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Izabela GÓRECKA

Dynamics of the surface sediments at the sea-floor along the Vistula Spit shoreface

Dominant directions have been determined for sedimentary transportation taking place along the Vistula Spit (Mierzeja Wiślana) at sea depths of 2, 5, and 10 m. The basic transportation of sediments has been found to take place from the west to the east. The least amount of longshore sedimentary transportation is that existing at a depth of 2 m. It translocates the sediments eastward up to the Przebrno and Krynica Morska area. The longshore stream at a depth of 10 m has the maximum extent since it is capable of translocating sediments along the entire segment of the shoreface under present study. The places are also delineated where either abrasion or aggradation of the sea-shore is likely. Based on this study a conclusion can be drawn that abrasion of the sea-shore can take place eastward of Stegna, in the area of Kąty Rybackie, and west of Krynica Morska, whereas aggradation can occur in the areas of Jantar, Krynica Morska and Piaski.

INTRODUCTION

Despite significant progress in recognizing the geological structure and development of the Vistula Spit (A. Makowska, 1988*a*, *b*, 1991; J. E. Mojski, 1987*a*, *b*, 1990*a*, *b*; A. Tomczak *et al.*, 1988), the issue dealing with movement of sea-floor sediments within the shorezone has not been condusively explained so far. The purpose of this paper is to make an attempt aimed at presentation of directions of translocation for the sea-floor sediments along the subaquatic shore slope of the Vistula Spit; this attempt is based on samples collected from sea-floor sediments at a sea depths of 2, 5, and 10 m. Previous studies on lithodynamic processes taking place in this area were often based on either samples of deposits collected from the beach and the fore dune (e.g. R. Gołębiewski, 1967) or observations of beach microforms only and on general laws governing the spit's development as well (B. Rosa, 1963).

The sediments sampled from the surface of the sea-floor at the shoreface of the Vistula Spit make up the subject of this study. Samples were collected from standard sea depths of

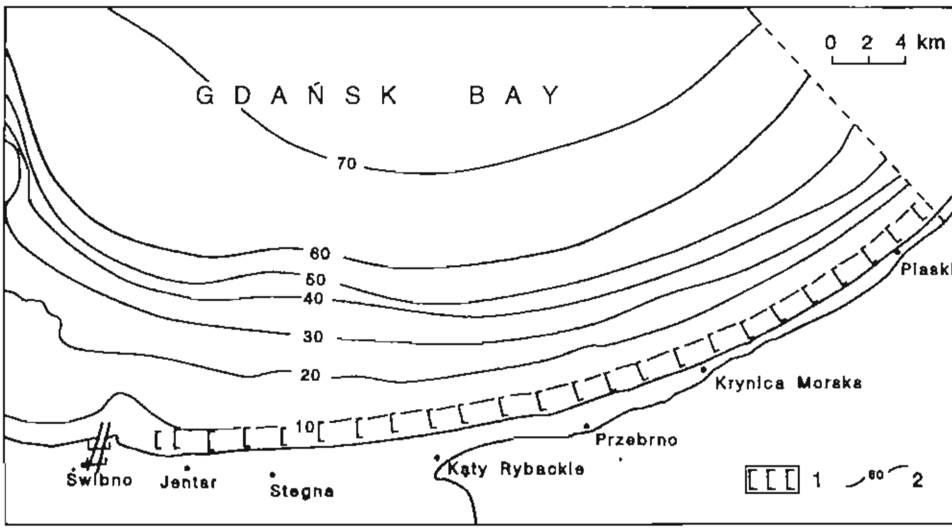

Fig. 1. Location of sampling profiles
1 — sampling profiles; 2 — isobaths
Lokalizacja profili badawczych
1 — profile badawcze; 2 — izobaty

2, 5, and 10 m along the entire segment of the coast from the Vistula river outlet at Świbno to the state boundary of Poland on the east. The sampling arrangement consisted of 24 profiles perpendicular to the shoreline, located at a distance of 2 km from each other (Fig. 1). The sampling period included August, September, and October, 1986, and July, 1987 as well. Also, an echosounder was used to take measurements of the sea-floor along each profile.

In addition, for the purpose of comparison, the present study made use of samples of river deposits collected from the Vistula river floor at the 937th and 939th kilometres of the river course (Fig.1). All the samples from the sea and river floor deposits were made available to the author of this paper by the Branch of Marine Geology of the Polish Geological Institute. Sampling by the Institute was carried out in the frame of the field work for the project *Geological Map of the Baltic Sea Bottom*, on the scale of 1:200 000, sheets: Gdańsk and Elbląg (S. Uścinowicz, J. Zachowicz, 1993*a*, *b*).

Determinations of: grain-size distribution, mineral-petrographic composition, percentage of heavy mineral contents, degree of roundness of quartz grains, along with display of the sea-floor as recorded on the echograms were included in a comprehensive analysis which was an attempt aimed at presenting the dominant directions of the sediment transportation in the area under study.

