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Original article

Beach and dune deposits on the Mediterranean coast of Andalusia (Spain) in the light of morphoscopic analysis of quartz grains

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ABSTRACT

This work aimed to investigate the abrasion of quartz grains from beach and dune deposits on the Mediterranean coast of Andalusia. Five sites were established on the coasts of Malaga and Almeria provinces: Genoveses, Monsul, Carraca, Malagueta, and Artola. Grain size and mineral composition were determined for 15 samples taken from beaches (6) and dunes (9). Quartz abrasion was established using the morphoscopic method. Investigated deposits, with two exceptions, are primarily medium-grained and moderate sorting. The share of quartz is relatively small – in aeolian sands, it is on average 38.3% and is higher than in beach sands (average 26.4%). The average proportion of fresh and angular NU grains is significantly higher in aeolian sands (58.9%) than beach sands (43.4%), indicating morphoselection's important role during wind transport. In beach sands, there are, on average, 32.4% of grains with aeolian abrasion (RM and EM/RM), which is twice as much as in dune sands (15.5%). The multiple predominances of EM/RM grains over RM grains indicate a relatively short aeolian activity.

KEY WORDS: coastal dunes, aeolian processes, quartz grain abrasion, morphoscopic analysis, Mediterranean coast

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1. Introduction

In Spain, coastal research has been conducted very dynamically for several decades. It concerns various issues, both natural and socio-economic, including coastal geology and geomorphology, sea level changes, coastal erosion, ecosystems, nature conservation, land use, tourist development, coastal management and others (e.g. ZAZO ET AL., 2013; DE ANDRÉS ET AL., 2017; MOLINA ET AL., 2020; MARRERO-RODRÍGUEZ & DÓNIZ-PÁEZ, 2022; MOLINA-GIL ET AL., 2022; ALCORLO ET AL., 2023; MARTORELL ET AL., 2023; MOLNER ET AL., 2024; TOLEDO ET AL., 2024a). One of the research problems undertaken is also the evolution of coastal dunes and the recognition of the relationship between the beach and the dune in various environmental conditions (e.g. ROMÁN-SIERRA ET AL., 2004; GUTIÉRREZ-BECKER, 2008; MUÑOZ-PEREZ ET AL., 2009; NAVARRO ET AL., 2011; SANJAUME & GRACIA PRIETO, 2011; BELLO-MILLÁN ET AL., 2016; NAVARRO-PONS ET AL., 2016; GARCÍA-ROMERO ET AL., 2019; FLOR-BLANCO ET AL., 2021; ARCE CHAMORRO ET AL., 2022; MIR-GUAL ET AL., 2023). Spain's coastal dune systems are diverse, resulting from the presence of both low coasts, supplied with sand by large rivers, and rocky coasts with material supplied by cliffs and shelves and by smaller rivers. These deposits are transported longitudinally by coastal currents, leading to the formation of many beaches and the subsequent development of dunes (SANJAUME & GRACIA PRIETO, 2011).

In Spain, larger dune systems occur on the Atlantic coast, with the largest dune field of Doñana being the most prominent (Rodríguez-Ramírez et al., 1996; Rodríguez-Vidal et al., 2014). There are fewer dunes on the Spanish Mediterranean coast due to the limited tidal ranges and the relatively smaller proportion of sandy deposits (Sanjaume & Gracia Prieto, 2011). Dunes are located here mainly on low coasts with mouths of the largest Mediterranean rivers carrying significant amounts of sand – Ebro, Llobregat, Fluvia, Ter, Turia, Segura and others (Rodríguez-Santalla et al., 2009, Pintó & Garcia-Lozano, 2016). Larger dune areas, apart from those located in the Ebro Delta, include the Empordá, Devesa del Saler, Guardamar de Segura, and San Pedro del Pinatar dunes (Sanjaume, 1988. Sanjaume & Gracia Prieto, 2011; Ibarra-Marinas et al., 2021; Toledo et al., 2024b). Limited conditions for the formation of dunes occur at the mouths and around the ramblas, characterized by the coarse-grained fraction's dominance and the sand fraction's deficiency.

Among the various aspects of the functioning of beach–dune systems on the coasts of Spain, the degree of abrasion of coastal deposits is relatively rarely studied (e.g., Kalińska & Nartišs, 2014; Arce Chamorro et al., 2022). This paper addressed this issue by presenting the research results on the degree of abrasion of quartz grains from beach and dune deposits on the Mediterranean coast of Andalusia.

