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Sediment transport patterns on the Estremadura Spur continental shelf: Insights from grain-size trend analysis

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ABSTRACT

Grain-size trend analysis (GSTA) was used to infer sediment transport patterns on Estremadura Spur continental shelf. Sediment transport patterns were defined using the Gao and Collins (1992) method applied on an extensive collection of superficial sediment samples collected from 14 to 706 m water depths and using a characteristic distance based on geostatistical analysis. Results are in relatively good agreement with known oceanographic drivers for the external shelf (internal waves, and upwelling) and measured near-bottom currents. At the mid and inner shelf computed sediment transport vectors yielded less coherent patterns probably related with low sampling density in relation to surficial sedimentary deposit dimensions and the presence of rocky outcrops.

1. Introduction

When considering wide areas like exposed continental shelves, the direction and intensity of sediment transport pathways are affected by extremely variable physical factors (wind waves, tides, currents, internal waves) and is one of the major issues in the characterization and monitoring of the marine environment. The analysis of spatial changes in grain-size parameters (mean, sorting and skewness) is a standard approach for the identification of sediment transport patterns, especially in complex systems due to its simplicity and cost effectiveness.

Sediment Trend Analysis (STA®) sediment pathways are based strictly on the sediment sample analyses without any consideration of known hydrodynamic conditions that could potentially influence sediment pathways (Hughes, 2005).

The basic assumption inherent in STA® (McLaren, 1981) is that in the natural environment, differences in grain-size distributions of a given sedimentary depository can be explained by selective transport. According to the McLaren model, although there are theoretically 8 possible combinations (trends) of the above-mentioned statistical parameters (Gao, 1996) only 2 combinations have a higher possibility of existing in natural environments, where sediment transport occurs in a downstream direction: (a) finer, better sorted and more negatively skewed (representing a low energy environment); or (b) coarser, better sorted and more positively skewed (characteristic of a high energy environment).

Gao and Collins (1992) re-examined the basic assumptions of the grain-size trend analysis (GSTA); they argued that although the two cases described previously may be the dominant ones, the presence of the other 6 trends can cause a high level of noise using the 1-D approach (Poulos and Ballay, 2010).

Gao and Collins (1991, 1992) and Gao (1996) proposed GSTA, a two-dimensional method to estimate sediment trends.

In a complex open marine environment, namely the continental shelf, the application of a two-dimensional approach is recommended (GSTA) in which no a priori transport directions are known (Poizot et al., 2006), as demonstrated in the English Channel and in the upper slope of the continental shelf of south-central Black Sea where net transport vectors identified by using residual grain-size trends are consistent with the local dominant oceanographic conditions.

Also, Cheng et al. (2004) support the use of GSTA for large-scale areas on the continental shelf, namely over the Bohai Straight, where results were consistent with current circulation patterns. Additional studies carried out on other continental shelves also support the use of GSTA in open marine environments (Lanckneus et al., 1993; Ravaioli et al., 2003; Shi et al., 2002; Zhu and Chang, 2000).

In an open sedimentary basin, delivery processes interact with physical forcing (the distribution processes) in a constant and delicate equilibrium which prevail until the occurrence of any local or regional alterations. Supply processes are responsible for the input of particles into a depositary while the resuspension and transport processes will

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promote circulation of particles until final and definitive settling. The formation of sedimentary deposits only occurs when transport ceases and particles accumulate. Considering these assumptions, the grain size of bottom sedimentary particles always reflects dominant physical processes.

The main goal of this work is to describe and represent the sedimentary transport at the Estremadura Spur continental shelf using Gao and Collins (1992) method implemented on GSTA (Gao, 1996). A critical characteristic distance (Dcr), necessary to deduce sediment transport trend, was specifically calculated based on the sediment sampling and textural variance of the available samples.

In this area there were no in situ measured data concerning the oceanographic conditions. A current meter was deployed specifically for this study, in order to allow a comparison between GSTA software results and the data collected (see § 4.1 below).

2. Study area

2.1. Estremadura Spur continental shelf

Estremadura Spur (Fig. 1) is located in the Portuguese continental margin. This important geomorphologic unit has a variable width, ranging from 15 km (in front of Peniche) to 70 km (in Lamparoeira parallel), depending on the location of the shelf break (between 50 m and 330 m).

Concerning the high abundance of rocky outcrops, it is expected that they significantly affect the sedimentary dynamics, for example by inducing local boundaries and barriers for bottom sediment circulation. The most significant outcrops that may represent an obstacle to sediment transport are the ones identified in Fig. 1 in the inner shelf off Peniche and Ponta da Lamparoeira. Also important are the reliefs of: Costeiras Pêro da Covilhã, Focinho e Queixada and Pico Gonçalves Zarco. The Peniche, Ponta da Lamparoeira and Costeiras Pêro da Covilhã rise approximately 20 m above the sea floor. Focinho e Queixada outcrops rise about 30 m and Pico Gonçalves Zarco rises about 78 m. The shallowest outcrops of Peniche, Ponta da Lamparoeira and Costeiras Pêro da Covilhã have much more significant extensions when compared with the deeper reliefs of Focinho and Queixada and Pico Gonçalves Zarco.