Sieve analysis was employed to determine the grain-size distribution. Standard sieves with openings ranging from –4 to 4 ϕ were set together to make this analysis. Grain-size parameters were calculated according to R. L. Folk and W. C. Ward's (1957) equations. The 1.0–0.5 mm fraction was used to study the mineral-petrographic composition; determination of percentage of the assemblage composed of quartz, feldspars, crystalline rock fragments, sedimentary rocks fragments (including sandstone and limestone) and of other components was included in this task. Percentage of heavy mineral content was determined for the 0.25–0.125 mm fraction by separation in heavy liquid.

The photographic method was applied to determine the degree of roundness of the quartz grains for the 1.0–0.5 mm fraction. Analyses of mineral-petrographic composition, heavy mineral content, and quartz grain roundness were made on samples that had been collected from a sea depth of 2 m. The samples of river deposit, collected at the 937th and 939th km, were also subjected to determination of both the mineral-petrographic composition and the degree of roundness. All analyses were made at the laboratory of the Branch of Marine Geology of the Polish Geological Institute, having its seat in Sopot.

RESULTS OF THE STUDY

There is a depth-related differentiation of deposits occurring within the shoreface of the Vistula Spit. Grain-size distribution functions shift toward the finer fractions with increasing depth. Deposits at all depths under study are almost always composed of fine-grained sands, the modal value of which is in the range of 0.25–0.125 mm. The maximum content of the fraction of 0.25–0.125 mm appears in the deposits at a sea depth of 5 m. Proportion of this fraction decreases shoreward; this is associated with an increase of the 0.5–0.25 mm fraction. As to the 0.125–0.063 mm fraction, its participation in the deposit increases seaward. Abundant organic remains including shells of molluscs (among other things) appear within the deposit existing at a depth of 10 m.

Table 1 presents values of average grain-size parameters for all the depths under consideration.

Table 1

Mean values ($\bar{x}$) and standard deviations (S) of grain-size parameters

Depth [m]	Total number of samples	Parameter	M_z	σ_I	Sk_I	K_G
2	24	$\bar{x}$ S	2.273 0.226	0.430 0.112	–0.123 0.096	1.162 0.140
5	24	$\bar{x}$ S	2.572 0.102	0.364 0.070	0.013 0.073	1.145 0.120
10	24	$\bar{x}$ S	2.858 0.132	0.391 0.081	0.095 0.084	1.098 0.114
Total	72	$\bar{x}$	2.568	0.395	–0.005	1.135

M_z — median grain diameter; σ_I — standard deviation index; Sk_I — skewness index; K_G — kurtosis index

The least differentiation of the mean grain diameter (M_z) values (Fig. 2) occurs along the 5 m isobath; this is supported by tbe standard deviation value (Tab. 1). This standard

