Grain-Size Analysis of the Beach-Dune Sediments and the Geomorphological Significance

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Abstract. Textural parameters are regarded as precious informational source for the genesis and evolution of coastal sedimentary environments. The purpose of this paper is to give a detailed insight of the grain size, sorting and skewness of sediments from the beach-dune system as well as to establish the relationships between them, the local characteristics of shaping agents and the coastal morphological units. Based on 139 sand samples prelevated from the beach-dune system of the Sărăturile beach ridge plain and of the Sacalin barrier Island, multivariate statistical analyses were used to emphasize the relations between the textural parameters with the morphology and the distance up to sediment sources. The main findings are (i) a slight increase of the grain size from south to north or better expressed from Danube mouth to the updrift side of Sărăturile beach ridge plain, (ii) a net difference in sorting pattern along transverse profiles from the northern Sacalin showing that beaches and foredunes exposed to the resultant wind drift direction (RDD), respectively to the north and north-east, are better sorted than those disposed discordant to the RDD.

Keywords: mean diameter, sorting, asymmetry, beach-dune system, flow mouth, Sfântu Gheorghe shore

1. Introduction

Grain size, sorting and skewness are the sediment textural parameters that give important information on the origin and evolution of coastal sedimentary environments (Carranza-Edwards, 2001). In fact, grain size distribution reflects both the fluidity (viscosity) and energetic factors of depositional environments (Sahu, 1964), having in mind the notable studies of the last 50 years that advanced different criteria and differentiation methods for the sedimentary depositional environments, based on textural parameters and derived indexes (Folk and Ward, 1957; Friedman, 1961; 1979; Sahu, 1964; Moiola and Weiser, 1968; Sagga, 1992).

Sediment mineralogical composition and texture on the Danube delta coast were assessed by the National Geology and Ecology Institute - GeoEcoMar, one of the main objectives being heavy minerals content determination (Fulga Costina in Stănică et al., 1998). The results of these reports and of other determinations are discussed by Stănică A., (2003) in the chapter dedicated to sediment analysis on the Sulina-Sfântu Gheorghe interdistributary shore. Comparing with the previous determinations where samples were prelevated along the shoreline within the beach face and emerged beach domains, the present study emphasizes the detailed transversal disposition of textural parameters on the emerged shore, and the detection of potential connections between sediment textures, local characteristics of the shaping agents and relief sub-units.

Our analysis focuses on sediment texture within the beach-dune systems correspondent to Sărăturile beach ridge plain and north-Sacalin Island, using multivariate statistical analyses that highlight the relation between orientation of the energetic factors and the grain size, sorting and kurtosis in sedimentary environments, their disposal within the seashore area, the presence in different landform types, the distance up to the sediment sources.

2. Methodology

139 sediment samples were taken in October 2004, following transversal morpho-sedimentologic profiles over the beach-dune system that covered a 10 km longshore distance, including all shore subunits: beach face (BF), beach face crest (BFC), summer berm (SB), high beach (winter berm – WB), dune stoss slope (SS), crest (DC) and lee slope (LS). Profiles location is shown in Figure 1. For a thorough analysis of the shape-grain size analysis, samples were prelevated on 9 parallel profiles normal/perpendicular to waterline and delimited by 5 meters intervals at R 48 benchmark situated 2.2 km north of Sfântu Gheorghe arm mouth. The total station was used to determine the *X*, *Y* and *Z* coordinates for each sample, reporting the height (*Z*) to local sea level.