2. Study area

The study area is located in Spain, on the Mediterranean coast of Andalusia. Geologically, it belongs to the Betic Mountains, the western segment of the Mediterranean alpine orogen. This area began to form in the Miocene due to the convergence between the African and Eurasian plates and the thrust of the Alboran plate. The Betic mountain ranges are characterized by the highest seismic activity on the Iberian Peninsula. The Mediterranean coast of Andalusia belongs to the Internal Betics Zone, composed of various rocks – sedimentary, igneous, and metamorphic. The Cabo de Gata area is composed of Neogene volcanic rocks, and the southwestern part of the coast is composed of flysch units (Campo de Gibraltar) (Vera, 2004).

The Mediterranean coast of Andalusia is morphologically diverse. From Tarifa to Gibraltar, the coast is rocky and exposed, while the long stretch of coast from Gibraltar to Cape de Gata is closely bordered by high mountains behind a narrow coastal plain along which are many beaches and shallow but exposed bays (Schwartz, 1982). Near Malaga and beyond, the coastal strip is narrow, and beyond it, the mountains rise steeply; apart from the lowlands of Motril and the Llanos de Almeria, this applies in general to the whole coast up to the Andalusian border with Murcia. Research sites were established on the coasts of two provinces of Andalusia – Malaga and Almeria (Fig. 1).

3. Materials and methods

Five sites were established on the Andalusian Mediterranean coast: Genoveses, Monsul, Carraca, Malagueta, and Artola (Fig. 1). Samples (15) weighing 200–300 g were collected from the surface from a depth of 10–15 cm. For all samples, basic grain size indices were determined according to the formulas of Folk & Ward (1957), using mainly the mean grain diameter Mz and δ sorting in this analysis. One to two teaspoons of sand were taken from the 0.8–1.0 mm and 0.5–0.8 mm fractions to analyze the mineral composition and quartz grain abrasion. The mineral composition was determined in a simplified manner but sufficient to assess the influence of the aeolian process on the deposit. The following were isolated: less resistant shells and carbonate minerals, more resistant quartz and non-quartz minerals (without marking, with different resistance). It was assumed that the greater the share of quartz grains, the longer the aeolian process lasts (Mycielska-Dowgiałło & Woronko, 1998; Woronko, 2012). The number of quartz grains counted for testing ranged from 100 to 800.

The abrasion of quartz grains was studied using the Cailleux morphoscopic method (1942), modified by Mycielska-Dowgiałło & Woronko (1998), using an optical microscope. The following grains are separated in this method: broken C, fresh and angular NU with a rounding degree of 0.1–0.2 on the Krumbein scale (1941), very well rounded and shiny EL with a rounding degree of 0.7–0.9, very well rounded and matt RM with a rounding degree of 0.7–0.9, moderately rounded and shiny EM/EL with a rounding degree of 0.3–0.6, and moderately rounded and matt EM/RM with a rounding degree of 0.3–0.6.

Shiny grains (EL, EM/EL) indicate long/short-time abrasion in fluvial or beach environments, and mat grains (RM, EM/RM) indicate long/short-time abrasion in aeolian environment. It should be noted that quartz grains in the beach environment in warm climate zones, in addition to mechanical abrasion, are also subjected to chemical etching (SETLOW, 1978). As a result of this process, a grain matting effect may occur (GOŹDZIK & MYCIELSKA-DOWGIAŁŁO, 1982; MYCIELSKA-DOWGIAŁŁO, 1988). It cannot be ruled out that under a scanning electron microscope (SEM), some of the grains classified as EM/RM type would be recognized as matte grains due to chemical etching.

It was assumed that the measure of the duration of the aeolian process is the ratio of RM and EM/RM grains – if there are more RM grains than EM/RM, then the aeolian processes operated for a long time and vice versa (MYCIELSKA-DOWGIAŁŁO & WORONKO, 1998, WORONKO, 2012).

Fig. 1. Location of the research sites on the Mediterranean coast of Andalusia

4. Results and discussion

Figures 2 and 3 below present the mineral composition of 0.8–1.0 mm and 0.5–0.8 mm fractions for samples from individual sites. Tables 1–3 present data on grain size and quartz grain abrasion in the above-mentioned fractions.