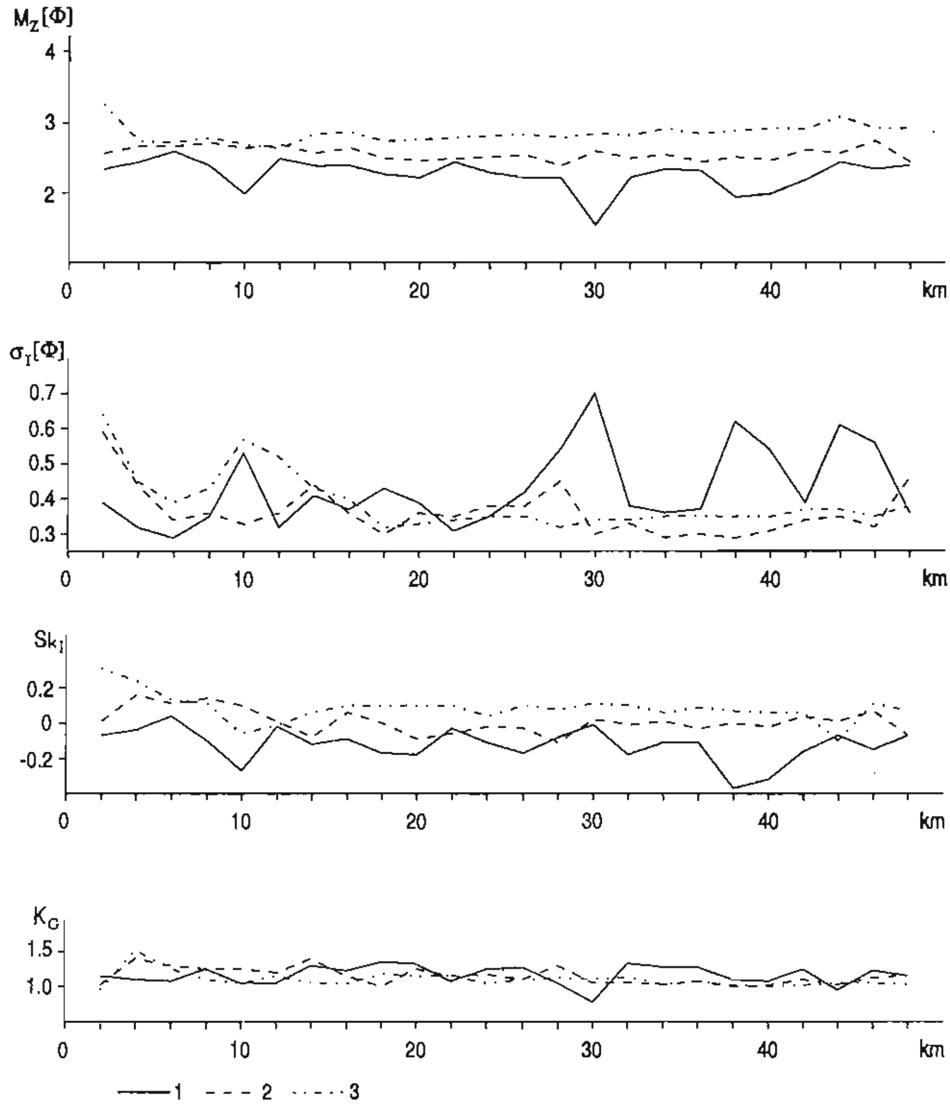

Fig. 2. Distribution of grain-size parameters M_z, σ_I, Sk_I, K_G along the Vistula Spit shoreface
1 — along the 2 m isobath; 2 — along the 5 m isobath; 3 — along the 10 m isobath
Wskaźniki uziarnienia (M_z, σ_I, Sk_I, K_G) wzdłuż podbrzeża Mierzei Wiślanej
1 — wzdłuż izobaty 2 m; 2 — wzdłuż izobaty 5 m; 3 — wzdłuż izobaty 10 m

deviation is as little as half compared with the deposits existing at the 2 m depth, being mostly composed of fine-grained sands. Exceptional is the deposit sample which was collected at the profile about 30 km away from the Vistula outlet (on the drawing the Vistula

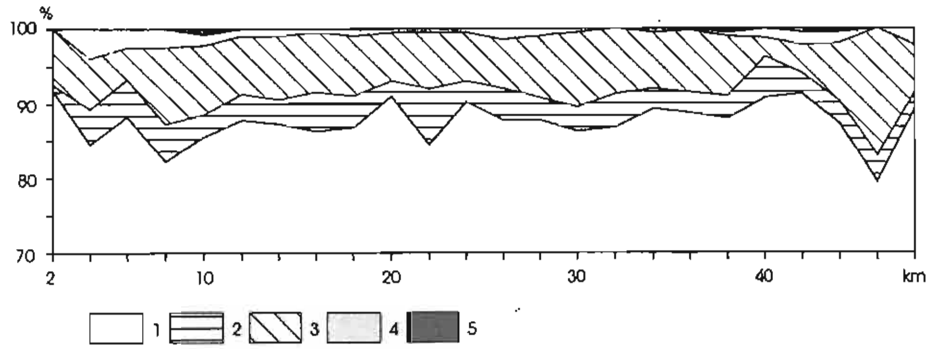

Fig. 3. Mineral-petrographic composition of the 1.0–0.5 mm fraction along the 2 m isobath
1 — quartz; 2 — feldspars; 3 — crystalline rock fragments; 4 — sedimentary rock fragments; 5 — other components
Skład mineralno-petrograficzny frakcji 1,0–0,5 mm wzdłuż izobaty 2 m
1 — kwarc; 2 — skalenie; 3 — okruchy skał krystalicznych; 4 — okruchy skał osadowych; 5 — inne składniki

outlet is marked with 0 km; and the first profile was located at a distance of 2 km eastward of the river outlet).

Sorting σ_I of the deposits within the shoreface of the Vistula Spit is best at a depth of 5 m, whereas the worst appears at a depth of 2 m (Fig. 2). When the 5 and 10 m isobaths are considered, then the poorest sorting appears in the sector between the 2nd and 16th km away from the Vistula outlet. In the case of the 2 m isobath the weakest sorting exists in the eastern shoreface (i.e. between the 30th km away from the Vistula outlet and the state boundary of Poland).

In the case of the 2 m isobath, there is a strong negative relationship between M_z and σ_I. The correlation coefficient is equal to –0.713 which provides evidence that with a decrease in grain diameter the sorting of the deposit improves. No correlation was found between M_z and σ_I for the deposit at a depth of 5 m, the correlation coefficient is very close to 0 and reach value of –0.076. A correlation coefficient of 0.19 was found for the deposit at a sea depth of 10 m; this value is not statistically significant. A positive value indicates improvement in sorting if diameter of grains in the deposit gets smaller. This is consistent with W. L. Boldyriew's (1991) observation that in the discussed environment aggradation processes are followed by depreciation in sorting. The best sorted are deposits undergoing transportation.