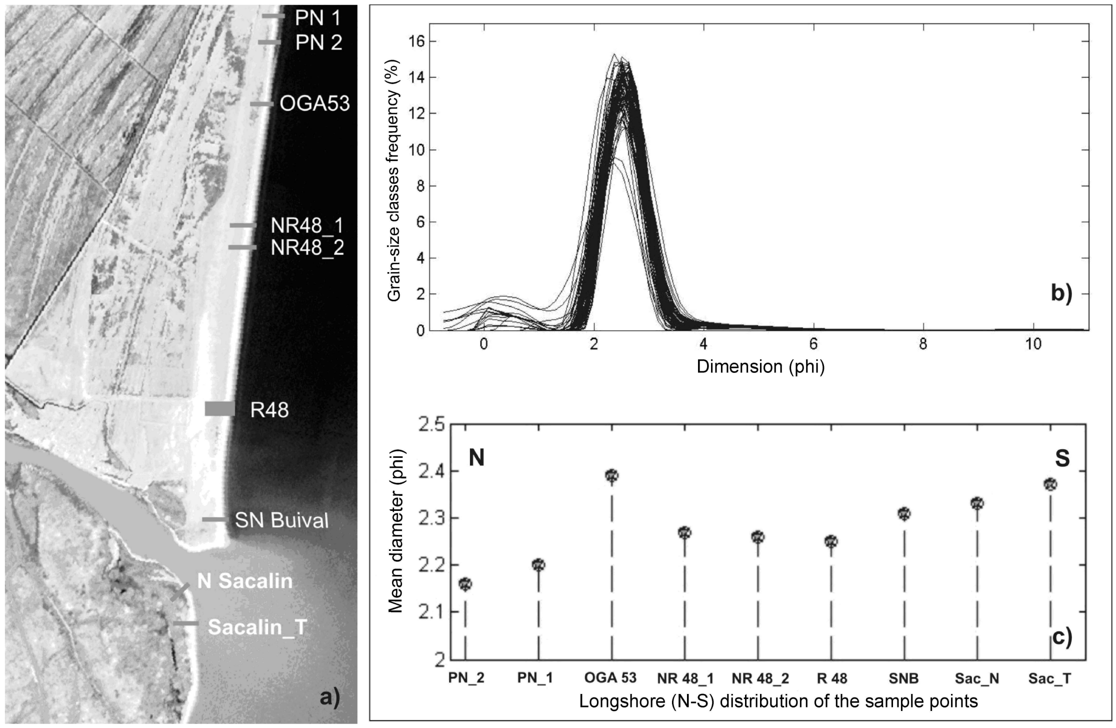

Fig. 1: **a) Morpho-sedimentologic profiles location; b) Grain-size frequency curves representation; the unimodal grain size character of sediments forming the fordunes and beach berms and the beach face bimodal character are visible; c) Longshore grain size distribution; the mean values of the samples collected on each profile are represented**

Sediment textural parameters were determined using the LS 13320 analyzer by LSDPA technique (*Laser Diffraction Particle Size Analysis*). In contrast with the sieving sediment analysis method (used in the previous studies on the Romanian Black Sea coast), the laser technique gives an increased accuracy in obtaining the textural parameters thanks to the high number of grain-size thresholds (84), ranging between 0.375 μm and 1821.88 μm. In the present work we used the Udden-Wentworth grain-size scale (Wentworth, 1922) modified by Krumbein (1934) and the formulas used in calculating the textural parameters by graphical methods (Folk and Ward, 1957; Folk, 1974). Thus, the primary data series expressed in microns was converted into phi (Φ) units and cumulatively represented. A one-dimension interpolation was applied to determine the exact statistic thresholds dimension according to each data range (Φ_5, Φ_{16}, Φ_{25}, Φ_{50}, Φ_{75}, Φ_{84}, Φ_{95}).

3. Results and Discussions

All the analyzed sediment samples are graphically represented in figure 1b). This grain-size overview for the Sfântu Gheorghe beach sediments shows fine sand (2-3 Φ / 0.25-0.125 mm) prevalence; the module and the grain-size averages groups in the fine sand class, no matter of the sampling point's position, most of the collected samples displaying a unimodal grain-size curve. This does not apply to the samples collected from the median beach face sector which present a bimodal distribution in all cases, with the high peak in the fine sand class and the secondary peak in the coarse sands (0-1 Φ / 1-0.5 mm) category. The second grain-size interval is an exception of the beach-dune system sediments grain-size overview, explained by the source-area exclusively modelled by waves uprush and backwash action, which creates an energy system superior to the subaerial ones, where the other samples were collected. Mean sand grain diameter within the beach-dune system is **2.28 Φ (0.205 mm)**; by excluding the samples from the median beach face sector (except for the BFC ones), mean grain-size for the subaerial beach-dune system component is 2.32 Φ (0.2005 mm).

