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Palaeoclimatic considerations of talus flatirons and aeolian deposits in Northern Fuerteventura volcanic island (Canary Islands, Spain)

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ABSTRACT

Fuerteventura volcanic island has been subject to considerable aeolian activity since the Late Pleistocene. The aeolian record includes inactive aeolian deposits with interbedded entisols, whose age by OSL dating ranges between 46 and 26 ky BP. The Corralejo active dune field, where sand sheets, nebkhas, coppice dunes, blowouts, barchans and transverse dunes have been described, constitutes a more recent Aeolian deposit. Here the age is about 14 ky BP. On Fuerteventura Island aeolian dust has been deposited on valleys and slopes. This last type of accumulation has been affected by gully incision, producing talus flatirons. Samples taken on the apex of these palaeo-slopes indicate an OSL age of 30 and 50 ky BP. A palaeoclimatic succession has been interpreted during which a prevailing arid period took place in OIS 4, with the accumulation of aeolian dust. A humid period occurred in OIS 2, during which slopes were dissected and formed talus flatirons. An arid period about 14 ky BP gave rise to the Corralejo dune field, which has continued until present with slight climatic oscillations.

1. Introduction

Fuerteventura volcanic island, located 28°N, constitutes a western climatic extension of the Sahara desert, at a transition to the more humid islands of the Canary archipelago. Within this climatically transitional environment, slight secular climatic changes can trigger different types of erosive and depositional processes which leave distinct imprints on the landscape. These types of sensitive landscapes are very useful for paleoclimatic reconstruction (Gutiérrez, 2005, 2008).

A continuous record of aeolian activity is recognizable on Fuerteventura in the form of (a) active and fixed dunes in its northern zone, and (b) thin deposits of aeolian dust from the Sahara and the Anti-Atlas Mountain Belt, deposited in valleys and on slopes, throughout the whole island. Later gully incision of the dust sedimented on the slopes has given rise to the formation of talus flatirons.

Talus flatirons have been recognized in high latitude climatic environments (Büdel, 1970; Gutiérrez et al., 2011) and in desert areas of intermediate latitudes (Koons, 1955; Everard, 1963; Gerson, 1982; Schmidt, 1996; Gutiérrez et al., 2006; Morgan et al., 2008). Talus flatirons develop below the slope scarp and constitute relict isolated forms exposed to different subaerial processes. On Fuerteventura Island there exists extensive development of this form, namely where the scarp is formed by tabular basalts (basaltic trap). The relict slope deposits include interbedded aeolian silts, which have been sampled in this study and dated by OSL. All of the existing publications related to such palaeoforms are restricted to stratified sedimentary deposits with horizontal or slightly inclined bedding planes that form gentle slopes below an upper escarpment.

The aim of the present work is to study diverse palaeoclimatic indicators such as talus flatirons or palaeo-slopes found across the island, augmenting previous studies by additional OSL and radiometric datings and developing new detailed geomorphic maps.

2. Geological and geomorphological setting

The volcanic island of Fuerteventura, together with Lanzarote island, form the Eastern Canary Islands (Fig. 1B), separated approximately 100 km from the African continent. It is the oldest island in the archipelago and was created by volcanic processes related to sea-floor spreading during the opening of the Atlantic Ocean. These two islands constitute an emerged branch of the Eastern Canarian Volcanic Ridge, which extends in a NNE–SSW direction, parallel to the African coast, along the Concepción Bank (Dañobeitia, 1988). The geological history of Fuerteventura Island is the longest and most complex of the Canary Islands. This island contains an extensive outcrop of the Basal Pre-Miocene Complex (Fúster et al., 1968), a fragment of Mesozoic oceanic crust including a thick sedimentary sequence overlying Lower Jurassic tholeiitic basalts (Carracedo, 2002) (Fig. 1B). Muñoz and Sagredo (2004) identified several phases in the island's development, with different Neogene and Quaternary

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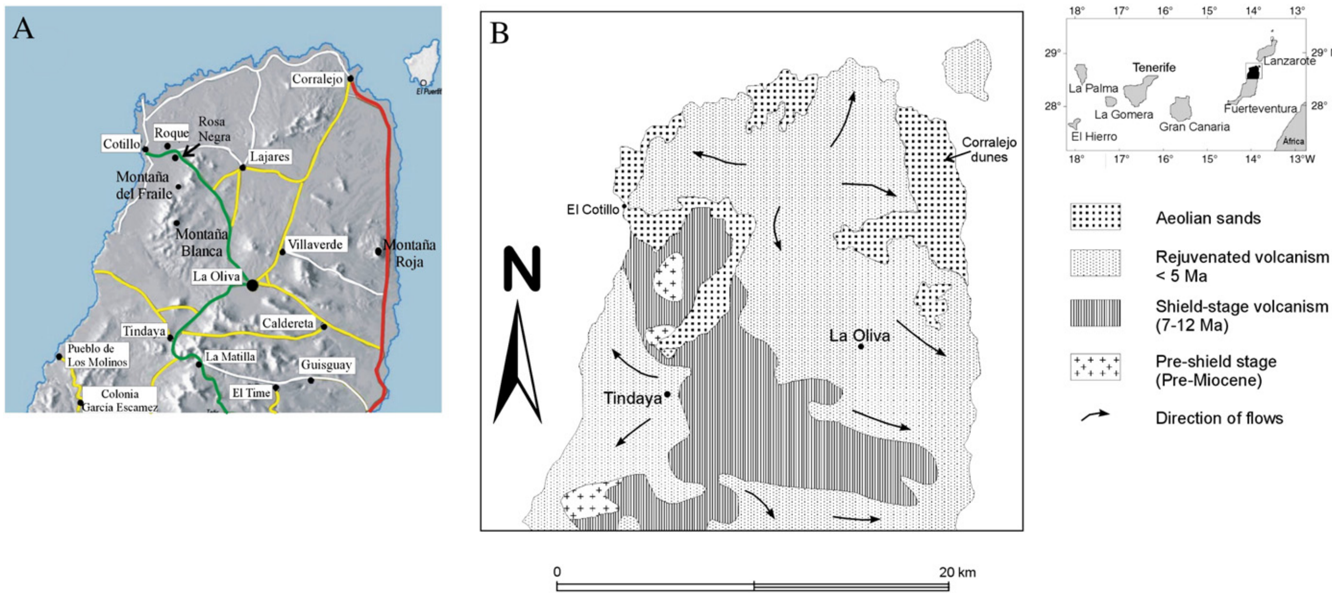

