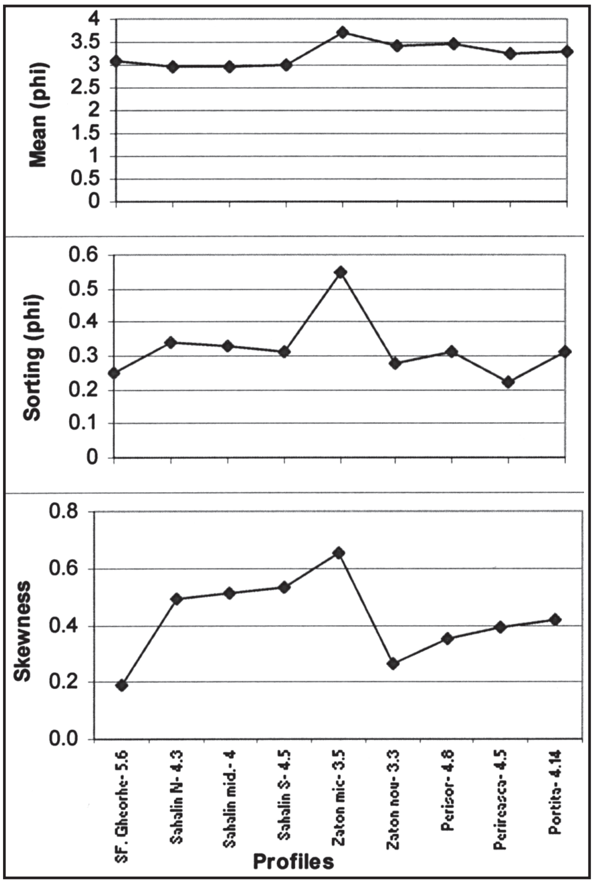

Fig. 9 Grain size parameters variation at profile 5

Near the shoreline, standard deviation values are somewhat higher but do not exceed 0.41 Φ, corresponding to very well-sorted or well-sorted categories. Standard deviation values increase in the case of fine sediments, reaching 1.7 – 2.20 Φ, corresponding to poorly sorted or very poorly sorted categories.

Skewness (Sk) displays a wide range of values, starting from values of –0.27, rarely –0.40 near the shoreline, corresponding to the coarse skewed character, continuing with symmetrical characters, fine skewed up to very fine skewed characters, with a maximum value of 0.85 characteristic of sediments with a high content of fine material.

SEDIMENT TRANSPORT PATTERN

An attempt has been made to establish sediment directions of transport by means of the GAO and COLLINS method (1992), proposing a two dimensional approach, using a sampling grid and defining trends by comparing the grain size parameters of each station with its nearest neighbours.

According to this method, trends vectors are drawn by simply connecting the stations (Fig. 10) showing any of the following four trend types:

Trend type 1: $\sigma_1 > \sigma_2$; $M_1 < M_2$; $Sk_1 > Sk_2$
Trend type 2: $\sigma_1 > \sigma_2$; $M_1 > M_2$; $Sk_1 < Sk_2$
Trend type 3: $\sigma_1 > \sigma_2$; $M_1 > M_2$; $Sk_1 > Sk_2$
Trend type 4: $\sigma_1 > \sigma_2$; $M_1 < M_2$; $Sk_1 < Sk_2$

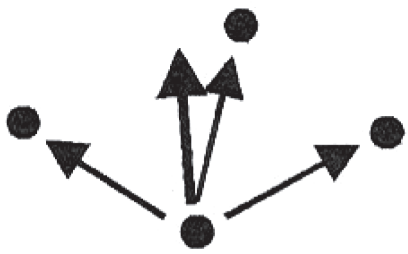

Figure 10. The resulting vector (the thicker arrow) obtained by summing the trend vectors (the thin arrows) drawn between neighbouring stations

with subscripts 1 and 2 indicating sampling sites 1 and 2 along the transport direction

Summing the vectors for each data station produces a single vector for this site.

The only drawback of the GAO and COLLINS method is that it can produce statistically valid trends even where no trend exists (Le Roux, J.P., Rojas, E.M. 2004). This is the reason why this paper has checked the validity of the four equations, in all the pairs of stations possible and has only taken into account groups of more than three stations situated approximately in the same direction.