Considering the mean values, longshore grain-size study reveals the decrease in sand particle mean diameter towards south, from the north sector of the Sărăturile beach ridge plain to Sfântu Gheorghe arm mouth and further, in the north of Sacalin Island. The gradual decrease in mean grain-size occurs in accordance with the main net sediment transport direction (north - south), proving the one-way trend of the major sediment transport processes: 1.002.380 m^3/yr (net sediment volume transported toward south), with a 2.9 ratio between the solid discharges of the two alternating north–south and south–north currents (Vespremeanu-Stroe, 2007). The calculated mean grain-size values range between 2.35 Φ near Sfântu Gheorghe mouth and 2.15 Φ at 8 km northward (Fig. 2).

The sedimentary material within the investigated area is generally *well sorted*, except for several samples collected from dunes crest, which correspond to *very well sorted* materials and the samples taken from the beach face, varying from *moderately sorted* and *moderately well sorted*. Notable differences occur between the inferior poor-sorted and median sector of the beach face system, the latter showing moderate sorting and higher grain-size values, and the very well sorted fine sand of the beach face crest, comparable with fordunes[1] material.

The spatial distribution of sorting degree in the beach-dune system indicates a good correlation between the material sorting degree and the prevailing acting agent. The sediments composing beach subunits subjected to wave action and evolving in a strong and variable modeling energy system (BF) present a lower sorting degree (σΦ) than the sedimentary substrate of the wind-shaped subaerial units (Fig. 3). The simultaneous sediment input reduction, process intensity and modeling factors number decrease contribute to the well sediment sorting degree maintenance. Sorting degree distribution over the beach-dune system highlights a very subtle distinction in sand transport capacity marked by different class dimension concentration in the distinct system subunits.

