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Source area determination of aeolian sediments at Jandia Isthmus (Fuerteventura, Canary Islands)

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ABSTRACT

The Jandia Isthmus (Fuerteventura, Canary Islands) is a complex aeolian system composed of Pliocene and Pleistocene marine deposits, which are partially covered of carbonate crusts, palaeosols and sand sheets. The area has been greatly influenced by climate changes during the Quaternary. Nowadays this area presents an arid landscape dominated by the aeolian processes. Grain size, mineralogical and micropalaeontological analyses have been carried out to identify the source area of these wind-blown materials, considering five possible sources: windward beaches, Pliocene dune cliffs, Upper Pleistocene aeolian deposits, carbonate crusts and basaltic outcrops.

Each one of these analyses has been used to discriminate between the possible sources. Especially useful has been the use of foraminifera as natural tracers of the aeolian dynamics, as well as the application of the Rietveld method to quantify the mineralogical composition from the X-ray diffraction analysis (XRD). These techniques indicate that erosion of the Upper Pleistocene aeolian deposits — which partially cover the Isthmus surface — is the process that presently supplies most of the aeolian sediments that blow across the Isthmus. This study suggests the existence of extensive backshore surfaces westward of the present shoreline, during both the Pliocene and the Upper Pleistocene. This backshore was the original source area of aeolian materials transported by the Trade Winds, combined with the dust supply from Saharan desert.

1. Introduction

The identification of the source and depositional areas of sediments is important to understanding the evolution and current behaviour of present sedimentary systems. Criteria to determine sediment provenance are based on comparing the different textural and compositional properties of sediments from the system and nearby areas.

In accordance with textural criteria, sediments in aeolian depositional environments tend to be better sorted than sediments from their source area, and they are typically finer and more positively skewed. Nevertheless, this is not always the case, since models of grain size trends define several possibilities: a) grain size increases or decreases in the sediment transport direction; b) skewness can be more positive or negative in the sediment transport direction; and c) only the sorting usually is improved from the source area to the depositional area (Gao and Collins, 1991; Chang et al., 2001; Le Roux et al., 2002).

In contrast, according to compositional criteria, the mineralogy is usually similar between the sediments of the depositional system and the sediments of the source area. However, the mineralogical composition of the sedimentary system is not only related to the mineralogy of sediments in the source area, but also to the chemical processes in the system itself. Sometimes, the major elements are present in different possible source areas, and consequently, it may be necessary to include an analysis of minor elements. Compositional analysis is performed through the determination of the carbonate content, the determination of the mineralogical composition or the identification of the microfossil content.

First, the presence of carbonates is determined using Bernard's volumetric method (Wiesmann and Nehring, 1951), or coulometry (Engleman et al., 1985). In coastal studies, carbonate content is related to marine biogenic sources (Calhoun et al., 2002), although it can be the result of input from continental areas (Carranza-Edwards et al., 1996).

Second, the identification of the minerals and rock fragments that constitute the sediments can be obtained by observation of thin sections, using petrographic microscopy. This method allows the quantification of the average composition of sediments by grain counting to a total number of 300 to 500 observations in each thin section (Galehouse, 1971). X-ray diffraction analysis following the Rietveld method helps to quantify the relative proportion for each

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mineral phase (Mumme et al., 1996), with greater accuracy than thin section analysis.

Third, benthic foraminifera provide important information about the long-term effects of sorting, energy levels, and source areas. In coastal areas, they have been used to identify sediment provenance (Li et al., 1998; Alejo et al., 1999; Hippensteel and Martin, 1999; Cann et al., 2000; Glenn-Sullivan and Evans, 2001). The existence of foraminifera in marine deposits is not only related to input from the sediment source, but also to biological production within the system (Murray and Alve, 1999). Consequently, for the analysis of the marine environments, it is necessary to differentiate between allochthonous and autochthonous foraminifera (Jorissen and Wittling, 1999). In contrast, the presence of foraminifera in aeolian deposits is simpler to analyse, because it is only related to their presence in the provenance area (Glennie and Singhvi, 2002). However, the foraminifera tracer technique gives best results when used in conjunction with other physical observations that provide both complementary and confirming evidence about the nature of associated transport processes (Scott et al., 2001).

Most provenance studies typically consider some of these techniques in order to determine the source area of sediments. However, results can differ according to the applied technique, as this study shows. This suggests that a combination of different techniques should be applied in the source area determination studies, better than only one technique.

This paper presents the application of textural, mineralogical and micropalaeontological criteria to determine the source area of modern aeolian sediments at Jandia Isthmus, the most extensive aeolian sedimentary environment of the Canary Islands. This system is very complex, including ancient and modern aeolian deposits, palaeosols, and carbonate crusts, which gives place to palaeontological and palaeoclimatic research projects funded by the IGCP (International Geological Correlation Programme) and EPGC (Earth Processes in Global Change) programmes of UNESCO-IUGS. Moreover, present aeolian processes and sink areas of this sedimentary system have been described by Höllermann (1990), and Alcántara-Carrió and Alonso (2002). However, the source areas of the sediments have not yet been determined satisfactorily.

