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The erosion of the beaches on the coast of Alicante: Study of the mechanisms of weathering by accelerated laboratory tests

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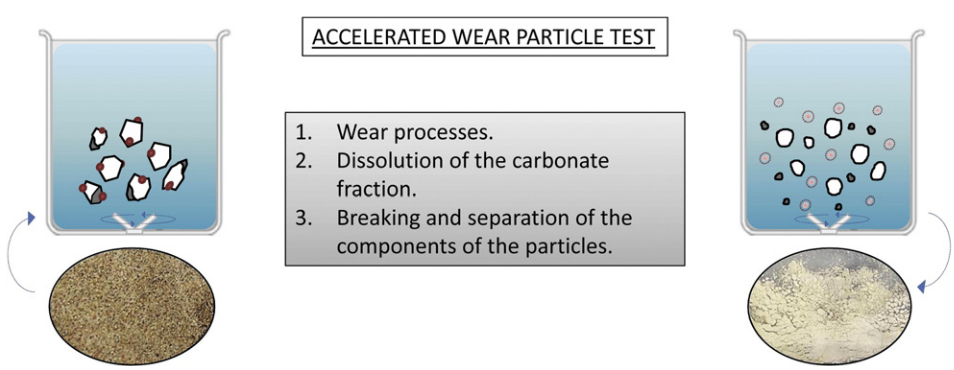
HIGHLIGHTS

- The investigation leads with the beaches erosion problem.
- Lithosphere, anthroposphere and hydrosphere processes participate in coast erosion.
- Simulation of sediment particles erosion by an accelerated wreathing test
- New hypothesis for the explanation of mechanisms involved in sand beach erosion.
- Particle erosion consist of: crashes, carbonate dissolution, carbonates separation

GRAPHICAL ABSTRACT



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ABSTRACT

One of the main problems that coasts around the world present, is the regression and erosion of beaches. However, the factors involved in these processes are unclear. In this study, the influence of sediment erosion on beach regression has been analysed. In order to do that, a three-step investigation has been carried out. Firstly, coastline variations of four Spanish beaches have been analysed. Secondly, a study on sediment position along the beach profile has been developed. Finally, the process that beach sediments undergo along the surf zone when they are hit by the incident waves has been simulated by an accelerated particle weathering test. Samples of sand and shells were subjected to this accelerated particle weathering test. Results were supplemented with those from carbonate content test, XRD, SEM and granulometric analysis. Results shows a cross-shore classification of sediments along the beach profile in which finer particles move beyond offshore limit. Besides, it was observed that sediment erosion process is divided into three sages: i) particles wear due to crashes ii) dissolution of the carbonate fraction, and iii) breakage and separation of mineral and carbonate parts of particles. All these processes lead to a reduction of particle size. The mechanism responsible of beach erosion would consist of multiples and continuous particle location exchanges along the beach profile as a consequence of grain-size decrease due to erosion.

1. Introduction

One of the most important problems in the world is the coastal erosion (Bird, 1985). Around 70% of sand beaches are suffering erosion

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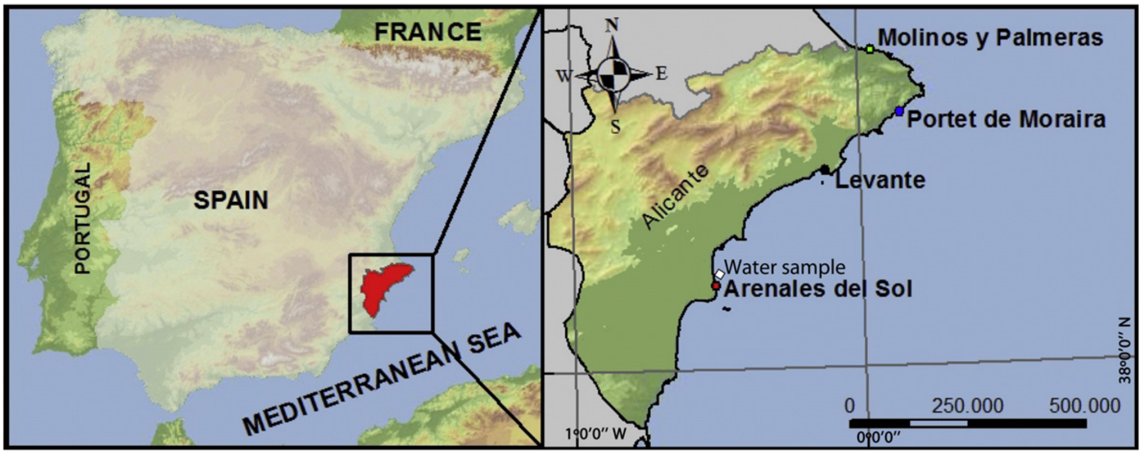

Fig. 1. Location of the studied beaches.