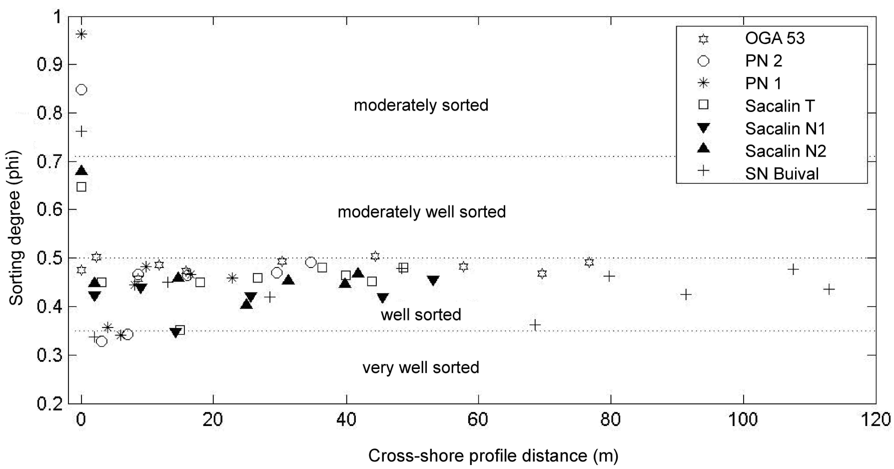

Fig. 2: **Sediment sorting: cross-shore and longshore profiles**

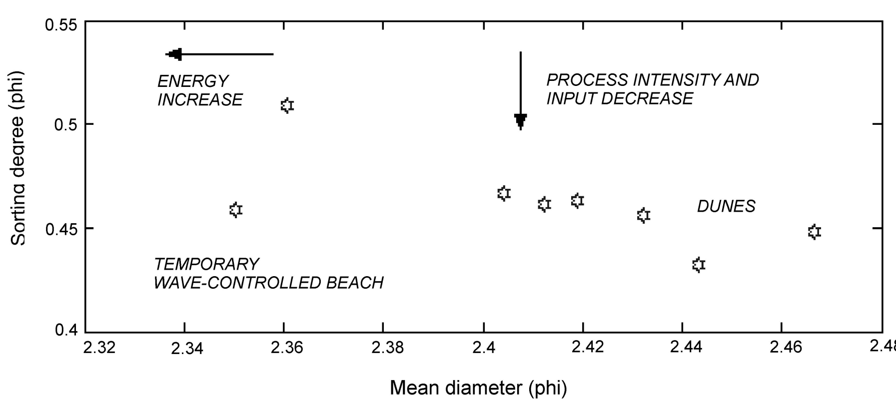

Fig. 3: **Mean sand grain diameter and sorting in different subzones of the beach-dune system** (modified from Carranza-Edwards, 2001)

[1] Fordunes (avandunes) are the coastal dune belt in the immediate proximity of the beach. This term is used to avoid any confusion about their position. Thus, the term coastal dunes have a more comprehensive meaning and regards altogether fordunes, dune belts, individual dunes or dune fields situated behind the foredunes.

The undertaken analyses indicate a sediment fraction distribution from medium and coarse on the central-inferior sector of the beach face to fine particles stored in dunes, and on the summer berm where very well sorted sediments transported by the offshore and longshore winds and overwash discharged sediments are present (Fig. 5a). This is supported by the asymmetry of the grain-size representation curve, which, in this case, indicates a positive asymmetry in dunes and also on the high winded (eolisated) beach (winter berm), as the very fine sand classes prevail, comparing to coarse sand (Fig. 5b).

The bimodal grain-size frequency curves represented for the beach face sector imposes a negative sediment asymmetry, due to coarse sand occurrence. Most of the samples present a moderated kurtosis distribution within the fordunes, which accentuates on the beach face (Fig. 5c).

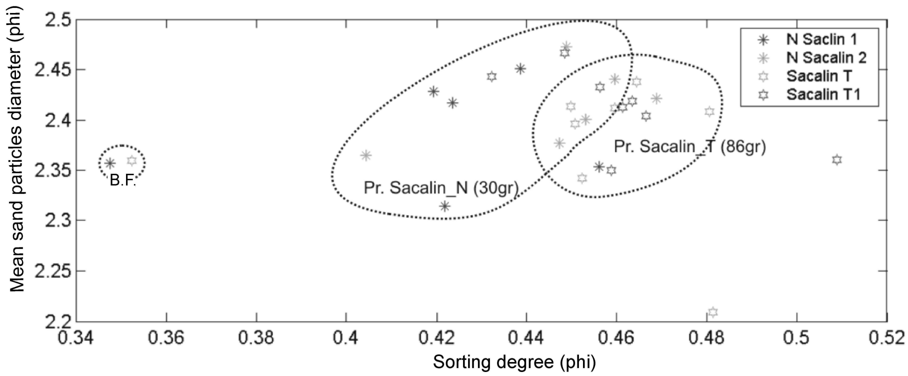

Fig. 4: **Grain sorting differentiation induced by profile orientation and the exposure to DRD**