Fig. 1. A. Geographical map of northern Fuerteventura Island. B. Geologic map of northern Fuerteventura Island, modified from Fúster et al. (1968), Fúster and Carracedo (1979), Ancochea et al. (1996) and Carracedo (2002).

subaerial volcanic episodes whose deposits accumulated upon the Basal Complex (Ancochea et al., 1996). An old Miocene basaltic sequence can be distinguished (Shield-stage Volcanism, Fig. 1B), constituted by basalts with interbedded pyroclastics (Zazo et al., 2008), subsequently subjected to a long and important subaerial erosion phase. Approximately 5 Ma ago, new pyroclastic-poor, viscous eruptions (Rejuvenated Volcanism in Fig. 1B) (Cendrero, 1966; Carracedo, 2002) emplaced *aa* lavas that formed wide stony rises or malpais (Ollier, 1988). These recent eruptions were separated by several periods of quiescence resulting in basaltic layers interbedded with Miocene through to Pleistocene beach deposits (Meco and Stearns, 1981; Zazo et al., 1997, 2002; Meco et al., 2002, 2003, 2006, 2007; Zazo et al., 2008).

Fuerteventura, with an area of 1725 km^2, is an island of moderate relief (Fig. 1A). Its highest point reaches 807 m (Zarza Peak) and is located in the southern ridge of the Jandía peninsula, to the south of the studied area shown in Fig. 1B. This arid environment, a western extension of the Sahara, has an annual average rainfall of 100 mm in its lower zones and about 250 mm at higher elevations. The island is influenced by the cold oceanic Canary Stream, which reduces temperature and precipitation. Annual average temperature is approximately 19 °C in the northern zone. Trade winds blow from the NE, especially in summer and autumn, although the prevailing winds blow from the north. The aridity of the zone favors the development of a scarce bush vegetation. The coast is affected by a prevailing littoral drift towards the south and the tidal range is low mesotidal (about 2 m).

Geomorphologically, Fuerteventura Island offers strong contrasts as a consequence of alternating eruptive emissions and quiescent phases, when volcanic materials were deeply eroded, in part due to the significant sea-level changes that occurred during the Pleistocene. Aeolian activity also affected the island, especially during sea-level lowstands. This activity was fed mainly by biogenic particles but also by African dust storms arriving in the area. Most of the exposed Fuerteventura surfaces are covered by superficial carbonatic crusts (Coudé-Gaussen, 1991).

The outcrops of the Basal Complex in the studied area form low hills that are weakly incised (Fig. 1B). Tabular volcanoes constitute a typical basaltic trap with stepped morphologies, clearly visible in the upper parts of the slopes, culminating in sharp ridges locally termed "cuchillos" ("knives"). The intermediate slopes are dissected by a high number of gullies which separate talus and pediment flatirons. Alluvial fans are also frequent in the lower parts (Fig. 2). The knife-shaped ridges are related to a strong slope-parallel retreat, characteristic of arid zones. South of El Cotillo (Fig. 1) a wide pediment is slightly incised by gullies, and is and is called the "Laderas de la Manta" ("Slopes of the Blanket") (Martínez de Pisón and Quirantes, 1994).

In the eastern and northern zones of the study area many volcanic cones erupted basaltic lavas, forming extensive aa malpais fields. Valleys are very wide and are the result of a long geomorphological history. The lava flows spread out over shallowly incised valleys, and subsequent erosion through the resistant lava flows resulted in inverted relief. Non-explosive, olivine-rich basaltic lavas were erupted from pyroclastic cones along a series of NE–SW-trending fractures. These eruptions were sporadic and are interbedded with, or overlain by, aeolian sands, colluvial or alluvial deposits (Ibarrola et al., 1989; Coello et al., 1992; Zazo et al., 2002; Criado et al., 2004).

Caliche has developed on many beach terraces, aeolian sands, alluvial-fan deposits, pediments and talus flatirons. All of them exhibit a high degree of reworking. The extensive occurrence of caliche and their characteristics indicate that their genesis has been controlled by climate and vegetation (Alonso-Zarza and Silva, 2002). Coudé-Gaussen and Rognon (1988) suggest that some calcareous crusts of Fuerteventura Island bear an aeolian origin.

3. Aeolian activity

Three different types of aeolian deposits can be recognized in Fuerteventura Island: stabilized deposits, active dune fields and ubiquitous aeolian dust deposits coming from Africa. Nevertheless, aeolian dust also appears in the former accumulations.

3.1. Stabilized dune deposits

Eruptive products from the basaltic volcanoes blanketed the paleolandscape of the island. Upon this paleotopography deposits of aeolian sand are exposed in gullies (arroyos), quarries, and hydrologic wells down to a depth of 150 m where the aeolian sands are interbedded with basalt (Coudé-Gaussen, 1991). These accumulations consist of organogenic aeolian sands, produced by the erosion of pre-existing marine sediments which were exposed during sea-level