The continental shelf break and the upper slope have a general N-S orientation (parallel to the coastline), except in the northern border of the study area, where the presence of the Nazaré Submarine canyon, with a WSW-ENE orientation, imprints the shelf break and slope morphology.

2.2. Shelf sedimentary deposits

The Estremadura continental shelf presents a wide variability of sedimentary deposits as a result of the morphological diversity and local heterogeneities. The bottom sedimentary cover can be described as follows: the inner shelf is dominated by well sorted fined grained littoral sands; the northern mid shelf (until ≈ 120 m depth) is covered by coarse particles (sandy gravel) with a nucleus of sandy gravel at 60 m depth; the southern mid-shelf (until 120 m depth) is covered by finer sediments with a nucleus of sandy mud at 115 m (the so-called Ericeira mud patch); and sediments from the outer shelf are dominated by sand and muddy sand.

Studies recently performed and summarized by Balsinha (2008) indicate that sediments have a terrigenous origin (detritic particles are

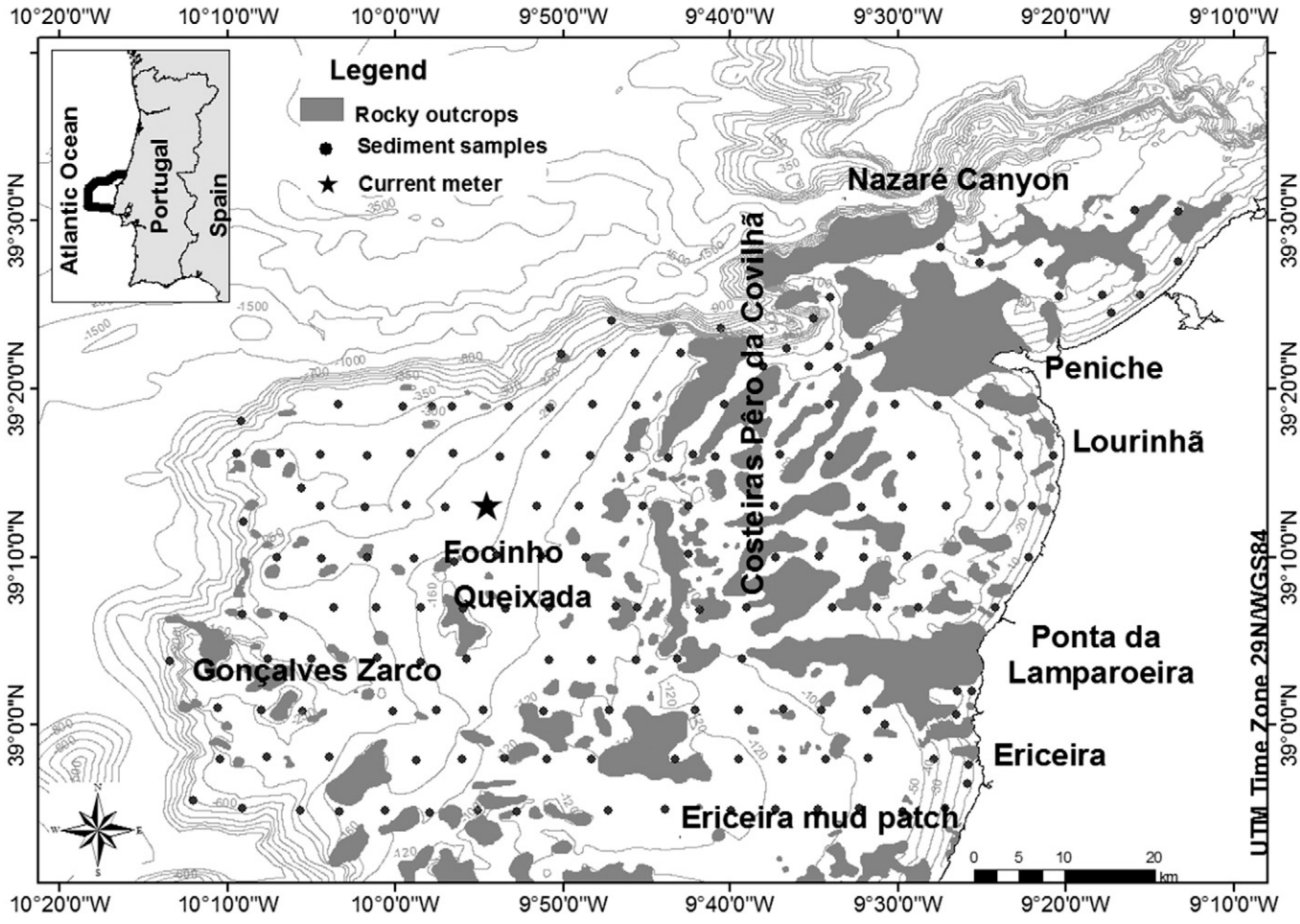

Fig. 1. Sediment samples' location (black dots), current meter (star) and rocky outcrops (gray) extracted from Balsinha (2008).