2. Study area

2.1. Geological setting

The Canary Islands are a volcanic intraplate archipelago located in the Atlantic Ocean, between latitudes 27° 37′ and 29° 25′N, and longitudes 13° 20′ and 18° 10′ W. The hotspot theory is generally accepted for the origin of the archipelago (Burke and Wilson, 1972; Schmincke, 1973; Geldmacher et al., 2001). Three stages have been described in the formation of the Canary Islands: i) shield-stage, an initial volcanic period that built more than 90% of the total volume, ii) erosional gap, and iii) post-erosional volcanism. Gran Canaria, Fuerteventura and Lanzarote islands are presently in the last stage, whereas La Gomera island is still undergoing erosion, and Tenerife, La Palma and El Hierro islands are in the shield-stage (Carracedo et al., 1998).

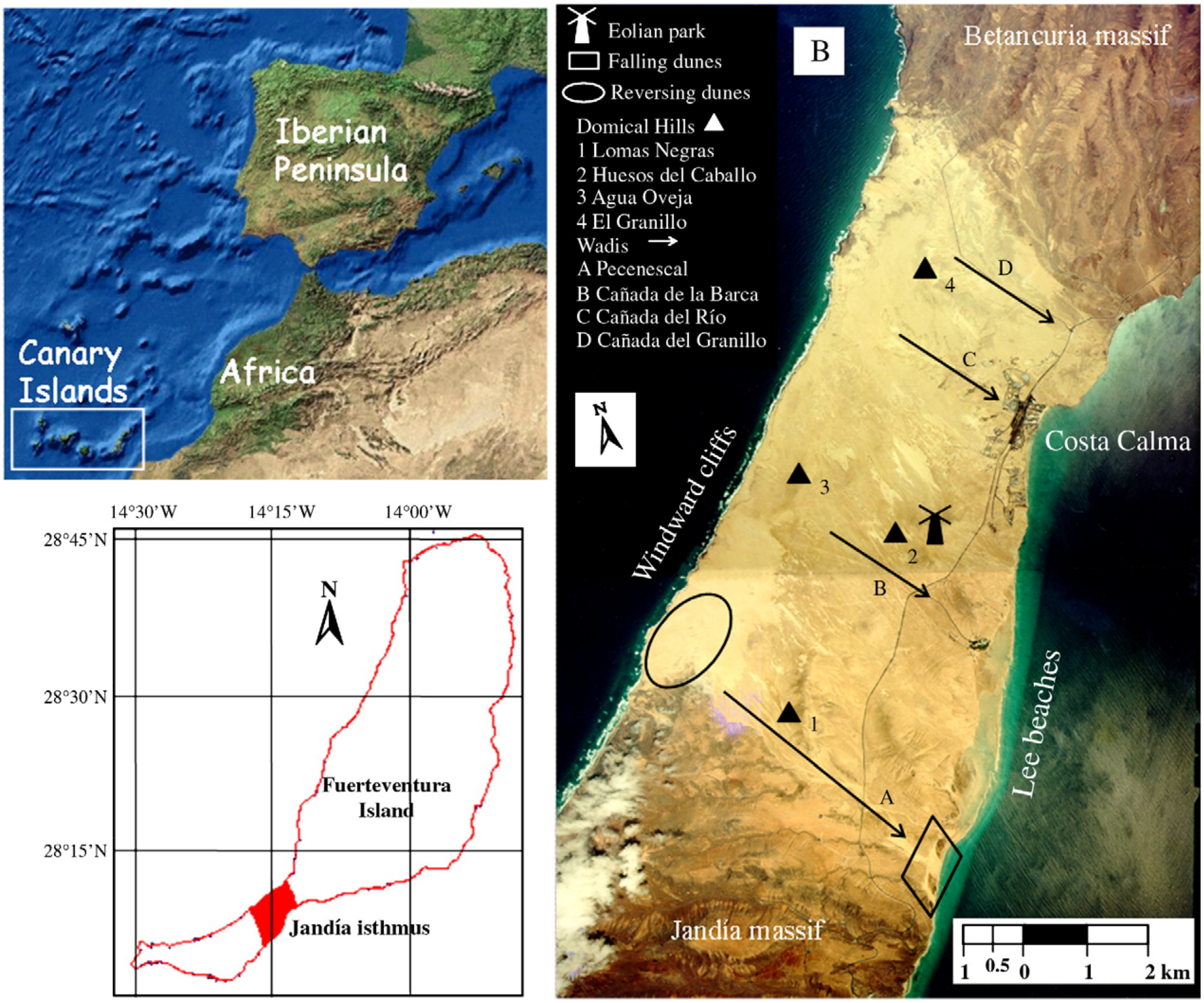

Fig. 1. Location of Jandia Isthmus and their main geomorphologic features.