Quaternary International 407 (2016) 4–13

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Middle to Late Pleistocene dunefields in rocky coast settings at Cala Xuclar (Eivissa, Western Mediterranean): Recognition, architecture and luminescence chronology

Laura del Valle [a], Lluís Gómez-Pujol [b], Joan J. Fornós [a, *], Alida Timar-Gabor [c], Valentina Anechitei–Deacu [c], Francesc Pomar [a]

[a] Grup de Ciències de la Terra, Universitat de les Illes Balears, Ctra. de Valldemossa, km 7.5, 07122, Palma, Illes Balears, Spain
[b] SOCIB, Balearic Islands Coastal Observing and Forecasting System, Parc Bit, Ctra. de Valldemossa Km 7,4, 07121, Palma, Illes Balears, Spain
[c] Faculty of Environmental Sciences and Engineering and, Interdisciplinary Research Institute on Bio-Nano-Sciences, Babeş-Bolyai University, Cluj-Napoca, Romania

A R T I C L E I N F O

Article history:
Available online 17 February 2016

Keywords:
Coastal aeolianites
Cliff-front dunes
Sand ramps
Pleistocene
Eivissa

A B S T R A C T

This study focuses on cliff-front anchored and sand-ramp aeolian dune accumulations in Cala Xuclar, Eivissa (Ibiza), Western Mediterranean, during different sea level falling stages from Middle to Late Pleistocene times. Stratigraphic mapping, conventional lithostratigraphic logging and OSL datings are used to reconstruct dune formation and evolution. Facies analyses result in the identification of six sedimentary units, three of which correspond to dune deposits formed at MIS 6 (145 ka), MIS 5d-c (~100 ka) and MIS 4 (77–73 ka) respectively. Additionally there is a beach deposit at (~2 m above present msl, which resembles the MIS 5a. This study concludes that each dune system corresponds to a relatively low sea-level stand that exposed enormous amounts of marine carbonate sands that was transported inland by migrating dunes under strong north–westerly winds. Therefore, sea-level fall and the related sediment supply owe likely to be key factors in the formation of these aeolianites systems.

1. Introduction

The Late Pliocene climate perturbation resulted in the establishment of a permanent Northern Hemisphere ice sheet and the onset of a chain of glacial and interglacial cycles (Shackleton et al., 1984; Herbert et al., 2010). In the Western Mediterranean, these cycles resulted in a serial of wet and dry periods (Martrat et al., 2004) in conjunction with an oscillating sea level (Dorale et al., 2010). This climate variation is characterized by the laying down of coastal sedimentary successions such as shallow-marine deposits (i.e. beaches), aeolianites, colluvial and alluvial deposits or palaeosols (Mckee and Ward, 1983).

Aeolianites are partially lithified former dune deposits cemented by carbonates (Fairbridge and Johnson, 1978) typically composed of fine-to medium grained, well-sorted sand. The character of the sand grains depends greatly on the local environmental setting, but the dominant constituents are quartz and feldspar grains and marine carbonate particles. The formation of coastal aeolianites occurs both during glacial and interglacial stages although there is an ongoing debate regarding the environmental conditions controlling their formation. There are Quaternary aeolianites accumulated during interglacial and interstadial sea level highstands, but it is also true that others have formed during glacial periods (Brooke, 2001; Fornós et al., 2009, 2012; Pappalardo et al., 2013).

The principal outcrops are located in the Mediterranean region, South Africa, southern Australia and the Caribbean, between 55°N and 45°S in latitude where many deposits have been documented in the last decades in order to unravel the landscape and climate evolution since the Middle-Late Pleistocene (El-Asmar, 1994; Clemmensen et al., 1997, 2001; Rose et al., 1999; Price et al., 2001; Frechen et al., 2004; Nielsen et al., 2004; Radies et al., 2004; Rodríguez-Vidal et al., 2004; Munyikwa, 2005; Andreucci et al., 2009, 2010a, 2010b, 2012, 2014; Fornós et al., 2009; Pavelic et al., 2011; Pappalardo et al., 2013).

Apart from a small number of studies, the majority of the literature has documented Pleistocene and Holocene transgressive dunefields along strandplain coastlines. Many of which have

* Corresponding author.
E-mail address: joan.fornos@uib.cat (J.J. Fornós).

http://dx.doi.org/10.1016/j.quaint.2016.01.050

addressed these systems along cliffed coastlines (i.e. Andreucci et al., 2010a and 2010b or Clemmensen et al., 1997). This rocky coast physiographical setting, due to the spatial variability in a narrow area, permits a constrained evaluation of the role of sediment supply, space accommodation and environmental drivers in aeolianite stratigraphy and architecture.

Different authors have noted the existence of Quaternary aeolian and fluvial sequences along the cliffed and rugged coast of Eivissa Island (Balearic Islands, Western Mediterranean) although none have characterized or described these outcrops in depth (Henningsen et al., 1981; Rangheard, 1971; Servera, 1997; García de Domingo et al., 2009). In this study, we document the sedimentary characteristics of a transgressive dune system that crops out continuously along the northwestern cliff coasts of Eivissa (Cala Xuclar) by means of sedimentological and stratigraphical analysis, and luminescence dating (OSL).

The aims of this study are to (a) unravel the factors that promote the dune formation paying special attention to sea-level oscillations, sand supply or wind regime and (b) explore how topography and terrestrial processes (i.e. fluvial and colluvial agents) participate in shaping the dunefield. The results are discussed in the framework of the last 150ka palaeoenvironmental and landscape evolution.

