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Interglacial-glacial climatic signatures preserved in a regressive coastal barrier, southeastern Australia

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ABSTRACT

Regressive barriers persisting in the landscape over interglacial-glacial cycles are important repositories of paleoclimatic signatures such as past sea level and regional aridity. The Gippsland region of Victoria contains a multi-barrier system formed during past interglacial-glacial cycles and the late-Holocene. An extensive series of parallel foredune ridges forming the elongate inner barrier was sampled for luminescence dating with ages indicating deposition ca.125,000–108,000 years ago coinciding with the later phase of the Last Interglacial (LIG) Marine Isotope Stage (MIS) 5e and the transition to MIS 5d. Ground Penetrating Radar (GPR) imaged beach-face reflectors within the LIG barrier indicate that sea level was within −2 to +3 m of present level during MIS 5e in this far-field location. Significant reworking of the barrier system through blowout and parabolic dune activity occurred between 23,000–18,000 years ago corresponding to the Last Glacial Maximum (LGM) with an estimated 160,000,000 m^3 of coastal sediments eroded and redistributed. The morphological changes to this coastal barrier over the most recent interglacial-glacial cycle (MIS 5e to present) also imply significant landscape instability during the LGM in southeastern Australia and are further evidence for extension of the geographical range and intensity of aridity at this time.

1. Introduction

The elevation of coastal barriers and their constituent facies such as beach and backbarrier estuarine and lagoons are important indicators of past sea levels (e.g., Thom et al., 1981; Cooper and Flores, 1991; van Heteren et al., 2000; Hearty et al., 2007; Tamura et al., 2010; Orrù et al., 2011; Murray-Wallace et al., 2016). However, barrier systems which persist within marginal marine environments over multiple glacial/interglacial cycles are exposed to a wide range of climatic conditions which can modify or remove a portion of their original sedimentary record. Such reworking means that these systems may act as palimpsest landforms recording palaeoclimatic signatures beyond the timeframe in which the barrier system initially formed. For example, recent studies have demonstrated aeolian reworking of coastal landforms in South Africa and southern Brazil during glacial periods (Bateman et al., 2004; Porat and Botha, 2008; Lopes et al., 2014).

The southern Australian continental margin preserves a rich and diverse suite of coastal landforms which have yielded excellent records of Quaternary landform evolution and information on past climate (e.g. Bowden, 1983; Bowler, 1976; Hill and Bowler, 1995; Nanson et al., 1992; Sprigg, 1979), sea-level highstands, and neotectonism (e.g. Murray-Wallace, 2002; Murray-Wallace and Belperio, 1991; Murray-Wallace et al., 1999, 2001; Sandiford, 2003). In particular, the temperate carbonate-dominated regions of western and southern Australia have received considerable attention with their long (temporal) record of interglacial barrier ridges and raised coastal successions (Playford, 1988) representing an important record of Quaternary sea-level change (Murray-Wallace et al., 2001) for global sea level reconstructions.

The eastern Australian coast is dominated by siliceous sediments (Short, 2010) with barrier sequences of mostly Holocene age with examples of barrier systems dating back to Marine Isotope State (MIS) 5 and MIS 7 in central and northern New South Wales (NSW) (Roy et al., 1994; Thom et al., 1994). However, barriers of late Pleistocene age are rare in southern NSW and eastern Victoria, thereby representing a

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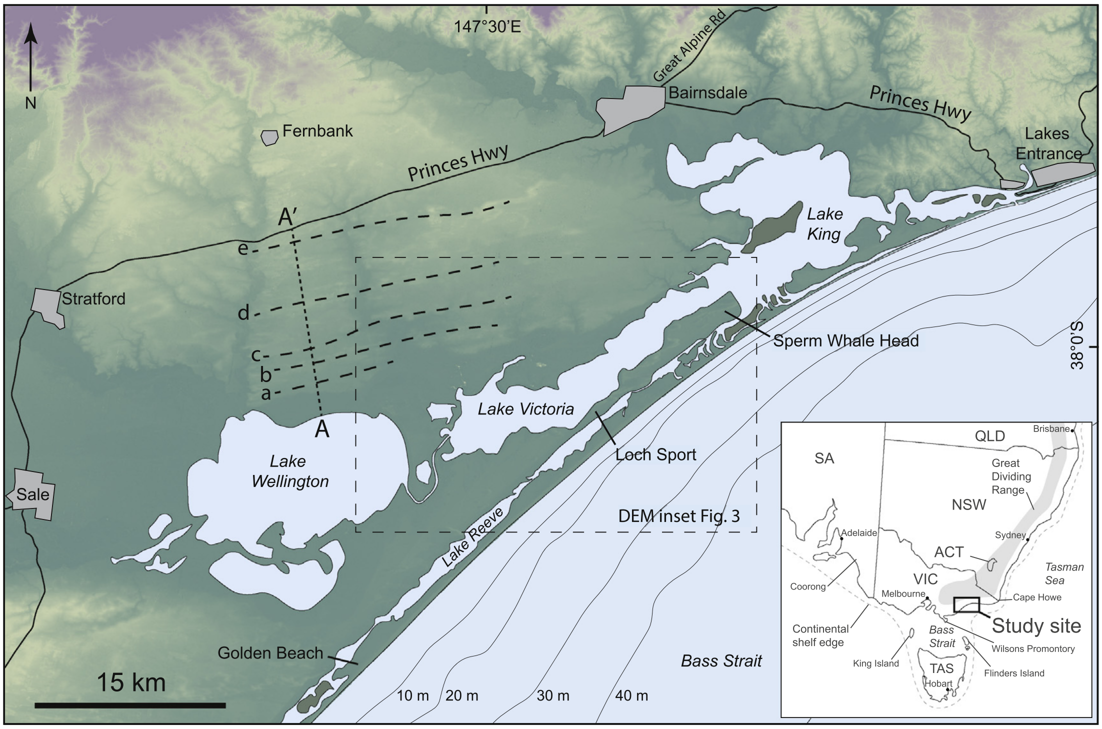

