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Punctuated progradation of the Seven Mile Beach Holocene barrier system, southeastern Tasmania

Thomas Oliver

University of Wollongong, tsno412@uowmail.edu.au

Paul Donaldson

BTM WBM

Chris Sharples

University of Tasmania

Michael Roach

University of Tasmania

Colin D. Woodroffe

University of Wollongong, colin@uow.edu.au

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Punctuated progradation of the Seven Mile Beach Holocene barrier system, southeastern Tasmania

Thomas S.N. Oliver^{1*}, Paul Donaldson², Chris Sharples³, Michael Roach⁴, Colin D. Woodroffe¹

¹School of Earth & Environmental Science, University of Wollongong, NSW, Australia, 2522

²BMT WBM, Newcastle, NSW, 2292

³Geography and Environmental Studies, University of Tasmania, Tasmania

⁴ARC Centre of Excellence in Ore Deposits, University of Tasmania, Tasmania

*Corresponding author

Abstract

Prograded barriers are depositional coastal landforms which preserve past shoreline locations and have been studied in order to understand the fundamental drivers of barrier formation. This paper reconstructs the Holocene history of the Seven Mile Beach, prograded barrier in Tasmania, Australia using optically stimulated luminescence (OSL) dating, ground penetrating radar (GPR), light detection and ranging (LiDAR) elevation models and sedimentological analyses. Shoreline progradation of the barrier commenced around 7300 years ago and continued to near present despite a ~3000 year pause in deposition between 6700 and 3600 years ago indicative of substantial changes in sediment availability. GPR imaged subsurface structures contain a record of seaward dipping reflectors preserved as sediment supplied beaches and dunes leading to shoreline progradation. In the past 500 years a large transgressive dune has formed, built from reworked barrier sands, and now dominates the eastern portion of the barrier implying that shoreline progradation has ceased. This study reaffirms the notion that relict foredune ridges are strongly aligned with modal wave refraction patterns in planform and emphasises the importance of sediment delivery as a key

driver of shoreline progradation through beachface and dune accretion. The substantial pause in shoreline progradation on this barrier system, as observed on others around the world, requires further explanation. Although changes in sediment delivery have been inferred, it may also be appropriate to reopen the debate on Holocene sea-level change in Tasmania.

Keywords

Relict foredune ridges; transgressive dune; optically stimulated luminescence dating, ground penetrating radar, LiDAR topography

1. Introduction

Prograded barriers commonly comprise a series of shore-parallel relict foredune ridges or 'beach ridges' *sensu stricto* (Hesp 2006) which preserve past shoreline positions (Taylor & Stone 1996; Otvos, 2000) while also commonly containing other dune elements such as parabolic dunes, blowouts and transgressive dunes (Dillenburg et al. 2004; Hesp et al. 2007). Investigation of the processes involved and the chronology of formation of these ridges provides information on coastal landform evolution at decadal to millennial timescales (e.g. Hede et al. 2015; Rémillard et al. 2015). Studies from around the world have demonstrated the validity of using optical luminescence dating to determine the timing of deposition of individual ridges (Timmons et al. 2010; Guedes et al. 2011; Reiman et al. 2011). Geophysical and sedimentological techniques provide further potential to investigate prograded barriers as repositories of paleoenvironmental information from which it may be possible to reconstruct sea-level changes (Tamura et al. 2008; Clemmensen & Nielsen 2010; Hede et al. 2015), storm erosion histories (Bristow et al. 2000; Dougherty 2014) and coastal response to regional climatic changes (see Tamura (2012) for review).

Several prograded barrier sites in southeastern Australia. have been constrained by radiocarbon dating which indicates their history of progradation (Thom et al. 1981a, 1981b).