The samples of deposits from the Vistula channel are mostly represented by medium-grained sands. A modal value and the median diameter are of the range of 0.5–0.25 and 1.0–0.5 mm, respectively. One sample of gravelly sand, which was collected at the 939th km, is the exceptional case; the median of this gravelly sand is 2.0–1.0 mm. The outlet cone of the Vistula river is built up of deposits similar, with respect to grain diameter, to those found in the Vistula channel, at its 937th and 939th km (M. Tarnowska, R. Zeidler, 1980; U. Kępińska, K. Wypych, 1990). It can be assumed that fractions greater than 1.0 mm are retained in the river channel. Other fractions, those which are the components of the Vistula's deposits, reach the outlet cone from where they are transported by currents and

Table 2

Mineral-petrographic composition of the 1.0–0.5 mm fraction in deposits of the Vistula Spit shoreface (at the 2 m depth) and in the Vistula river (in percent)

Study area	n	Parameter	Quartz	Feldspars	Crystalline rock fragments	Sedimentary rock fragments	Others
The Vistula Spit shoreface	24	$\bar{x}$ S	87.34 2.86	3.94 1.36	7.49 2.78	1.16 1.02	0.07 0.17
The Vistula river	6	$\bar{x}$ S	85.84 3.30	2.44 1.43	9.44 1.92	2.11 0.91	0.17 0.18

n — total number of samples; other explanations see Table 1

waves, thus supplying the sea with sedimentary material. As it was concluded by W. K. Gudelis and J. M. Jemielianow (1982), the material with grain diameter not greater than 0.25 mm plays a substantial role in supplying the sea by the river.

The results of the mineral-petrographic analysis dealing with the shoreface segment under study has been graphically displayed on Figure 3. The averaged mineral-petrographic composition of both the shoreface and the Vistula's deposits is shown in Table 2.

The heavy mineral content is variable in the deposits of the Vistula Spit shoreface (Fig. 4); in the 0.25–0.125 mm fraction it changes from 0.02 (at the 20th and 22nd km away from the Vistula outlet) to 0.26% (at the 34th km away from the same reference point). The sea-floor deposits with the least content of heavy minerals in the said fraction occur between Kąty Rybackie and Przebrno. The increase in the heavy minerals content is observed eastward as well as westward of the area just mentioned. The averaged content for all the samples collected from the depth of 2 m is equal to 0.15%, and its standard deviation is 0.07%.

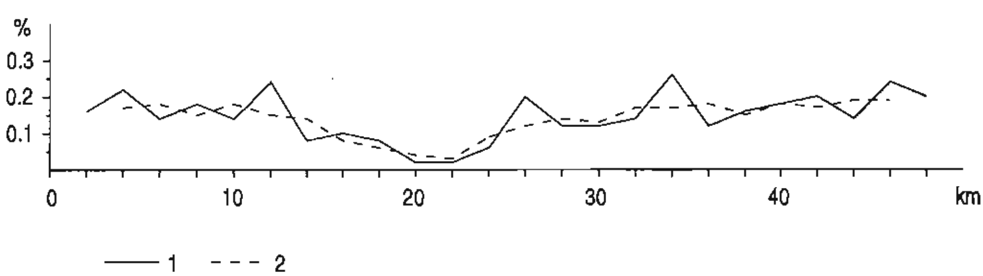

Fig. 4. Heavy mineral contents in the 0.25–0.125 mm fraction along the 2 m isobath
1 — heavy minerals; 2 — consecutive mean

Zawartość minerałów ciężkich we frakcji 0,25–0,125 mm wzdłuż izobaty 2 m
1 — minerały ciężkie; 2 — średnia ruchoma

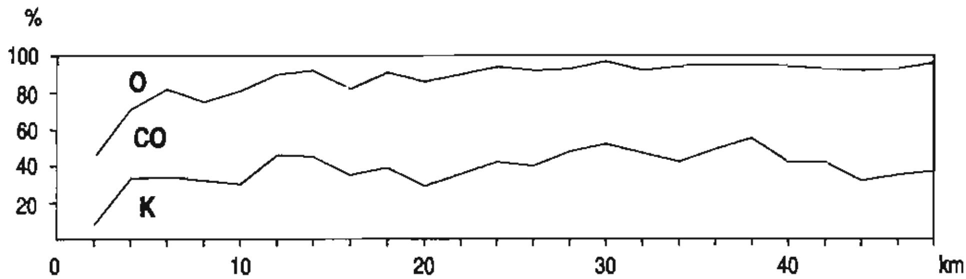

Fig. 5. The content of quartz grains in the three classes of roundness, in the fraction of 1.0–0.5 mm, along the 2 m isobath

K — angular grains; CO — subrounded grains; O — rounded grains

Zawartość ziarn kwarcu w trzech klasach obtoczenia we frakcji 1,0–0,5 mm wzdłuż izobaty 2 m