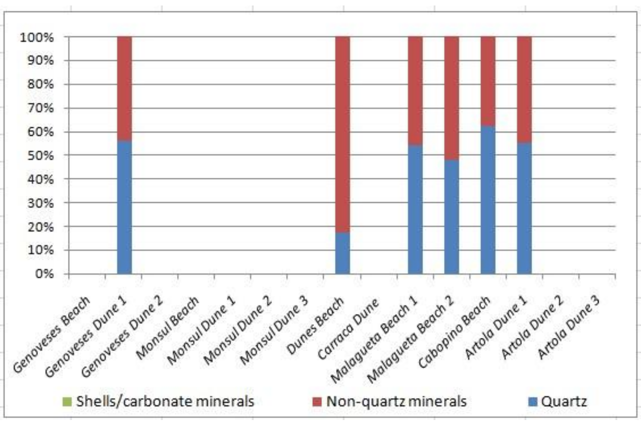

Fig. 2. Mineral composition of the fraction 0.8-1.0 mm (no column means no fraction or non-representative number of grains in the sample)

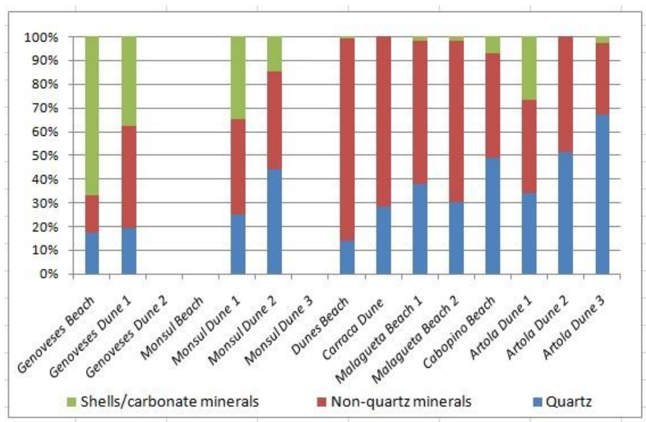

Fig. 3. Mineral composition of the fraction 0.5-0.8 mm (no column means no fraction or non-representative number of grains in the sample)

Table 1. Mean grain size (Mz) and sorting (δ)

Site	Sample	Mean Mz [mm]	Mean sorting δ [phi]
Genoveses	Genoveses Beach	0.358	0.58
	Genoveses Dune 1	0.321	0.58
	Genoveses Dune 2	0.261	0.57
Monsul	Monsul Beach	0.287	0.59
	Monsul Dune 1	0.302	0.70
	Monsul Dune 2	0.415	0.58
	Monsul Dune 3	0.356	0.50
Carraca	Dunas Beach	0.310	0.81
	Carraca Dune	0.316	0.72
Malagueta	Malaqueta Beach 1	0.616	0.59
	Malaqueta Beach 2	0.451	1.06
Artola	Cabopino Beach	0.266	1.13
	Artola Dune 1	0.242	0.62
	Artola Dune 2	0.302	0.62
	Artola Dune 3	0.325	0.95

Table 2. Quartz grain abrasion in the fraction 0.8–1.0 mm

Site	Sample	Quartz grain abrasion [%]					
		C	NU	EL	EM/EL	RM	EM/RM
Genoveses	Genoveses Beach	non-representative number of grains					
	Genoveses Dune 1	0	37	0	21	0	42
	Genoveses Dune 2	no fraction 0.8-1.0 mm					
Monsul	Monsul Beach	no fraction 0.8-1.0 mm					
	Monsul Dune 1	non-representative number of grains					
	Monsul Dune 2	non-representative number of grains					
	Monsul Dune 3	no fraction 0.8-1.0 mm					
Carraca	Dunas Beach	0	55	0	10	0	35
	Carraca Dune	no fraction 0.8-1.0 mm					
Malagueta	Malaqueta Beach 1	5	50	6	15	0	26
	Malaqueta Beach 2	4	49	3	7	3	34
Artola	Cabopino Beach	3	42	2	12	3	38
	Artola Dune 1	0	43	0	19	0	38
	Artola Dune 2	no fraction 0.8-1.0 mm					
	Artola Dune 3	no fraction 0.8-1.0 mm					