More recently the chronology of some of these barriers has been more accurately determined using optically stimulated luminescence (OSL) dating of quartz grains. OSL dating allows the time since deposition of sediment to be determined whereas radiocarbon dating of biological materials dates the cessation of radiocarbon uptake (e.g. the death of the organism) which may predate the sedimentary event. Since the first use of OSL to supplement a radiocarbon chronology and reconstruct the depositional history of Guichen Bay, South Australia (Murray-Wallace et al. 2002), several other coastal plains around Australia have been investigated using OSL. Sites such as Cowley Beach (Nott et al. 2009), Keppel Bay (Brooke et al. 2008), Iluka-Woody Bay (Goodwin et al. 2006), Moruya (Oliver et al. 2015) and Admiral Bay (Engel et al. 2015) have provided important contributions to understanding Australian coastal morphodynamics and palaeoenvironmental changes on local to regional scales adding to a larger body of international research. In contrast to mainland Australia, the Late Quaternary coastal landforms of Tasmania have not received comparable attention, despite being both geographically extensive, and internationally significant in inspiring the early insights into ridge formation processes (Davies 1957; 1958; 1961; Oliver et al. 2016) (Figure 1 c). Detailed chronological studies of Tasmanian coastal deposits are concerned with uplifted marine deposits of neotectonic significance (e.g. Murray-Wallace and Goede 1991; 1995) and terrestrial dune activity (Duller & Augustinus 1997; 2006); see also McIntosh et al. (2009) for a review.

This study uses OSL dating, ground penetrating radar (GPR), airborne Light Detection and Ranging (LiDAR) elevation data and sedimentological analyses to reconstruct the Holocene deposition of the Seven Mile Beach barrier and describe the Late Quaternary landforms against which it is emplaced. These datasets provide an opportunity to explore the importance of various drivers of progradation and their influence barrier on morphology in a deeply embayed coastal setting. This study also tests the hypothesised influence of modal wave refraction patterns controlling barrier planform configuration proposed by Davies (1958; 1959) (Figure 1 c). The study constitutes the first OSL chronology of a Holocene ridge

sequence in Tasmania and enables the first direct comparison with similar barriers around mainland Australia and the world.

2. Study site

The Seven Mile Beach barrier system is located approximately 15 km ENE of Hobart in southeast Tasmania and comprises approximately 30-40 sub-parallel relict foredune ridges around 4-6 m above mean sea level (MSL) that form a low-lying coastal plain at the head of Frederick Henry Bay (Figure 1). The barrier is situated within the Tasmania Basin, which is a continental margin basin, comprising a thick flat-lying sequence of Late Carboniferous to Late Triassic sedimentary units (Bacon et al. 2000; Stacey and Berry 2004). Jurassic dolerites intrude extensively into this basin sequence and it is variably overlain by Paleogene, Neogene and Quaternary sediments. Quaternary terrestrial aeolian dunes are common throughout this region of SE Tasmania (McIntosh et al. 2012) and there has been considerable discussion of uplifted Last Interglacial shallow marine deposits and their neotectonic significance (Murray-Wallace and Belperio, 1991; Murray-Wallace and Goede, 1991; Murray-Wallace et al., 1990; Murray-Wallace et al., 2013; Slee et al., 2012; Shin, 2013; McIntosh et al., 2013).

Thom et al. (1981a) reported an uncalibrated radiocarbon age of 4500 ^{14}C yrs BP at the rear of the Seven Mile Beach barrier indicating a Holocene age for the ridge sequence. The barrier impounds a shallow barrier estuary known as Pitt Water into which drains the Coal River with a catchment size of 540 km² (Lewis 2006). Southeastern Tasmania experiences a wave climate dominated by long-period southwesterly swell with H_s generally between 2-6 m. Swell waves are refracted into Frederick Henry Bay (Jennings 1955, Davies 1958) and have controlled the alignment of the relict foredune ridges (Oliver et al. 2016) (Figure 1 c).

Sediments to the NW of the relict foredune ridge sequence consist of infilled backbarrier lagoonal deposits, regressive estuarine plain sequences and terrestrial aeolian dunes. The landward margin of the barrier, which forms the southern shoreline of Pitt Water estuary is called Five Mile Beach. This estuarine shoreline has a cliffed profile with much slumping and is cut into weakly lithified or unconsolidated wave and wind deposited barrier sand. Sediment eroded from this shoreline is actively reworked into the estuary and historical aerial imagery suggests that the erosion is occurring at an average rate of 0.2 m per year (Sharples et al. 2012).