After interpreting the overall data at least one of the equations (Trend type 4) is valid for neighbouring stations situated East of Sakhalin Island, at a water depth of 4-5 meters. It was thus noted that between Sf. Gheorghe distributary and the South of Sakhalin Island, the Mean value increases, Sorting (σ) is better and the value of Skewness (Sk) increases, confirming the fact that sand particles are transported by the longshore current to the South of Sakhalin Island (profile 5).

The further circulation of sediments from the area of Zatonul Nou Lake Southwards cannot be confirmed on textural bases. The transport of sediment East of Sakhalin Island has been inferred and even quantified by Giosan, L. *et al.*, who believe that the transport of sediments is increasing from the Sf. Gheorghe distributary area to the middle part of the island, and decreasing towards the South.

It is very likely that the circulation of sand is greatly reduced South of Sakhalin Island. At the same time, the increased content of shell fragments in the composition of sediments, determining the increasing Mean and the decreasing Sorting, can perturb the correlation between the textural characters and the direction of transport.

The above mentioned model was also confirmed in the transversal profiles (Fig. 5-8) but only for the stations situated between the swash area and the borderline of littoral sands and clayey sediments, suggesting the transport of sediments from the beach area out towards open sea. This shifting tendency is also proved by other methods or observations, and was especially evident during stormy periods.

CONCLUSIONS

The sediments in the littoral area between Sf. Gheorghe and Gura Portiței consist mainly of sands, starting from the shoreline to a depth of approximately 7 meters and 20 meters.

Textural parameters evolve within completely normal limits for littoral sediments. Thus, near the shoreline, there are coarser sand sediments that are well-sorted and present coarse skewness, and at depths of over 1-2 meters sand sediments become very well-sorted but present fine skewness. At depths of over 7 meters there are sediments consisting of clayey silt or silty clay that are poorly sorted and present fine skewness.

The sand content in the composition of sediments, together with the particle diameter (in millimetres) decreases almost linearly.

The bimodal character of the distribution noted in the case of some of the sediments indicates the existence of one or more sources of sedimentary material, the most important of which include fluvial materials, shell-derived material, fine material resulting from biotic processes, material resulted from suspensions, etc.

The interpretation of grain size parameters for the purpose of highlighting some transport tendencies of the sediments has yielded poor results due to the high concentration of organogenous particles from shells, which are often larger in size and this upsets the normal distribution of textural parameters.

Two slight sediment transport tendencies can however be noted, especially near the shoreline at water depths of 4-6 meters, from Sf. Gheorghe distributary East of Sakhalin Island and along the whole perimeter from the shore out towards the open sea.

REFERENCES

Anastasiu N., Jipa D., 1983 - Texturi şi structuri sedimentare. Editura Tehnică Bucureşti

Folk R.L., Ward W. C., 1957 – Brazos River bar, a study in the significance of grain size parameters. Jour. Sed. Petrology, 27/ 1

Gao, S., and Collins, M., 1992 – Net sediment transport pattern inferred from grain-size trends based upon definition of „transport vectors”. Sediment Geol.. 80/1992 47-60

Giosan, L., Bokuniewicz, H., Panin, N., Postolache, I., 1998 - Longshore sediment transport along Romanian Danube Delta coastal zone. GEO-ECO-MARINA 3/1998 11-24 Bucharest

Le Roux, J.P., Rojas, E.M., 2004 – Sediment transport pattern determined from grain size parameters Int. Workshop HWK Delmerhorst 15-16 apr. 2004 – From Particle Size to Sediment Dynamics

Mc.Laren, P., Bowles, D., 1985 – The effects of sediment transport on grain size distribution, J. Sediment Petrol. 55/ 1985 457-470

Panin, N., Jipa, D., 1998 - Danube river sediment input and its interactions with the North–Western Black Sea result of EROS Projects. GEO-ECO-MARINA 3/1998 23-35 Bucharest

Parrado, J.M. Achab, M., 1999 - Grain–size trends associated with sediment transport pattern in Cadiz Bay (South-West Iberian Peninsula) Boletin Instituto Espanol de Oceanografia 15 (1-4) 1999. - 269-282 Cadiz

Panin N., *et al*. – Monitoringul geoecologic al sistemului Dunăre-Deltă-Litoral-Marea Neagră, Centrul Român de Geologie şi Geoecologie Marină

Shepard F.P., 1954 - Nomenclature based on sand-silt-clay rations.Jour, Sed. Petrology 24/1