(Bird, 2011). Coasts represent in most cases touristic areas and so preventing them from erosion is a common need. Nourishment and civil works are frequently carried out so as to avoid that problem (Aragonés et al., 2016b). Thus, coastal erosion leads to economic costs. In the concrete case of Spain, tourism is an important source of income. It represented 10.9% of Spanish Gross Domestic Product in 2012 (Instituto Nacional de Estadística, INE, 2015). Consequently, preventing Spanish coast from erosion is necessary in order to keep this economic input.

Previous works (Aragonés et al., 2015; López et al., 2016; Pagán et al., 2016) have proved that Spanish Mediterranean coasts are suffering erosion. In sand beaches, erosion is a consequence of sediment transport from nearshore to offshore. In order to prevent this phenomena, it is necessary to know and understand all the parameters that have influence on erosion, as well as their evolution in the "recent past" as for the coastal dynamics (Bardají et al., 2009). Factors related to coastal erosion can have a different origin. On the one hand we can find parameters that depend on human activity in the area and on the other hand, natural factors as morphology, sediment composition or maritime climate (Isla et al., 1998; Juárez and Isla, 1999; Marcomini and López, 1997; Pardo and López, 1998; Rosselló and Sanjaume, 1986).

Among natural factors that alter the coastal system, we can underline the action of wind and water. Both of them have influence on the morphology, sediment distribution and the presence of biological ecosystems that give rise to our beaches (Jabaloy-Sánchez et al., 2010).

One of the most common human actions is beaches nourishment. Sand extraction and discharge leads to a sedimentology change and this is considered as a variable in the erosive process of the beach (Marcomini and López, 1997; Schnack et al., 1983). Furthermore, the construction of coastal defences, marinas, commercial ports, seafronts or jetties have altered the coastal dynamics, specifically the longitudinal and transversal sediment transport. As a consequence, sedimentology and coastal morphology has been modified too (Pardo and López, 1998; Rosselló and Sanjaume, 1986; Sanjaume, 1985).

There are authors that use the medium sediment grain-size as a variable in the calculation of the beach equilibrium profile (Aragonés et al., 2016b; Dean, 1977; Larson, 1991; Vellinga, 1982). The latter has been widely used to obtain the aggregate volumes needed for beaches nourishment. This fact exposes the importance of sediments for the coastal processes understanding.

As stated before, swell is the main responsible of sediment transport from nearshore to offshore. However, when trying to understand coastal erosion, swell is not the only factor that must be considered. Sediment characteristics should be analysed too. Sediment grain-size plays an important role in sediment transport. Suspension is the most frequent way of transport of sediments. Since lager particles need more energy to stand in suspension than smaller ones, when the speed of current decreases, sediments settle selectively. Coarser materials are the first ones to lay down. As long as energy decreases, finer particles deposit on the seabed. Thus, authors such as Demarest and Kraft (1987) relate coastline variations with the movement of sediments along the nearshore since they can switch their positions along the equilibrium profile. Sediments located beyond the offshore limit will hardly return to nearshore (Hallermeier, 1978, 1980; Stauble and Cialone, 1997). Previous works have demonstrated that sediments located beyond offshore limit are affected by gravitational movements leading to a transversal transport of finer sediments from the continental shelf to the abyssal plain (Aragonés et al., 2016a).

Sediments from the swash zone move towards off shore generating a grain size distributions along the beach profile. The best sediment classification follows the aggregate transport direction (Stauble and Cialone, 1997). This transversal transport generates a transversal sediment classification (Guillén and Hoekstra, 1996; Niedoroda et al., 1985) that is a consequence of the swell and currents. Coarser grains remain near the coastline and finer grains move towards offshore. When beaches are nourished, a non-uniform transversal distribution of sediment grain-size occurs. In this distribution, a maximum value of medium sediment grain-size (D_{50}) appears near the breaker zone (González et al., 1997).

All this considerations lead the authors to the conclusion that studying the erosion problem in Spanish coasts implies the study of sediment behaviour in this area. Considering that erosion is a consequence of sediment transport from nearshore to offshore, the first objective of this work is to analyse whether in the area of study swell is capable of

Table 1
Characteristics of beaches in the studied area. Orientation referred to the North.

Beach name	Township	Length (m)	Width (m)	Origin of sediment	Orientation
Molinos y Palmeras	Denia	2334.6	61.8	Natural terrestrial input	312°
Portet de Moraira	Teulada	360.7	19.6	Marine dredging	200°
Levante	Benidorm	2262	60.2	Natural terrestrial input and marine dredging	187°
Arenales del Sol	Elche	5626.1	91.4	Natural terrestrial input and marine dredging	81°