The frontal portion of the barrier has been reworked following progressive foredune formation during the late Holocene. An interdune deflation hollow with a basal elevation of 0-2 m above MSL is backed by a large hummocky transgressive dune in the eastern portion of the barrier and a high single foredune in the western portion. Evidence from aerial photography suggests these dunes were active prior to the 1950's after which extensive planting of marram grass (*Ammophila arenaria*) resulted in widespread dune stabilisation. Only the north-easternmost margin of the large transgressive dune at Sandy Point remains mobile. A single high foredune is present south of the Hobart airport with a smaller deflation hollow between it and the active foredune ridge which is laterally continuous behind the present day beach. This active foredune ridge is periodically cut back during storms and subsequently rebuilds. A low-angle beachface with a berm at an elevation of 1-1.5 m prevails during fairweather conditions.

3. Methods

3.1. Interpretive mapping and sedimentological analysis

Major morphostratigraphic units were mapped in ArcGIS following interpretation using aerial imagery and a Digital Elevation Model (DEM) derived from high resolution airborne LiDAR data acquired in 2008 by the Tasmanian Government Department of Primary Industries, Parks, Water and Environment (DPIPWE). Major units were delineated by their visual

character and surface form, and subsequent ground truthing was carried out for units of interest.

Lithological and structural information was obtained from several outcrops of coastal facies and sedimentary logs were made of several shallow auger holes (maximum depth 2.7 m) through units not suited to geophysical investigation. Samples from outcrops and auger holes were described using a binocular microscope to determine lithology, grain size, roundness and sorting.

3.2. GPR collection and processing

GPR data was collected using a Mala ProEx system; an unshielded 50 MHz antenna was used along transect BR5, whereas shielded 100 and 250 MHz antennas were both used along four transects spread through the central portion of the barrier BR1-BR6 (Figure 1 a). Transect BR3-4 contains a 20 m lateral displacement between BR3 and BR4. Profiles were collected in common offset mode and sampling interval for the 50, 100 and 250 MHz antennas was set to 0.5 m, 0.1 m and 0.05 m respectively. Sampling interval for the 100 MHz and the 250 MHz antenna was controlled by a survey wheel attached to the Mala ProEx system and this wheel was calibrated prior to measurement with a 100 m tape measure. Sampling interval for the 50 MHz antenna was entered manually using a tape measure. A common midpoint (CMP) survey and hyperbola curvature matching for prominent diffractions in 'wet' and 'dry' sand layers were used to establish appropriate velocity values for depth correction during data processing. The final two-layer velocity structure adopted values of 0.14 m/ns above the water table and 0.06 m/ns below the water table reflecting the well documented variance in velocity between dry and wet sands (e.g. Bristow 2009; Neal and Roberts 2000).

GPR datasets were processed using ReflexW v.2.1.1 and standard processing routines were applied including desaturation, first arrival time correction, spatial filtering and bandpass filtering. After testing of various migration processing routines, a diffraction stack

migration was applied to the trace data to collapse diffractions and restore reflectors to their true geometry. Topography correction was applied to each radar profile, based on ground elevations extracted from a LiDAR derived DEM.

3.3. OSL dating

Sample locations were selected based on GPR transect locations and the most pronounced topographic ridges shown in the LiDAR data were preferentially sampled. Samples of aeolian dune sediment (>80% quartz) were collected for OSL dating from the base of an auger hole around 70-80 cm deep with 50 mm diameter metal tubes 150 mm in length. Each sample was capped and taped and placed in black plastic bags. A handheld GPS was used to record sample locations in the field as well as a large scale map of the barrier showing a digital elevation model (DEM) derived from LiDAR data. Fourteen samples were processed at the University of Wollongong OSL dating laboratory (Table 1).