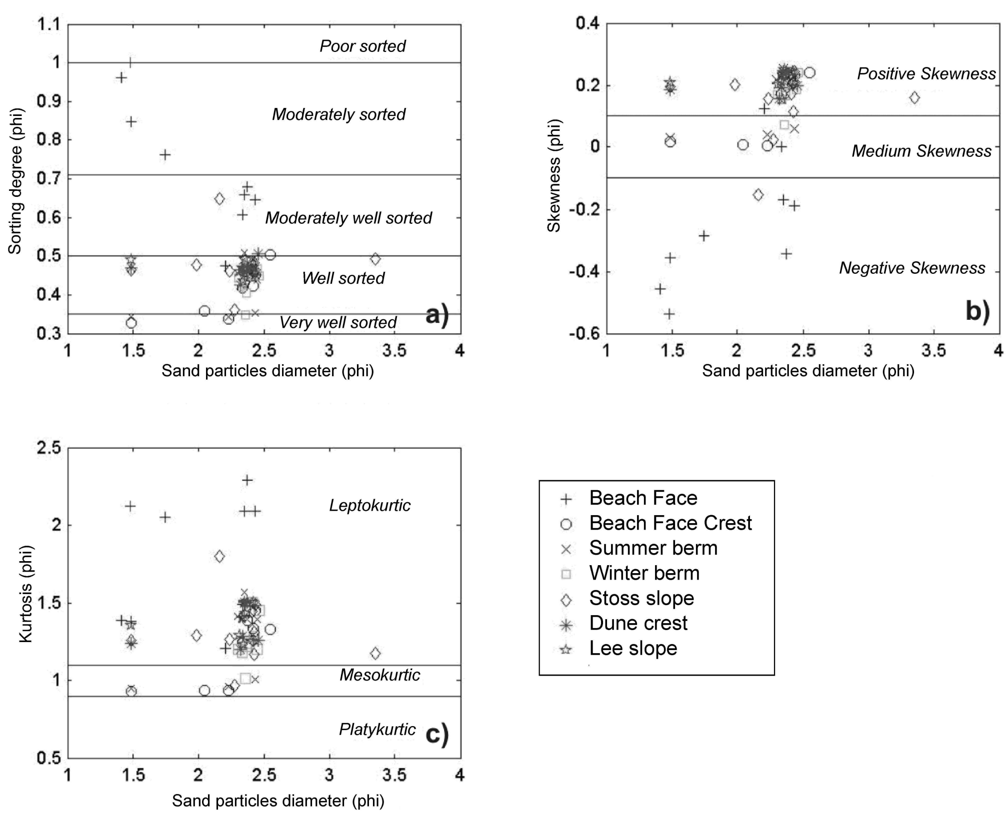

Fig. 5: **Morphological beach-dune system subunits representation by bivariate relations between mean grain size and (a) sorting, (b) asymmetry, (c) kurtosis**

Figure 4 describes the correlation between grain size and sorting on four profiles in two sectors in the north side of the Sacalin Island. Although the two sectors (Sacalin_N vs. Sacalin_T) are only separated by a 300 m distance, the sorting degree clearly changes, because of the difference in shoreline orientation and implicitly, in waterline perpendicular morpho-sedimentologic profiles. The Sacalin_N profiles have a 30° orientation (the angle between North and profile alignment), while the Sacalin_T profiles are 86° oriented. Considering that the aeolian sediment transport drift resultant direction (DRD) is NNE – 197.1° (Preoteasa and Vespremeanu-Stroe, 2004), the Sacalin_N profiles orientation generally corresponds with DRD (approximately 15° difference), while the Sacalin_T profiles and DRD are clearly discordand (cca. 70° difference). The comparative analysis of the textural parameters at the two locations presents significant differences in sediment sorting: a better sorted sand in Sacalin_N than in Sacalin_T because of the direct beach-dune system exposition to DRD at the first location (*proxy* for aeolisation potential prevailing winds direction: NNV-NE). This finding (the correlation between sediment sorting and DRD exposure) should be verified in other coastal environments. The decrease tendency in mean grain diameter toward south maintains on Sacalin I., in accordance with the longshore net sediment transport.

4. Conclusions

Fine and medium sands (from 1 to 3 Φ / 0.12 to 1 mm) category, followed by coarse sands (from 0 to 1 Φ/ 0.5 to 1 mm) in the beach face median-inferior sectors prevail in the analyzed beach-dune system. The modulus and grain size average range in the class of fine sands, irrespective of the sampling point's position, most of the samples showing a unimodal grain-size scale; exceptions are the samples collected from the median beach face sector which exclusively register a bimodal distribution.