K — ziarna kanciaste; CO — ziarna częściowo obtoczone; O — ziarna obtoczone

Segregation of grains with respect to degree of roundness is taking place during transportation. In 24 samples collected from deposits along the 2 m isobath the most common are subrounded quartz grains (Fig. 5). Their content ranges from 37.7 (at the 2nd km away from the Vistula outlet) to 60% (at the 44th km from the same reference). Angular grains make up the second class with respect to their abundance. Their content is between 8.3 (at the 2nd km away from the Vistula outlet) to 55.3% (at the 38th km), respectively. Rounded grains appear in as much as 2.7 (at the 30th km away from the Vistula outlet) to 54% (at the 2nd km), respectively. The mean values for particular degrees of roundness are presented in Table 3 for quartz grains in the fraction of 1.0–0.5 mm. The amount of rounded grains is successively decreasing from the Vistula outlet to a distance of 36–38 km from this reference. Simultaneously, the number of angular grains increases within the same distance. The degree of roundness often allows for determination of sources from which the deposits originate. Similar percentage of both the rounded and angular grains in the Vistula's deposits as well as in the sample collected at the profile 2 km away from the river outlet

Table 3

The roundness of quartz grains of the 1.0–0.5 mm fraction in the deposits of the Vistula Spit shoreface and the Vistula river (in percent)

Study area	Total number of samples	Parameter	Grains		
			angular	subrounded	rounded
The Vistula Spit shoreface	24	$\bar{x}$ S	38.9 9.8	48.8 6.5	12.3 11.4
The Vistula river	5	$\bar{x}$ S	8.4 4.5	45.5 13.2	46.1 16.0

For explanations see Table 1

Table 4

Dominant processes and directions of sedimentary transportation, and deviations grain-size parameters of some lithologic indices, at the depth of 2 m

Parameters	Kilometres																							
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
M_z	+	+	+	+	–	+	+	+	+	–	+	+	–	–	–	–	+	+	–	–	–	+	+	+
σ_I	–	–	–	–	+	–	–	–	0	–	–	–	–	+	+	–	–	–	+	+	–	+	+	–
Sk_I	+	+	+	+	–	+	+	+	–	–	+	+	–	+	+	–	+	+	–	–	–	+	–	+
K_G	–	–	–	+	–	–	+	+	+	+	–	+	+	–	–	+	+	+	–	–	+	–	+	+
Quartz/feldspars	+	–	–	–	+	–	+	–	–	+	–	+	–	+	–	–	+	+	+	–	+	+	–	+
Sedimentary rock fragments	–	+	+	+	+	–	–	–	–	–	–	–	+	+	–	–	–	–	–	+	+	+	–	+
Heavy minerals	+	+	–	+	–	+	–	–	–	–	–	–	+	–	–	–	+	–	+	+	+	–	+	+
Grains angular	–	–	–	–	–	+	+	–	+	–	?	+	+	+	+	+	+	+	+	+	+	–	–	–
Dominant process	A				E	A				A–E			E				A		A–E		A			
Dominant directions of sediment transport	→														→			←		→				

A — areas of coastal zone with dominant aggradation processes; E — areas of coastal zone with dominant erosion processes; A–E — areas of coastal zone with both the aggradation and erosion processes of equal intensity; + — positive deviations; – — negative deviations; 0 — no deviations; for other explanations see Table 1 suggests that the Vistula river is one of the sources of deposits supplying the coastal zone of the Vistula Spit. Glacial till in the western part of Gdańsk Bay may be the second source since it contains 65–70% of rounded and subrounded quartz grains and less than 35% of angular grains (M. Michałowska, S. Uścinowicz, 1985).

LITHODYNAMIC INTERPRETATION OF THE STUDY RESULTS

Lithodynamic interpretation of grain-size parameters was based on relative assessment of particular results. Mean values for appropriate grain-size parameters were considered the reference level. Other lithologic factors were also compared to the mean values; this included: the ratio of quartz grains to feldspar grains (quartz/feldspar), content of sedimentary rocks fragments, content of heavy minerals, and proportion of angular grains in the deposits. The image of deviations as obtained for particular lithologic factors is presented in Tables 4, 5, and 6.

In this study an assumption was made that aggradation might be evidenced by:

— positive deviations of both the mean grain diameter (M_z) and the skewness of granulometric distribution (Sk_I);

— negative sorting deviations (σ_I);

— positive deviations of kurtosis of granulometric distribution (K_G);

— decrease of the quartz/feldspar ratio;

— negative deviations in heavy minerals content;

— positive deviations in the content of angular quartz grains;

— positive deviations in the content of sedimentary rocks fragments.

The above makes up the the simplest interpretation model for the obtained results. It is worth while remembering that the Vistula river, supplying sedimentary material to the coastal zone of the Vistula Spit, has an important bearing on such features as granular composition of deposits in the western part of the shoreface, degree of roundness of quartz grains and a number of particular deposit components. In addition, the occurrence of an unsaturated longshore stream may cause the appearance of contradictions in the aforementioned interpretation model.

Bars, and particularly their quantity and height, can also be treated as indicators of lithodynamic processes taking place in the coastal zone. From interpretation of echograms it can be concluded that there are some characteristic sectors along the entire shoreface of the Vistula Spit that differ from each other with respect to morphology of the sea-floor (Fig. 6).