Under dim red-light conditions around 4 cm of sediment at either end of each sample tube was separated and not used for luminescence measurements and served as an indicator of sample moisture content and determination of the environmental dose rate using ICP-MS and ICP-OES analysis (completed by Intertek Genalysis). Environmental dose rate was calculated from the concentrations of uranium, thorium, and potassium determined by ICP-MS and ICP-OES analysis using the conversion values reported by Guérin et al. (2011). An assumed water content of $5\% \pm 2.5\%$ was adopted for all samples due to the uncertainty of time-varying hydrological conditions in free-draining quartz sand soils. The cosmic dose for each sample was calculated taking into consideration geographic position, sediment density, altitude and depth of overburden following the methods of Prescott and Hutton (1994).

Sub-samples of light-safe 180-212 μm quartz grains were isolated and prepared for measurement following the procedure outlined by Oliver et al. (2015). Twenty-four 3 mm diameter aliquots of quartz were prepared on stainless steel discs and were loaded onto a Risø TL/OSL reader for stimulation, measurement and irradiation. Prior to measurement of

equivalent dose (D_e) values, a preheat-plateau was used to assess the thermal stability of the quartz grains (Figure 2). Based on this pre-heat plateau experiment a pre-heat cut-heat combination of 180/160 respectively was adopted for all D_e measurements. D_e values were estimated using a modified single-aliquot regenerative-dose (SAR) procedure (Murray and Wintle, 2000). To ensure the suitability of the SAR procedure for each multi-grain aliquot, standard tests were applied, including a recycling ratio test, recuperation test (Murray and Wintle, 2000) and OSL-IR depletion ratio test (Duller, 2003). Luminescence data for each aliquot was processed in 'Luminescence Analyst' version 3.24 © University of Wales, 2007 and dose response curves were fitted with an 'Exp+Linear Fit' function. The final D_e and overdispersion values for each sample were calculated using the central age model (CAM) (Galbraith et al. 1999).

4. Results

4.1. Terrestrial aeolian dunes

Relict terrestrial aeolian dunes, similar to those described by Thom et al. (1994), occur landwards of Seven Mile Beach coastal barrier in the form of a fragmented dune ridge and subtle sand sheet that slopes gently to the southeast (Figure 1 a). This terrestrial aeolian dune unit is best exposed in a disused sand quarry where three distinct facies are evident based on lithology, sedimentary structures and two thermoluminescence (TL) ages completed by D. Price at the University of Wollongong in 2010 (Donaldson, 2010). The uppermost layer at this exposure consists of a cross laminated sandsheet ~1 m thick composed of fine to medium grained, well-sorted sub-angular to sub-rounded sands with an immature soil profile. A truncated palaeosol containing abundant charcoal separates this feature from a massive quartz sand deposit ~5 m thick, composed of fine to medium grained, well-sorted sub-rounded grains of quartz. Increasing organics and charcoal were evident in the top 1 m of this facies, immediately below the palaeosol. This massive sand

deposit returned a TL age of $26,100 \pm 3,400$ years from its mid-upper portion, indicating deposition occurred during the Last Glacial Maximum (LGM).

A 10-15 m thick deposit of cross bedded strata underlies the LGM massive sands. This lower facies comprises fine to coarse grained, variably sorted, sub-rounded grains of quartz sands with a subordinate component of lithic fragments including strongly magnetic fine grained sands. The cross bed structures are variable and include high to low angle trough cross-bedding and planar cross-bedding with strongly bimodal N-S dip direction, some horizontal bedding, inverse grading, granule ripples and trace fossil burrows are also evident. A sample for TL dating taken near the base of this cross-bedded sequence gave an age of $53,800 \pm 3,500$ years, indicating deposition occurred during early MIS 3.

Whereas Davies (1959) considered this feature to be a raised coastal barrier of Holocene age, the preserved surface morphology evident in the LiDAR-derived DEM, the sedimentary characteristics observed from exposed sections, and the TL ages indicate that it is a terrestrial dune that was apparently active during multiple phases of MIS 2 and MIS 3. The chronology of this aeolian sequence broadly coincides with terrestrial dune activity in northeast Tasmania between 17,000-24,000 years (Duller and Augustinus 2006) and the general increased aeolian activity documented in the Late Pleistocene period throughout Tasmania (McIntosh et al. 2009). The orientation of these terrestrial aeolian dune features deposited during the LGM conform to reconstructed palaeowind directions (Thom et al. 1994; Duller and Augustinus 1997; 2006).