The overtaken analyses indicate a sedimentary fractions distribution from coarse on the beach face, to the finest, stocked in dunes (due to aeolian sorting) and on the summer berm (marine sorting through overwash processes and aeolian sorting during longshore and offshore winds).

A decreasing trend of the mean sediment diameter was detected on north to south longshore profile, as approaching Danube's mouth.

The analysis of the samples prelevated on the Sacalin Island demonstrates the correspondence between sorting degree and sediment exposure to the modeling agent (wind drift). In this case, the better sorting of the Sacalin_N samples, where the cross-shore profiles are conformably oriented to the DRD (approximately 15° difference) is relevant, comparing to the Sacalin_T profiles, discordantly oriented.

The sediments composing the beach subunits under wave incidence, in a high modeling energy system (BF and BFC), show a lower sorting degree than the sedimentary substrate of subaerial wind-modeled units. The sedimentary material within the analyzed area is *well sorted*, except for several samples collected from fordunes which ranges in the *very well sorted* material class and the samples prelevated on the beach face, oscillating from *moderately well sorted* and *moderately sorted*.

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ANNEXES

Profile name Position – UTM coord.	Location	Distance (m)	Mean size (Mz-Φ)	Sorting (σ)	Asymmetry (SK)	Kurtosis (KG)
PN_1 N: 4978357 E: 676530	FP	0	1.411	0.963	-0.456	1.387
	CFP	4	2.047	0.358	0.008	0.935
	BV	6	2.225	0.342	0.04	0.961
	BC	8.1	2.307	0.445	0.17	1.199
	BI	9.7	2.425	0.482	0.208	1.31
	VM	16.5	2.422	0.467	0.201	1.262
	CD	22.8	2.316	0.459	0.203	1.293
PN_2 N: E:	FP	0	1.483	0.848	-0.357	1.381
	CFP	3	2.15	0.328	0.016	0.928
	BV	7	2.208	0.342	0.029	0.949
	BV	8.5	2.453	0.467	0.186	1.2
	BI	16	2.443	0.465	0.194	1.257
	VM	29.6	2.381	0.469	0.186	1.238
	CD	34.6	2.305	0.491	0.207	1.357
OGA 53 N: E:	FP	0	2.206	0.475	0.124	1.204
	CFP	2.2	2.546	0.502	0.24	1.329
	BV	8.5	2.299	0.457	0.219	1.410
	BV	11.7	2.39	0.486	0.198	1.237
	BV	15.8	2.42	0.474	0.209	1.258
	BI	30.4	2.356	0.494	0.161	1.173
	BI	44.4	2.459	0.505	0.198	1.258
	VM	57.8	2.462	0.483	0.231	1.35
	CD	69.5	2.413	0.469	0.223	1.345
	VU	76.8	2.36	0.492	0.249	1.43
NR 48_1 N: E:	FP	0	2.196	0.607	0.002	1.49
	CFP	3.2	2.298	0.419	0.173	1.247
	BV	7	2.333	0.487	0.224	1.391
	BV	13.7	2.426	0.453	0.2	1.285
	BV	20	2.162	0.456	0.114	1.166
	BI	26.8	1.981	0.648	-0.152	1.8
	BI/SS	39.3	2.43	0.476	0.203	1.287
	VM	52.3	2.307	0.465	0.194	1.285
	CD	69.1	2.385	0.489	0.220	1.376
	VU	79.1	2.253	0.47	0.212	1.397
NR 48_2 N: E:	FP	0	1.96	0.648	-0.181	-
	CFP	4	2.255	0.507	0.217	-
	BV	8	2.236	0.459	0.158	-
	BV	14.5	2.323	0.405	0.126	-
	BV	21	2.448	0.477	0.213	-
	BI	29	2.405	0.482	0.216	-
	BI/SS	38	2.308	0.469	0.17	-
	VM	50.3	2.365	0.454	0.198	-
	CD	68.5	2.026	0.646	-0.122	-
	VU	81	2.33	0.496	0.184	-
R 48 N: E:	FP	0	1.413	1.181	-0.404	1.534
	CFP	4	2.395	0.488	0.233	1.461
	BV	9	2.483	0.533	0.244	1.528
	BV	18	2.38	0.484	0.237	1.425
	BV/BI	26	2.312	0.488	0.222	1.37
	BI	34	2.323	0.468	0.215	1.341
	BI	41.5	2.326	0.487	0.201	1.307
	VM	52	2.426	0.506	0.242	1.412
	VM	66.8	2.389	0.486	0.225	1.388
	CD	79	2.331	0.464	0.218	1.365
	VU	85.5	2.349	0.479	0.24	1.445
	VU	89	2.349	0.535	0.21	1.469