2. Regional and geological setting

The island of Eivissa (Ibiza) it is located in the south-western part of the Mediterranean Sea and is the third largest (571 km^2) and the most westerly island of the Balearic Archipelago (Fig. 1). The main structure of the island is composed of a series of thrust sheets (mainly of Middle Triassic to Middle Miocene carbonate deposits) formed during the Alpine compression (Upper Oligocene to Middle Miocene) and trending NE–SW (Rangheard, 1971, 1984). These thrust sheets correspond to the northeasterly continuation of the Subbetic Mountains of southern Spain (Fornós et al., 2002). The bedrock geology of Eivissa is composed of Miocene and Mesozoic rocks (García de Domingo et al., 2009). Muschelkalk limestone and dolomite, as well as Keuper loams and clays, constitute the Triassic basement of the island, whereas Jurassic limestone and dolomite breccia, Cretaceous and Middle Miocene limestone overlie this basement and constitute the major relief of the island (Fig. 1). Quaternary fluvial, alluvial and colluvial sediments fill the central basins, whereas Pleistocene successions characterized by shallow-marine to coastal aeolian and fluvial deposits crop up patchily along the cliffed coast (del Valle et al., 2015). The Balearic Islands, and among them Eivissa, have been considered tectonically stable since the Pliocene with relatively little deformation (Fornós et al., 2002; Just et al., 2011). Small cliffy bounded bays with sandy or gravelly-boulder pocket beaches characterize the present-day coast. Holocene and recent coastal dunes developed at the south and southeastern bays of Eivissa and have been stabilized by shrub vegetation (Servera, 1997).

One of these representative Pleistocene successions is in Cala Xuclar (WGS84 39°06′16″N; 1°30′54″E), along the northwest cliff coastline of the island (Fig. 1). This outcrop extends continuously for 1 km at the bottom of a small bay, 1.34 km in width and 1.21 km in depth, bordered by cliffs 2–9 m in height of Upper Miocene limestone, Cretaceous dolostone and Lower Jurassic dolomite breccia. The Pleistocene succession rests at the bottom of the bay on Lower Jurassic bedrock with a well-developed unconformity and shows great lateral variability of coastal aeolian, shallow-marine, colluvial and fluvial deposits, with palaeosols (Fig. 2).

3. Methods

3.1. Facies analysis

The conventional method of lithostratigraphic logging has been used (Tucker, 1988), with the acquiring of additional information on cross-bed dip direction for palaeowind analyses, and samples for grain size and mineralogy analyses. The terminology for sediment deposits and the criteria for their recognition have been modified from Andreucci et al. (2009). This terminology links lithology, grain size, sedimentary structures and macrofossil characteristics. Facies have been named according to the main lithology (C: conglomerate, B: breccia; S: sandstone and P: palaeosol), dominant texture (a: sand, m: mud, s: silt), grain size (c: cobble, d: pebbles, e: medium to very coarse sand; h: fine to medium sand), sedimentary structures (l: laminated, p: planar cross-bedded, t: through cross-bedded, u: low angle cross-bedded, g: granoclassification), biogenic features (f: highly fossiliferous, r: root-races). Therefore a facies labelled as *Shu* corresponds to a fine to medium grained sandstone with low-angle cross-bedded stratification.

Seventeen vertical logs (Fig. 3) were measured in the field and correlated on the base of major unconformities and homogenous units, bounding surfaces or according to presence of continuous palaeosols. Unconformities are understood as abrupt facies change in vertical and lateral extensions at the study area. At each log major units have been characterized in terms of sediment size, composition and mineralogy. The percentage of carbonates has been obtained by hydrochloric acid etching, and grain size determined by means of thin section and digital image analyses. Images were obtained using a binocular microscope with MOTIC Image 2.0 software and the analysis of grain size was performed using the free image analysis software IMAGE_J. Mineralogy of sediments was determined with a Siemens D-5000 X-ray diffractometer using Cu Kα radiation by means of randomly oriented powders of the bulk samples of sediments after pre-treatment of samples with H_2O_2 to remove organic matter. The pressed powder diffraction patterns were recorded from 3° to 65° 2θ in steps of 0.03°, 0.3-s counting time per step, at 25 °C room temperature, and logged to data files for analysis. Phase determination and semi-quantitative analysis were made by the X-Powder ver.2010.01.09 Pro software using the DifData database (Downs and Hall-Wallace, 2003).

3.2. OSL analysis

3.2.1. Sample collection and preparation

Four sample blocks (~70 × 70 × 50 cm; ~5 kg) were collected for luminescence dating from Pleistocene carbonate aeolian deposits at Cala Xuclar and analysed in the Luminescence Dating Laboratory of Babes Bolyai University in Cluj-Napoca. The aeolianite blocks were extracted from the stratigraphic layers considered to be representative of the succession. OSL dating is based on the ability of quartz (and other minerals) to retain charges from naturally occurring radioactivity present in sediment. Many studies have shown that sand grains are effectively zeroed during wind-blown transportation and therefore can be confidentially used for OSL dating (Sivan and Porat, 2004; Roberts et al., 2008). Despite OSL has become a fundamental chronological tool of Quaternary siliciclastic successions, recent contributions have highlighted the suitability of this method for aeolian deposits poor in quartz, such as carbonate aeolianites (Murray and Clemmensen, 2000; Nielsen et al., 2004; Fornós et al., 2009).

The aeolianites collected at Cala Xuclar, contain between 1 and 8% of siliciclastic grains, primarily quartz. Blocks were detached in shadowed low light conditions and wrapped in lightproof material, labelled and documented and transported to the laboratory.