There are as many as four bars developed at the profile 2 km away from the Vistula outlet, that constitute evidence of a large volume of sedimentary material. A characteristic feature of the area between this profile and the one located 8 km away from the Vistula outlet is the presence of two bars being not very high but extensive and visibly undulated. This indicates the predominance of aggradation processes. Only 10 km eastward of the Vistula outlet, the morphology of the sea-floor suggests that this area is subject to washouts of aggraded sediments. The phenomenon of erosion is of local character only since starting at the location 2 km farther eastward of the Vistula outlet the volume of material accumulated in bars increases again. Successive increase of the depth at which bars are being

Table 5

Dominant processes and directions of sedimentary transportation, and deviations of grain-size parameters, at the depth of 5 m

Parameters	Kilometres																							
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
M_z	+	+	+	+	+	+	–	+	–	–	–	–	–	–	+	–	–	–	–	–	+	+	+	–
σ_I	+	+	–	0	–	0	+	0	–	0	–	+	+	+	–	–	–	–	–	–	–	–	–	+
Sk_I	0	+	+	+	+	+	–	+	–	–	–	–	–	–	+	–	+	–	–	–	+	+	+	–
K_G	–	+	+	+	+	+	+	–	–	+	+	+	–	+	–	–	–	–	–	–	–	–	–	+
Dominant process	A							E							A–E						A			E
Dominant directions of sediment transport	→																						←	

Table 6

Dominant processes and directions of sedimentary transportation, and deviations of grain-size parameters, at the depth of 10 m

Parameters	Kilometres																							
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
M_z	+	–	–	–	–	–	–	+	–	–	–	–	–	–	0	–	+	0	+	+	+	+	+	+
σ_I	+	+	0	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sk_I	+	+	+	+	–	–	–	+	+	+	+	–	+	–	+	+	–	–	–	–	–	–	+	–
K_G	–	+	+	+	–	+	–	–	+	+	+	–	–	+	–	+	–	–	–	–	–	–	–	–
Dominant process	A				E			A–E									A							
Dominant direction of sediment transport	→																							

For explanations see Table 4

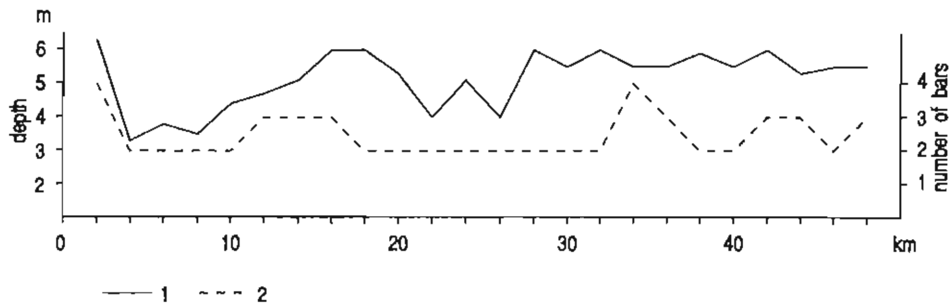

Fig. 6. Characteristics of the sea-floor at the Vistula Spit shoreface
1 — depths of occurrence of the foot of proximal slope of the outermost bar; 2 — a number of bars
Charakterystyka dna podbrzeża Mierzei Wiślanej
1 — głębokości występowania podstawy odmorskiego stoku ostatniej od brzegu rewy; 2 — liczba rew

developed, along the eastward direction up to the 18th km away from the Vistula outlet, proves that the dynamics of the environment intensify in this direction (the wave parameters are also increasing).

Most likely, there is a decrease in the environment dynamics in the area of Kąty Rybackie and Przebrno (between the 20th and 26th km east of the Vistula outlet). The bars in this area are weakly developed, often with their crests cut off; also, they are not too high. In the sector between the 28th and 30th km away from the Vistula outlet, the number of bars and their height indicate shortage of sedimentary material required to saturate the high energy longshore stream.

Abundant sedimentary material which takes part in constructing the bars appears in the east part of the shoreface of the Vistula Spit starting from the Krynica Morska area. Transverse sections through the shoreface exhibit well developed morphology dealing with both the bar slopes and the troughs. The bars are high, their crests are sharp; the troughs reach 6 m in depth.

The deposits at a depth of 2 m, for which the Vistula is one of the sources, are being translocated eastward to the Przebrno or Krynica Morska area (Tab. 4). From calculation, a conclusion can be drawn that 70% of the total annual sediment transportation in the vicinity of the Vistula outlet cone is shared by eastward transportation (M. Tarnowska, R. Zeidler, 1980). Along its course, transport ability of longshore stream increases under the influence of gradually intensifying dynamics of the environment. From such relations the decrease results in the saturation of the sedimentary transportation (J. Onoszko *et al.*, 1980), and consequently a gradual intensification is observed in the erosion processes along the translocation course of the longshore stream. As the result, enrichment in heavy minerals may be recorded within the sediments occurring east of the Skowronki area.

