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Late Quaternary coastal evolution and aeolian sedimentation in the tectonically-active southern Atacama Desert, Chile

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ABSTRACT

Analyses of aeolianites and associated dune, surficial carbonate and marine terrace sediments from north-central Chile (27° 54′ S) yield a record of environmental change for the coastal southern Atacama Desert spanning at least the last glacial-interglacial cycle. Optically stimulated luminescence dating indicates phases of aeolian dune construction at around 130, 111–98, 77–69 and 41–28 ka. Thin-section and stable carbon and oxygen isotope analyses suggest a predominantly marine sediment source for the three oldest dune phases. Aeolianites appear to have accumulated mainly from tectonically-uplifted interglacial marine sediments that were deflated during windier and/or stormier intervals. Bedding orientations indicate that sand-transporting winds varied in direction from S-ESE during MIS 5e and WNW-ESE during MIS 5c-5a. Winds from the southeast quadrant are unusual today in this region of the Atacama, suggesting either major shifts in atmospheric circulation or topographic airflow modification. Thin-section evidence indicates that the aeolianites were cemented by two phases of vadose carbonate, tentatively linked to wetter periods around 70 and 45 ka. Tectonic uplift in the area has proceeded at an average rate of 305–542 mm kyr^{-1}. The study illustrates the complexity of understanding onshore-offshore sediment fluxes in the context of Late Quaternary sea-level fluctuations for an area undergoing rapid tectonic uplift.

1. Introduction

Evidence for late Quaternary environmental change within the hyperarid Atacama Desert of northern Chile is spatially and temporally limited. Most terrestrial records arise from palaeoecological investigations in the Andean precordillera, are limited to radiocarbon timescales, and thus date back no further than 50 ka (e.g. Betancourt et al., 2000; Latorre et al., 2002, 2003, 2006; Maldonado et al., 2015; Quade et al., 2008; Mujica et al., 2005). These studies indicate increased winter precipitation at > 52, 40–33 and 24–17 ka south of 25°S, and increased summer precipitation in two distinct phases from ca.18–14 ka and ca.13.8–9 ka (De Porras et al., 2017). The latter two periods are recognised regionally as the “Central Andean (or Atacama) Pluvial Event” (Placzek et al., 2009; Quade et al., 2008; Gayo et al., 2012; Latorre et al., 2013). Available marine records from offshore of northern Chile span a longer time-period, but are still restricted in number. These show that the Last Interglacial (LIG) and Last Glacial Maximum (LGM) were relatively wet along the coast compared to a dry Holocene, with major wetter and drier periods since 120 ka coinciding broadly with orbital precession maxima and minima, respectively (e.g. Lamy et al., 1998, 2000; Stuut and Lamy, 2004; Kaiser et al., 2008; Contreras et al., 2010).

In the near-coastal zone of north-central Chile, terrestrial palaeoenvironmental investigations are restricted to studies of Holocene swamp forest development (Maldonado and Villagrán, 2002, 2006), late Holocene fog ecosystem evolution (Latorre et al., 2011), rodent middens (Díaz et al., 2012) and Quaternary palaeosols (Pfeiffer et al., 2012). This is due mainly to a lack of sites with suitable organic material for radiocarbon dating. In the absence of biological proxies, analyses of wind-blown sediments offer the greatest potential for understanding past conditions in this zone. Studies of near-coastal transverse dunes have been undertaken in northern Chile (e.g. Araya Vergara, 2001; Paskoff et al., 2003; Castro Avaria et al., 2012) and southern Peru (e.g. Finkel, 1959; Gay, 1962, 1999; Hastenrath, 1967, 1987), with ages of dune initiation (Hesse, 2009a) and periods of