Table 3. Quartz grain abrasion in the fraction 0.5–0.8 mm

Site	Sample	Quartz grain abrasion [%]					
		C	NU	EL	EM/EL	RM	EM/RM
Genoveses	Genoveses Beach	0	57	0	8	2	33
	Genoveses Dune 1	0	52	0	25	0	23
	Genoveses Dune 2	no fraction 0.5-0.8 mm					
Monsul	Monsul Beach	non-representative number of grains					
	Monsul Dune 1	0	75	0	16	0	9
	Monsul Dune 2	1	64	0	12	0	23
	Monsul Dune 3	no fraction 0.5-0.8 mm					
Carraca	Dunas Beach	3	74	0	6	4	13
	Carraca Dune	0	88	1	4	0	7
Malagueta	Malaqueta Beach 1	3	32	6	30	0	29
	Malaqueta Beach 2	3	36	6	22	3	30
Artola	Cabopino Beach	6	18	9	19	9	39
	Artola Dune 1	0	60	13	9	0	18
	Artola Dune 2	0	52	12	27	0	9
	Artola Dune 3	1	21	17	41	3	17

4.1. Genoveses site

The Genoveses site is located in the province of Almeria, about 3 km south of San Jose. The site's name refers to the beach and dune fields in a small Mediterranean cove in the Sierra de Cabo de Gata mountain range. The area comprises Miocene volcanic rocks (rhyolitic ignimbrites and andesitic lava flows and surges). The relief is distinguished by domed and conical elevations descending with cliffs to the sea (Rigol & Chica-Olmo, 1998; Fernández, 2003). Several dune systems have been identified at lower altitudes, both fossil from the last interglacial period and Holocene, including currently mobile ones with the participation of the dominant north-easterly winds (Bardají et al., 2011). Some dunes climb the slopes of the hills, adapting to the morphology of the volcanic substrate. Due to its natural values, the area is protected as the Cabo de Gata-Níjar Natural Park and Geopark (Labus, 2009; Lorenc & Janusz, 2019). It is the driest area in Europe, with an annual rainfall of about 150 mm (AEMET, 2024).

Samples were taken from the central part of the beach (length about 1.5 km) and from the proximal slope and the culmination of one of the small dunes in the southern part of the cove (Fig. 4). In the surroundings of this mobile dune, cemented oolitic dunes from the last interglacial period are exposed (Bardají et al., 2009). All samples of deposits represent moderately sorted (δ is 0.57–0.58) medium-grained sands, but grain size refinement is noticeable from the beach (Mz – 0.358 mm) through the proximal slope (Mz – 0.321 mm) to the dune culmination (Mz – 0.261 mm) (Table 1).

Fig. 4. General view of the Genovese Beach with small dunes in the foreground

In the beach sands, the 0.8–1.0 mm fraction is mainly shells, and the number of quartz grains was not representative of the abrasion degree studies (Fig. 2). In the sample from the dune peak, neither the above nor the 0.5–0.8 mm fraction occurred at all (Fig. 3). Therefore, a comparative analysis of beach and aeolian sands from the proximal slope of the dune was carried out for the 0.5–0.8 mm fraction. The share of quartz grains is small and amounts to 17% and 19%, respectively. The beach sands are dominated by shells (67%), which are almost twice as small on the proximal slope of the dune (37%), but at the same time, as much as 42% are non-quartz minerals (Fig. 3). Both sediments are characterized by a dominant share of NU grains – fresh and angular, 57% and 52%, respectively (Table 3). It is significant that in beach sands, grains associated with the water environment (EL and EM/EL) constitute only 8%, and grains resulting from aeolian processes (RM and EM/RM) – 35%. Dune sands are characterized by a similar share of grains with aeolian and water abrasion characteristics, 23% and 25%, respectively.

4.2. Monsul site

The Monsul site is located about 3 km southwest of the Genoveses site and in the same geographic region. The beach is, however, much smaller, with a maximum width of 270 m. This area comprises rocks formed during underwater volcanic eruptions – different sizes of andesitic rocks cemented by a fine-grained matrix. The curiosity of the area is a mobile dune climbing the volcanic elevation to a height of over 30 m (Fig. 5). Winds from the south and southwest participate in the formation of the dune (BARDAJÍ ET AL., 2011).