4.2. Holocene sedimentary deposits

4.2.1. Regressive estuarine plain

Between the terrestrial aeolian dune succession and the landward margin of the Seven Mile Beach barrier ridge sequence lies a poorly exposed regressive estuarine plain unit comprising four distinct facies; a basal fossiliferous calcrete, a calcareous clay rich gravelly sand layer, a sandy clay to clayey sand layer and an upper clayey sand layer. This unit is at

least 1.7 m thick and is exposed on the eroding Pitt Water shoreline at Five Mile Beach. The basal fossiliferous calcrete layer occurs at approximately 1.65 m above MSL. No sediment from these facies has been dated to constrain the timing of the somewhat higher water levels or possible high energy wave events indicated by this facies' character and depositional position. The lower facies of this regressive estuarine plain display characteristic properties of palaeotsunami deposits such as fining upwards, an erosional base and mixed coastal and terrestrial sediments. Further investigation of this unit is needed to ascertain if it is related to other published evidence from elsewhere in southeastern Tasmania of possible tsunami deposits preserved in back-beach settings (Clark et al. 2011).

At the western end of this deposit is an infilled backbarrier lagoon sequence marked by a broad low-lying clayey surface around +2-3 m above MSL. A 1.75 m core through this unit reveals a broadly upward fining sequence with plastic clay to sandy clay with interfingering beds of clayey sands near the base. These clayey sands contain calcareous concretions up to 400 mm in diameter that are likely to have been derived from a marine quartz carbonate sand source where the shelly fraction has leached out to form the concretions. Underlying this lagoonal sequence is a sandy unit noted by Cromer (1980) and interpreted as a transgressive sand. Broadly these two units, the regressive estuarine plain and the infilled backbarrier lagoon, indicate a transition from marine dominated deposition to fluvial or other terrestrial depositional processes.

4.2.2. *Relict foredune ridge morphology and sedimentary character*

A detailed examination of the Seven Mile Beach barrier surface morphology from the LiDAR-derived DEM shows 30-40 sub-parallel relict foredune ridges (Figure 1 a). The ridge-crest elevations of these reach between 4 and 6 metres above MSL (Figure 3). There is a distinct change in ridge alignment at the landward margin of the barrier northeast of Hobart Airport (Figure 1 a). In the eastern portion of the barrier a large hummocky transgressive dune and associated erosional interdune deflation hollow is present (Figure 1 a). In this eastern portion

of the barrier the relation of the relict foredune ridges to the alignment of the present shoreline is more complicated and there is evidence of greater dune activity in the past. A large established foredune and smaller deflation hollow is also evident directly southeast of the Hobart airport runway (Figure 1 a).

The Seven Mile Beach relict foredune ridges are composed of aeolian sediments that have been pedogenically modified at the surface. These aeolian sediments overlie beach and backshore sediments with occasional broken shell fragments which increase in abundance with depth. The sediments are light yellowish brown, medium grained, well-sorted, sub-angular to rounded grains of quartz and carbonate. Landwards, carbonate grains decrease at shallow depths and calcareous rhizoconcretions are present and prolific in the exposed sediments along the eroding shoreline of Five Mile Beach. A semi-indurated calcrete layer is present also in the mid profile of the landward ridges only.

4.2.3. *GPR-imaged relict foredune ridge internal structures*

Five GPR transects across the Holocene relict foredune ridges provide insight into the internal structure of the barrier deposits. The key units identified from the LiDAR DEM, including the ridge alignment change, the shore parallel ridges, and the deflation hollow, have been imaged. GPR was also collected across the mobile easternmost portion of the hummocky transgressive dune and revealed high angle planar cross-beds with tangential downlap bases and regular reactivation surfaces (Donaldson 2010).