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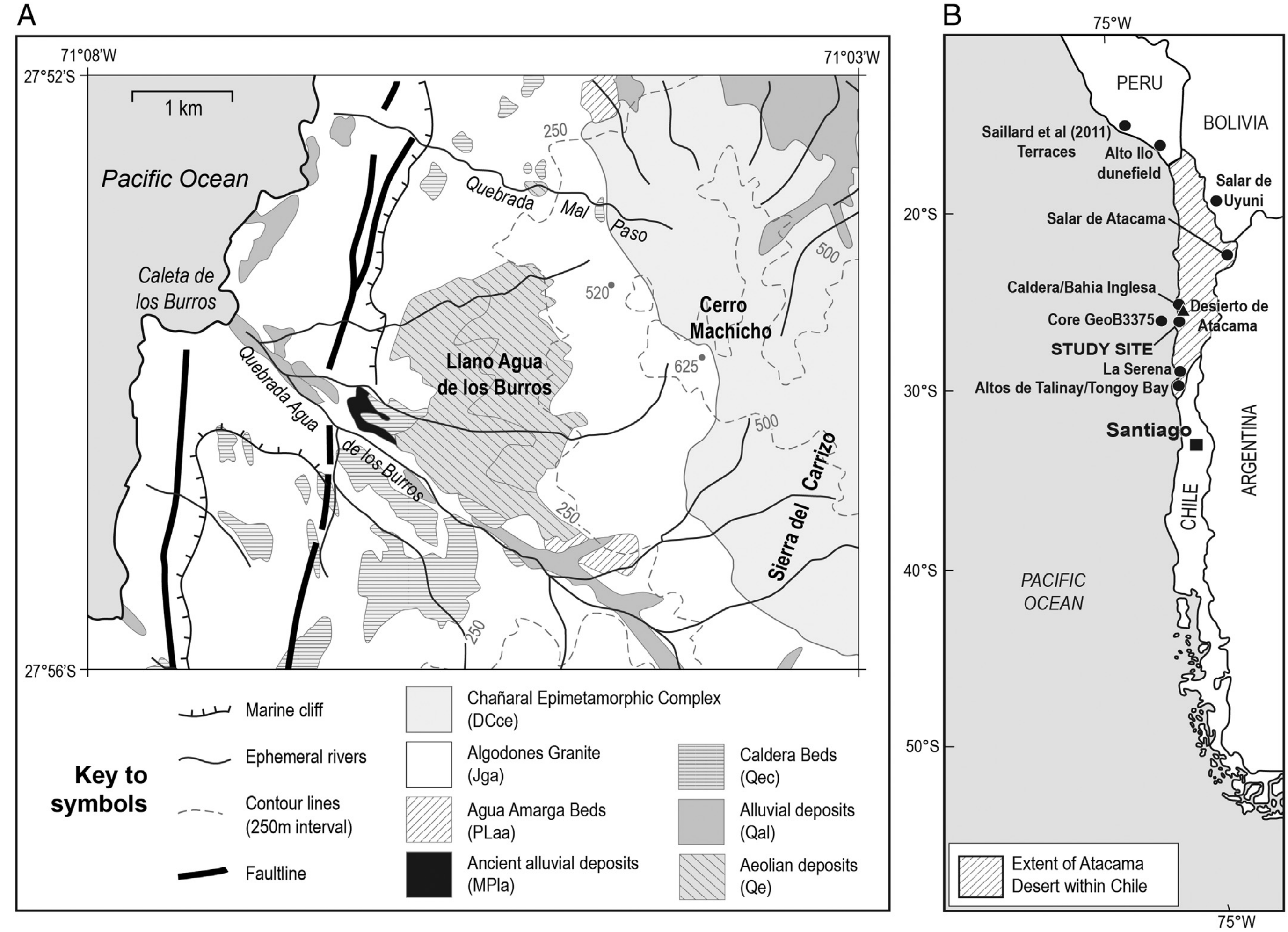

Fig. 1. A. Simplified geological map of the study area, indicating the distribution of igneous, metamorphic and sedimentary units in the vicinity of Llano Agua de los Burros. The main aeolianite outcrop forms the easternmost part of the area of Qe at the centre of the map; B. Location map, including other sites mentioned in the text.

enhanced sediment supply (Hesse, 2009b) in southern Peru estimated from rates of historical sand transport and tectonic contexts. Well-dated studies of near-coastal aeolian deposits are limited to work by Londoño et al. (2012) in the Alto Ilo dunefield, southern Peru (ca.17° 30′ S), and Veit et al. (2015) around La Serena, central Chile (30–33° S). In southern Peru, episodes of aeolian sediment accumulation were identified by optically stimulated luminescence (OSL) at ca.55–45, 38–27, 22–16 and 12 ka, generally coincident with periods of enhanced moisture availability in the Peruvian Andes and Altiplano (Londoño et al., 2012). In contrast, aeolian sediment accumulation in central Chile was punctuated by episodes of palaeosol development (PostIR$_{225}$ luminescence dated to 135–125, 59–47 and < 14 ka), implying formation mainly during drier rather than more humid periods (Veit et al., 2015).

This study presents an extensive new palaeoenvironmental dataset derived from near-coastal carbonate aeolianite and associated sediments at Llano Agua de los Burros (27° 54′ S, 071° 04′ W), 70 km southwest of Copiapó in north-central Chile (Figs. 1 and 2), an area close to the northernmost extent of mediterranean coastal climatic conditions. We combine OSL dating, aeolianite micromorphology, particle size data and stable isotope geochemistry to address two specific research problems: (i) identifying the factors that influenced aeolian sediment accumulation and preservation in the study area; and (ii) determining the impact of rapid regional tectonic uplift upon the nature of the aeolianite sequence. In other parts of the world, carbonate aeolianite has been shown to yield information about offshore sediment production, onshore sediment accumulation, and past climatic conditions, including palaeowind direction and moisture variability (e.g. Fairbridge, 1995; Vacher, 1997; Brooke, 2001; McLaren, 2007; Porat and Botha, 2008; Roberts et al., 2009); we explore similar themes here. The distribution and stacking of aeolianite sequences can also provide information on tectonic regimes (Muhs et al., 2014). In South Africa and most of Australia, coastal aeolianites are located in a tectonically-stable setting, and deposits from numerous glacial-interglacial cycles are stacked vertically (Bateman et al., 2011; Cawthra et al., 2014); those on the Coorong coastal plain in southern Australia, which is slowly uplifting, form barriers across a wide coastal plain (e.g. Murray-Wallace et al., 2010). Here, we use our OSL results to independently estimate local uplift rates and assess the influence of rapid uplift upon aeolianite formation.

2. Regional and site context

2.1. Geological and tectonic setting

Llano Agua de los Burros (LAB) is located 2.5 km from the Pacific Ocean at the foot of the Sierra del Carrizo coastal range (Fig. 2B), which consists of Devonian-Carboniferous meta-sandstones, slates, phyllites, marbles and metabasites (Blanco et al., 2003). The region is situated above a flat subduction slab (Gutscher et al., 2000) and, as a result, is highly active tectonically. In common with other parts of the coastline of northern Chile and southern Peru, the study area displays uplifted