Samples were collected from the beach (approx. 50 m from the shoreline) and in three locations on the dune – on the proximal slope (No. 1) and the distal slope (No. 2 and 3). All samples of deposits represent medium-grained sands, with the beach sands being finer (Mz – 0.287 mm) than the aeolian sands (0.302–0.415 mm) (Table 1). The sands are moderately sorted (δ is 0.50–070).

Due to the lack of analyzed fractions or an unrepresentative number of grains, quartz grain abrasion was determined only for the aeolian sands from samples 2 and 3. In their mineral composition, quartz grains constitute 25% and 44%, respectively; shell fragments – 35% and 15%, and non-quartz minerals – 40% and 41% (Fig. 3). Both samples are characterized by a very large share of fresh and angular NU grains, 75% and 64%, respectively, and a dozen or so percent of EM/EL grains. Weak aeolian abrasion is evidenced by the lack of RM grains and a small share of EM/RM grains, 9% and 24%, respectively.

Fig. 5. Climbing dune in the Monsul site

4.3. Carraca site

The Carraca site is located on the Mediterranean coast in Torrox, about 250 m southeast of the mouth of Arroyo del Manzano. Along the undiversified coast with a beach up to about 70 m wide, a short section (about 500 m) is covered by a belt of low (2–3 m) dunes several dozen meters wide (Fig. 6). The hinterland of the area is urbanized. The dunes are called Carraca Dunes, and the beach is called Dunes Beach.

Two deposit samples were taken at the site – one from the coastal part of the beach and one from the dune culmination (in the central part of the dune field). The deposits are almost the same in average grain diameter (0.310 mm and 0.316 mm) and are moderately sorted (Table 1). Their composition is dominated by multi-colored non-quartz minerals, constituting 85% and 72%, respectively, in the fraction of 0.5–0.8 mm (Fig. 3). The share of quartz is therefore small (14% and 28%), and shells (1%) occur only in beach sands.

Fig. 6. The Carraca Dune located along the Dunes Beach, Torrox

The abrasion degree of quartz grains of the 0.5–0.8 mm fraction is very low – in beach sands, there are as many as 74% of fresh and angular NU grains, and in aeolian sands, there are even more of them – 88%. Beach sands contain 17% of grains with aeolian abrasion features (RM+EM/RM), more than twice as much as dune sands (7%). It is probably related to selective wind transport (easier blowing of angular grains from source deposits).

4.4. Malagueta site

The Malagueta site is on the city beach in the highly urbanized Malaga, a few hundred meters from the port. A promenade limits the beach. Two samples of beach deposits were taken from the site – in the shoreline zone and the upper part of the beach (Fig. 7). The first ones represent coarse-grained sands (Mz – 0.616 mm) and moderately sorted (δ – 0.59), and the second ones are medium-grained sands (Mz – 0.451 mm), poorly sorted (δ – 1.06) (Table 1). The mineral composition of both sediment samples is quite similar. In the 0.8–1.0 mm fraction, the share of quartz is 54% and 48%, respectively, and in the 0.5–0.8 mm fraction it is less – 38% and 30% (Figs 2, 3). The remaining components are non-quartz minerals (shells constitute only 2%, exclusively in the finer fraction).

Fig. 7. The Malagueta Beach, Malaga

The degree of abrasion of quartz grains is quite characteristic – in the coarser fraction, 49–50% are fresh and angular NU grains, and grains with aeolian abrasion features (RM+EM/RM) constitute 26% in the shoreline zone, and much more in the upper part of the beach – 37% (Table 2). In the finer fraction, individual genetic types of grains have similar percentage shares (Table 3).

4.5. Artola site

The Artola site is located in the province of Malaga within the Artola Dunes – Cabopino dune system (Fig. 8). Two dune series can be distinguished here – younger, mobile, partially covered with vegetation occur in the first line from the shore, while older, overgrown with trees and bushes dunes occur further away (Bardají et al., 2011). The Artola Dunes – Cabopino area was supplied with sediments brought from the Fuengirola River mouth area by a coastal current drifting westwards. However, due to the construction of the marina, the coastal topography changed significantly, and the supply of deposits on the beach was interrupted (Málvarez et al., 1998). As a result, Cabopino Beach is currently being eroded, which threatens the Artola Dunes ecosystem.