Fig. 1. Regional map of the Gippsland region of Victoria in relation to southeastern Australia. Dotted rectangle denotes LiDAR data displayed in Fig. 3. Ward (1977) transect A-A′ (see Fig. 2) is displayed with prominent dune barriers demarcated 'a' to "e".

significant gap in understanding of the palaeo sea level, and specifically Last Interglacial (LIG) sea level, in the region between Wilsons Promontory and Sydney (Fig. 1) (see also Fig. 1 in Murray-Wallace and Belperio (1991)). Furthermore, while terrestrial dune activity has been documented at Wilsons Promontory in southernmost Victoria (see Fig. 1 for location) (Hill and Bowler, 1995; Gardner et al., 2006) and around Tasmania (Bowden, 1983; Duller and Augustinus, 2006; McIntosh et al., 2009, 2012) there has been a paucity of geochronological investigations of dune mobility at the southeastern edge of mainland Australia despite the presence of large parabolic dunes in this region (Lees, 2006). In addition, this region is situated in a climatic zone of Australia likely to be particularly sensitive to shifts in temperature and humidity of the westerly circulation associated with climatic changes during the late Quaternary (Hesse et al., 2004).

The absence of protective caprocks (such as calcretes in carbonate-dominated systems primarily composed of re-cemented marine-derived skeletal carbonate sand) means that the siliciclastic systems of southeastern Australia are susceptible to erosional modification during glacial phases as shown by Thom et al. (1994) in central NSW. Therefore, while some portion of the original barrier sedimentary record may be modified or destroyed during glacial phases, these secondary terrestrial landforms provide insight into palaeoclimatic conditions through the most recent interglacial-glacial cycle. In order to understand the palaeoclimatic significance of both the initial barrier deposition with respect to sea level, and the subsequent terrestrial dune reworking, recent studies have used combinations of remotely sensed high-resolution elevation datasets such as airborne Light Detection and Ranging (LiDAR), Ground Penetrating Radar (GPR) and luminescence dating (e.g. Mallinson et al., 2008). These technologies allow multiple phases of climatic change preserved in a coastal barrier to be distinguished providing an independent record of landscape-climate interactions. Understanding the nature of these landscape-climate interactions is important in determining the effect of future climatic changes on a regional scale.

In this study we examine the Late Pleistocene coastal barrier in the Gippsland region of Victoria (Fig. 1) using Optically Stimulated Luminescence (OSL) dating, sedimentological techniques, geophysics (GPR) and airborne LiDAR. The aim of the work is to determine the age of the pre-Holocene successions to constrain LIG sea level in this far field location. The study also aims to assess the degree of terrestrial dune reworking that a barrier is subjected to during a full glacial cycle with implications for extracting palaeoenvironmental information from siliciclastic coastal sand barriers that persist over multiple eustatic cycles.

2. Regional setting

The Gippsland region of Victoria is located on the southeastern edge of mainland Australia, approximately 230 km east of Melbourne and forms a wide gently terraced plain south of the Great Dividing Range (Fig. 1). This plain is blanketed by Quaternary sediments of marine and fluvial origin (Figs. 1 and 2) which overlie thick Miocene-Pliocene sediments, principally limestones (e.g. Gippsland Limestone) and sandstones (e.g. Jemmys Point Formation; Jenkin, 1968). The Jemmys Point Formation represents a Plio-Pleistocene raised coastal barrier which underlies the coastal dunes dominating the present topography (Holdgate et al., 2003). Ward et al. (1971) and Ward, (1977) identified a series of raised coastal dune-barriers (25–60 m above present-day MSL) interspersed with other beach, nearshore and tidal marsh facies (Fig. 2) which were assigned relative ages based on their elevation compared with other raised marine terraces around the world. While these older raised dune and beach facies imply a longer-term uplift signature, at present the area is considered to be tectonically stable with no uplift occurring in the last 200 kyr (Holdgate et al., 2003).

Bird (1961) first described the surficial coastal barrier successions of the Gippsland region identifying several phases of barrier deposition which are most clearly expressed in the region around Sperm Whale Head (Fig. 1). Bird (1965) later identified a "prior barrier", "inner barrier" and "outer barrier" interpreted to have formed during successive interglacials (Fig. 3) after comparison with the northern NSW coast and the work of Thom (1964, 1965). The Holocene "outer barrier" was drilled by Thom (1984) who demonstrated substantial variability in