Profile name Position – UTM coord.	Location	Distance (m)	Mean size (Mz-Φ)	Sorting (σ)	Asymmetry (SK)	Kurtosis (KG)
SN Buival N: E:	FP	0	1.746	0.762	-0.285	2.049
	CFP	2	2.225	0.337	0.006	0.935
	BV	13	2.411	0.451	0.206	1.36
	BV	28.5	2.332	0.42	0.155	1.183
	BI	48.5	2.44	0.478	0.224	1.405
	BI/VE	68.5	2.273	0.362	0.024	0.966
	VM	79.8	2.238	0.462	0.156	1.264
	D	91.3	2.317	0.426	0.156	1.203
	CD	107.6	2.374	0.477	0.184	1.405
	VU	113	2.343	0.436	0.153	1.23
N Sacalin_1 N: E:	FP	0	1.48	1.0	-0.538	2.124
	CFP	2	2.417	0.424	0.204	1.338
	BV	9	2.451	0.439	0.22	1.392
	BV	14.2	2.357	0.348	0.074	1.01
	BI	25.6	2.314	0.422	0.152	1.191
	VM	45.6	2.429	0.419	0.203	1.331
	CD	53.1	2.353	0.456	0.241	1.503
N Sacalin_2 N: E:	FP	0	1.724	0.679	-0.345	2.291
	CFP	2	2.473	0.449	0.242	1.387
	BV	14.6	2.44	0.46	0.244	1.504
	BV/BI	25	2.365	0.404	0.167	1.221
	BI/VM	31.3	2.4	0.453	0.205	1.299
	CD	39.8	2.377	0.447	0.211	1.362
	VU	41.8	2.4221	0.469	0.244	1.505
Sacalin T_1 N: E:	FP	0	2.027	0.647	-0.189	2.087
	CFP	3	2.396	0.451	0.23	1.451
	BV	14.9	2.359	0.352	0.06	1.009
	BI	18	2.414	0.45	0.244	1.505
	BI	26.6	2.412	0.46	0.231	1.446
	BI/VM	36.4	2.209	0.481	0.173	1.443
	VM	39.9	2.438	0.464	0.243	1.489
	CD	43.9	2.342	0.452	0.235	1.486
	VU	48.7	2.408	0.481	0.259	1.571
Sacalin T_2 N: E:	FP	0	2.01	0.659	-0.17	2.088
	CFP	3	2.443	0.432	0.232	1.42
	BV	14.5	2.361	0.509	0.252	1.569
	BI	28	2.467	0.449	0.24	1.449
	BI	38.1	2.412	0.461	0.241	1.486
	VM	46.5	2.448	0.5	0.271	1.626
	VM	55.1	2.432	0.456	0.241	1.447
	CD	59.6	2.413	0.463	0.242	1.487
	VU	61.6	2.35	0.459	0.221	1.41
	VU	63.1	2.404	0.467	0.24	1.499

Database table – Sediment textural parameters in the beach-dune system; the R 48 benchmark presents only the base-profile values; For location the following abbreviations were used: BF – beach face; BFC – beach face crest; SB – summer berm, WB – high beach (winter berm), SS – stoss slope, DC – dune crest, LS – lee slope.

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