At the Artola site, four deposit samples were collected – one from the Cabopino Beach and three from dune fields, including two samples from a mobile dune – from the proximal slope (no. 1) and the culmination (no. 2), and one sample from the distal slope of an older dune (no. 3). The beach sands are medium-grained (Mz – 0.266 mm) and poorly sorted (δ – 1.13) (Table 1), containing 62% quartz grains in the coarse fraction and half as much (33%) in the finer fraction. A significant share of carbonate minerals and shells is noticeable in the finer fraction, 30% and 5%, respectively (Fig. 2, 3).

Fig. 8. General view of the Artola Dunes

The aeolian sands are medium-grained and moderately sorted, with the sample from the older dune being slightly coarser and less sorted (Table 1). Differences in mineral composition are noticeable between the deposits of the younger and older dunes. In the latter, the share of quartz grains is the highest (67%), not only in the described site but also among all samples from the study area (Fig. 3).

It indicates a longer aeolian transport compared to the younger dunes, which enriches the deposit in resistant quartz and removes less resistant components. In turn, the sample from the proximal slope of the mobile dune is characterized by a significant 27% share of less resistant components, including 24% shells. In the sample from the culmination of the younger dune, there are no shells; it is represented by quartz (51%) and non-quartz minerals (49%) (Fig. 3).

The abrasion analysis of quartz grains of the 0.8–1.0 mm fraction, occurring only in beach deposits and on the proximal slope of the mobile dune, did not show any significant differences between them. The shares of individual grain types are similar or the same, with fresh and angular NU grains dominating 42% and 43%, respectively, and moderately rounded and mat grains at 38% each (Table 2).

On the other hand, the abrasion analysis of quartz grains of the 0.5–0.8 mm fraction revealed significant differences between the analyzed deposit samples (Table 3). Fresh and angular NU grains predominate in the younger dune deposits – 60% on the proximal slope and 52% on the culmination. Both moderately and very well rounded shiny grains predominate in the older dune – the total share of EL and EM/EL grains is 58% (Table 3). It means that the longer aeolian transport inferred above did not significantly affect the mattify of quartz grains because only 20% of the grains belong to the RM and EM/RM types. In this context, the high share of grains of this type in the Cabopino Beach deposits is worth attention, amounting to 48%, the highest in the studied area. It seems quite probable that this is the result of morphoselection – the first blowing of irregularly shaped grains (NU) from the beach onto the dune causes the enrichment of beach sands with more rounded grains. Considering the ongoing beach erosion, one can also carefully consider the washing out older aeolian deposits. Bardají et al. (2011) cite an unpublished study by Lhenaff (1977), which describes marine deposits between Malaga and Fuengirola changing higher into sands that could be classified as aeolian and associated with the last interglacial.

4.6. Discussion

On the coasts of Malaga and Almeria, devoid of tides and microtides, the main source of material for dunes is the beach. It is from its deposits that foredunes are formed, and dune fields develop with sufficient sand supply and space (Bardají et al., 2011). However, many beaches in this area are gravel, which limits the possibility of supplying sand deposits for dunes.

On the coast of the province of Malaga, the coarseness of beach deposits is related to the supply of material by rivers (permanent and seasonal) flowing in a fast current from nearby mountains. A factor limiting the development of more extensive dune systems is the occurrence of a narrow, significantly sloping coastal plain. The highly intensive development of cities and tourist resorts is also significant, which first led to the degradation of existing foredunes and now hinders the formation of new dune fields. According to Gómez-Zotano (2014) research, Malaga has lost 45% of its foredune systems over the last six decades due to anthropogenic pressure. The best preserved dune system today is Artola Dunes–Cabopino (Málvarez et al., 1998).

There are more extensive deflation surfaces on the coast of Almeria than on the coast of Malaga, and at the same time, the wind activity is more significant (Bardají et al., 2011). Nevertheless, due to urban expansion, occupation of land for greenhouses, and tourist pressure, almost 13% of the dunes have been degraded (Gómez-Zotano, 2014).

The obtained research results can be compared with data for coastal deposits in Western Crete in the eastern part of the Mediterranean Sea (Dulias, 2023). Like the deposits from the coast of Andalusia, these are medium-grained and moderate sorting sands. In terms of this feature, examined deposits do not differ also from modern beach sands in other regions, for example, the Pacific, the Gulf of California, the Caribbean, the Gulf of Mexico (Edwards, 2001), and the Baltic Sea (Tylkowski & Samołyk, 2011; Žilinskas et al., 2018).