A significant seaward outflow of a large volume of a sedimentary material is taking place in the area east of Przebrno where erosion processes are dominant (in the sector between the 26th and 32nd km away from the Vistula outlet). Deposits are coarser in this area and less sorted than that in other sectors. The remaining lithologic indices except the grain-size parameters seem to indicate the dominant character of aggradation processes in this area. Most likely, exposure of older strata that had been formed within the shoreface under different conditions is the reason why some features typical for aggraded sediments can be found within deposits subjected to erosion. Simultaneously, a part of the sediments is still being translocated eastward up to Krynica Morska, where it is subject to aggradation.

There is no evidence of the existence of large-scale sedimentary transportation at a depth of 2 m in the eastern sector of the Vistula Spit from the Krynica Morska area to the Polish boundary. From the dynamic point of view, the sector seems to be effectively unstable. The sediments are translocated in two directions and both streams are of local extent only. Some difficulties in interpretation of processes in this area can be due to the lack of data for the Russian sector of the Vistula Spit.

The sedimentary transportation at the 5 m depth takes place from the Vistula outlet to the Piaski area (Tab. 5). In the vicinity of Sztutowo, the longshore stream becomes unsaturated; this fact is the reason for the dominance of processes of erosion over aggradation along a significant stretch of the stream. East of Przebrno, the longshore stream is additionally loaded with the sediments having formerly been deposited at the depth of 2 m. This contributes to the change in character of the stream. The volume of sedimentary material becomes sufficient to make the longshore stream saturated. Gradual intensification of aggradation, starting from Krynica Morska to the neighbourhood of Dziady and Piaski, may be caused by the change in hydrodynamic conditions. Considering that the area located 48 km eastward of the Vistula outlet is erosional, an assumption can be made that the Piaski area is being supplementarily supplied with sedimentary material having been translocated from the border area.

The sediments at a depth of 10 m translocate eastward along the entire shoreface (Tab. 6). Initially saturated with sediment load from the Vistula river, the longshore stream improves its transport ability, thus becoming unsaturated. As a result, the area east of Stegna is subject to erosion. In the vicinity of Sztutowo the longshore stream becomes saturated again, and starting from the Krynica Morska area the process deposition of the load grains starts once more giving rise to aggradation.

CONCLUSIONS

A comprehensive analysis of sea-floor deposits sampled at depths of 2, 5, and 10 m along the entire shoreface of the Vistula Spit, combined with an image of the sea-floor as recorded on echograms, allowed for presentation of dominant directions of the sedimentary transportation in the area under study (Fig. 7). From the author's study a conclusion can be drawn that primary transportation of the sea-floor sediments within the Polish segment of the coastal zone of the Vistula Spit is taking place from west to east. The maximum eastward extent of transportation reaching Poland's state boundary occurs at a depth of 10 m. The shortest extent is that in the case of sedimentary transportation which is taking place at the depth of 2 m; this stream is capable of translocating the sediments to the area of Przebrno and Krynica Morska.

In his study R. Gołębiewski (1967) stated that there were two longshore streams of prime importance. According to the R. Gołębiewski's study, the extent of eastward transportation was less than that stipulated by the author of this paper for the depth of 2 m. The said

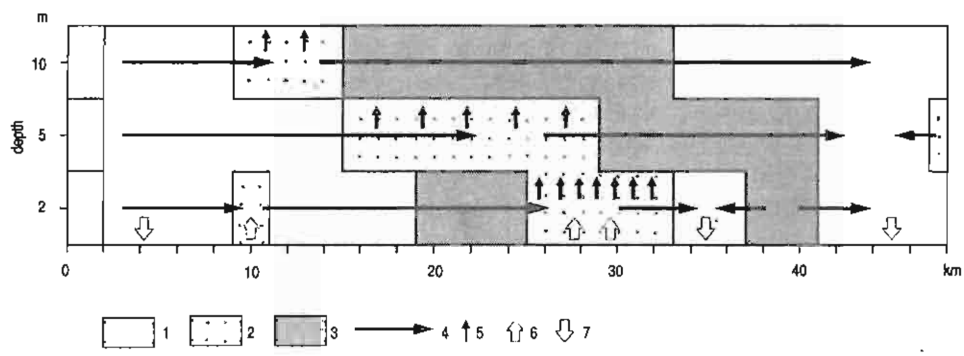

Fig. 7. Dominant directions of sedimentary transportation within the coastal zone of theVistula Spit and the aggradation areas
1 — coastal zone with dominant aggradation processes; 2 — coastal zone with dominant erosion processes; 3 — coastal zone subjected to both erosion and aggradation processes of equal intensity; 4 — longshore sediment transportation; 5 — transversal migration of deposits; 6 — domination of abrasion processes of the shore; 7 — domination of aggradation processes of the shore

Główne kierunki potoków rumowiska w strefie brzegowej Mierzei Wiślanej oraz obszary sedymentacyjne
1 — strefa brzegowa o przewadze procesów akumulacji; 2 — strefa brzegowa o przewadze procesów erozji; 3 — strefa brzegowa o równowadze procesów akumulacji i erozji; 4 — wzdłużbrzegowy transport osadów; 5 — poprzeczne migracje osadów; 6 — przewaga procesów abrazji brzegu; 7 — przewaga procesów akumulacji brzegu

sedimentary transportation is only capable of translocating the sediments to the Sztutowo or Skowronki area. When considering R. Gołębiewski's conclusion that the decrease in depth is followed by decreasing distance that sediments are translocated from the west (his conclusions were based on samples collected at the beach), then findings by the author of this paper may provide confirmation for R. Gołębiewski's work (1967).

S. Musielak (1980) situated a submarine abrasion surface in the vicinity of the eastern boundary of Poland (in the area of Dziady and Piaski, among others). According to him, the abrasion surface is a source supplying the longshore stream moving eastward with sediments. However, the study carried out by the author of this paper did not reveal erosional processes on the sea-floor within the area mentioned by S. Musielak. On the contrary, large volumes of deposited sands were found.

The distance that sedimentary material is transported along the 2 m isobath, as delineated from the degree of roundness of the quartz grains, is consistent with the extent of deposits originated from different supply sources and existing at a depth of 10–50 m (M. Michałowska, S. Uścinowicz, 1985). The maximum transport distance to the west of sediments with dominant angular grains is observed at depth of 10 m, whereas the least extent — at the depth of 50 m. This is consistent with the theory that the decreasing degree of sedimentary transportation toward the east follows a decreasing depth.

The analysis of both the sedimentary zones of the Vistula Spit shoreface as distinguished in this paper and the dominant directions of sedimentary transportation was employed to delineate the places of likely abrasion as well as aggradation of deposits on the sea-shore (Fig. 7). The abrasion of the shore is likely to occur east of Stegna, in the area of Kąty Rybackie, and west of Krynica Morska. Aggradation on the sea-shore may take place in the vicinity of Jantar, Krynica Morska, and Piaski. A study by E. Zawadzka (1989), based on averaged changes of the foot of the fore dunes, reveals the abrasion of the sea-shore occurring in the area of Kąty Rybackie, whereas the aggradation takes place in the area of Krynica Morska and Piaski. According to I. Semrau (1989), three abrasion areas were distinguished here: the first in an area west of Piaski, the second in the vicinity of Przebrno, and the third — in a coastal sector close to the Vistula outlet. The results of the study, based on analysis and lithological interpretation of shoreface deposits, are consistent with observations of processes taking place on the sea-shore; this demonstrates both the effectiveness and the suitability of the lithodynamic study to solving a number of issues of practical importance.

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Oddział Geologii Morza
Państwowego Instytutu Geologicznego
Sopot, ul. Polna 62
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Izabela GÓRECKA

DYNAMIKA POWIERZCHNIOWYCH OSADÓW DENNYCH PODBRZEŻA MIERZEI WIŚLANEJ

Streszczenie

Scharakteryzowano powierzchniowe osady denne podbrzeża Mierzei Wiślanej na odcinku od ujścia Wisły w Świbnie do wschodniej granicy Polski. Próbki osadów pobrano na głębokościach 2, 5 i 10 m, wzdłuż 24 profili prostopadłych do brzegu, odległych od siebie o 2 km. Na podstawie uziarnienia osadów, składu mineralno-petrograficznego, zawartości minerałów ciężkich, stopnia obtoczenia ziarn kwarcu oraz obrazu dna zarejestrowanego na echogramach, wyodrębniono obszary sedymentacyjne podbrzeża Mierzei Wiślanej i określono kierunki przemieszczania się osadów dennych.

Stwierdzono, że ruch osadów podwodnego skłonu Mierzei Wiślanej na głębokości 2 m odbywa się w kierunku wschodnim do okolic Krynicy Morskiej. Na wschód od Przebrna następuje odpływ dużych ilości materiału dennego w stronę morza. Od okolic Krynicy Morskiej do granicy państwa wyodrębniono dwa potoki osadów o zasięgu lokalnym.

Transport osadów dennych na głębokości 5 m następuje od ujścia Wisły do okolic Piasków. Istnieje duże prawdopodobieństwo, że okolice Piasków są zasilane także przez materiał osadowy, pochodzący z rosyjskiej części podbrzeża Mierzei Wiślanej. Brak danych z tego rejonu utrudnia interpretację.

Osady denne na głębokości 10 m przemieszczają się w kierunku wschodnim wzdłuż całego badanego podbrzeża Mierzei Wiślanej.

Na podstawie obrazu dynamiki osadów dennych podwodnego skłonu Mierzei Wiślanej wyznaczono także miejsca możliwej abrazji i akumulacji osadów na brzegu. Wyniki okazały się zbieżne z bezpośrednimi pomiarami i obserwacjami procesów zachodzących na brzegu morskim, wykonanymi przez E. Zawadzką (1989). Świadczy to o przydatności badań litodynamicznych w rozwiązywaniu wielu praktycznych i ważnych zagadnień związanych z brzegiem morskim.