In Western Crete, in the 0.8–1 mm fraction, less resistant carbonate minerals dominate (on average, 77%), while the content of more resistant quartz is low (on average, 18%) (Dulias, 2023). It means that most deposits are relatively young and only briefly in the range of aeolian processes. The mineral composition of beach and dune sands from the Andalusian coast is characterized by a generally higher proportion of resistant grains – an average of 33% quartz in the 0.5–0.8 mm fraction and almost 49% in the 0.8–1.0 mm fraction. On the other hand, coastal deposits in Western Crete are dominated by moderately rounded and mat grains

EM/RM, on average 79%, while in the studied deposits from the Andalusian coast, there are almost four times less of them (on average slightly less than 21%). One can also cite the results of the research by Kalińska & Nartišs (2014), who report that the share of EM/RM grains in coastal dunes in the Corrajero site on Fuerteventura ranges from 51.3% to 88.3%. Arce Chamorro et al (2022) performed a morphological analysis of quartz grains from fossil aeolianites occurring on the Atlantic coast of Galicia using the Powers method (1953) and, complementarily, for the most representative quartz grains by scanning electron microscopy (SEM). The authors report that in three sites, sub-rounded grains dominate; in one site, sub-angular grains occur alongside sub-rounded grains.

Generally, beach and dune deposits of the studied area are characterized by weak abrasion of quartz grains. The low content of resistant mineral components in the deposits and the predominance of EM/RM grains over RM grains indicate a relatively short stay in the aeolian environment. The results of studies also indicate a significant role of morphoselection during aeolian transport (e.g., Winkelmolen, 1971; Reineck & Singh, 1975).

5. Conclusions

Based on the conducted research and obtained results, the following was established:

1. Investigated deposits are medium-grained, except for coarse sands from the coastal part of Malagueta Beach (Mz – 0.616 mm). Dune sands are generally finer than beach sands – average grain diameters are 0.316 mm (range 0.242–0.415 mm) and 0.381 mm (range 0.266–0.616 mm), respectively.
2. Sorting of the investigated deposits is moderate, except for poorly sorted sands from Cabopino Beach (δ – 1.13) and sands from the upper part of Malagueta Beach (δ – 1.06). In general, dune sands are better sorted than beach sands – the average δ value is 0.65 (range 0.50–0.95) and 0.95 (range (0.58–1.13), respectively.
3. The share of quartz in the 0.5–0.8 mm fraction in aeolian sands is, on average, 38.3% and is higher than in beach sands (on average, 26.4%). In the latter, non-quartz minerals predominate, with an average of 52.2%. Notably, many non-quartz minerals occur in the sands of Malagueta Beach (on average 64%) and in the Carraca site – as much as 85% in beach sands and 72% in dune sands. Grains of low resistance (shells and carbonate minerals) occur mainly in the Genoveses and Monsul sites in Cabo de Gata and in the Artola site – in beach and mobile dune sands.
4. Most samples did not have a fraction of 0.8–1.0 mm, or the number of quartz grains was not representative for morphoscopic analysis. Based on data for four beach sand samples from Malagueta Beach, Dunas Beach, and Cabopino Beach, it was determined that they are dominated by fresh and angular grains NU, with a share ranging from 42 to 55%, with an average of 49%. Grains with aeolian abrasion characteristics (mat, moderately, and very well rounded) account for an average of 35% (26–41%).
5. Ouartz grain abrasion in the 0.5–0.8 mm fraction, determined for most samples (12 out of 15), reveals significant differences between beach and dune sands. Although both deposits are dominated by fresh and angular NU grains, their average share is higher in aeolian sands – 58.9% (range 21–88%) than in beach sands – 43.4% (range 18–74%). It indicates the important role of morphoselection during wind transport, especially over short distances, as in the study area. It seems quite likely that blowing irregularly shaped grains from the beach to the dune enriches beach sands with more rounded grains, including those with a surface matted due to aeolian abrasion within the beach. It is evidenced by the twice as high total share of RM and EM/RM grains in beach sands (average 32.4%) as in dune sands (average 15.5%). It cannot be ruled out that some of the grains classified as EM/RM type in the SEM examination would be considered matt grains due to chemical etching.
6. The abrasion of beach and dune deposits in the studied area is generally low, and the multiple predominance of EM/RM type grains over RM grains indicates relatively short wind transport.

Founding

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