GPR lines BR1 and BR2 (see Figure 1 a and Figure 4) indicate that the upper portion of the relict foredune ridge deposits contain structureless aeolian capping while the middle to lower sediments are characterised by seaward (S) dipping packages, comprising backshore, beachface and upper-shoreface sediments. The wave deposited packages identified in the GPR comprise internal clinoform structures that typically shallow towards their bases and are often laterally bound by concave surfaces. A 50 MHz profile (BR5 see Figure 5) in the

landward portion of the ridge plain shows some clinoform reflections which downlap onto a lower sub-horizontal basal surface, which broadly corresponds with a lithological change to transgressive sand identified in cores by Forster (1997) and Cromer (2006) at 4 to 5 m below MSL. The upper termination of dipping clinoform reflections is characterised by toplap and an associated change in geometry to lower-angle sometimes convex reflections at around 2 m above mean sea level, which likely image beach berm deposits. The GPR line BR6 (Figure 6), which traverses the change in ridge alignment, shows seaward dipping clinoforms consistent in geometry with GPR lines BR1 and BR2 and indicates that beachface sediments have been directly welded on to one another with no subsurface evidence of erosional signatures associated with ridge truncation and realignment.

The GPR section across the deflation hollow (BR3-4, Figure 7) shows similar seaward-dipping clinoforms to those seen in BR1 and BR2 (Figure 7) indicating a similar mode of deposition. This indicates that progradation of the barrier has occurred out to the present shoreline before the erosional phase of transgressive ridge building and deflation hollow development occurred.

4.2.4. Relict foredune ridge depositional chronology

Fourteen OSL ages were determined from samples collected on the Holocene barrier to constrain the chronology of the relict foredune ridges forming the Seven Mile Beach barrier (Figure 1 a). These ages indicate progradation of the shoreline over a ~7000 year period. The three ages between ~7300 and ~6800 close to Hobart airport demonstrate that the landward ridges formed during the mid-Holocene when the sea level was at or near present height (see Figure 1 a and profile C in Figure 3). The three ages between ~7300 and ~6800 ages are also from samples located either side of the change in ridge alignment and show that this occurred relatively rapidly and that there was no substantial pause in ridge deposition.

The anomalous age of $24\,250 \pm 1280$ for the landward ridge may be due to sampling into the terrestrial aeolian dune unit to the northwest (discussed below) on to which the Holocene barrier is welded. The core taken when collecting the sample dated to $24\,250 \pm 1280$ showed a far more strongly podsolised soil profile than was evident in the Holocene ridges. The age of 7320 ± 330 years ago was taken from a cross section of the ridge stratigraphy exposed from ongoing erosion along Five Mile Beach (Figure 1 a). Examination of the sedimentary facies in this section revealed seaward-dipping bedding with heavy mineral lenses typical of upper shoreface storm lag deposits and similar to those described by Dougherty (2014) for Omaha, New Zealand. The elevation of these heavy mineral lenses exposed along the Five Mile Beach shoreline at the most landward ridge was consistent with the upper beachface elevations on the modern shoreline. It appears thus from these two ages and the observed sedimentary features, that the backshore slope of this most landward ridge may be composed of aeolian terrestrial dune sediment and the foreshore slope with seaward-dipping heavy mineral lenses of Holocene age (see Figure 6). This implies that the Holocene barrier is welded directly onto the aeolian terrestrial dune. The age of this most landward ridge is in accord with recently published OSL ages for the most landward ridges at prograded barriers in southern New South Wales (Oliver et al. 2015; Oliver and Woodroffe 2016; Oliver 2016) and also corresponds with the best estimates of the cessation of the post-glacial marine transgression (PGMT) in Australasia according to Lewis et al. (2013).

A horizontal offset in the OSL dating transects also corresponds with an apparent ~3000 year phase of substantially reduced progradation rate from ~6750 to ~3600 years ago (Figure 1 a). To test whether the ridges are consistent in age alongshore, a sample was collected and dated near the Hobart airport from the same ridge dated 3280 ± 150 years ago in Profile A (see Figure 1 a and Figure 3). This ridge may be traced as a continuous feature alongshore between the two dated samples sites. The age of 3250 ± 150 years ago near the Hobart airport confirms that deposition has been contemporaneous along the ridge corroborating the swash-aligned formation of the ridge and indicating negligible longshore

transport. Therefore a ~3000 year hiatus in deposition between ~6750 and ~3600 seems evident despite the spatial offset of the sampling transects.

The eastern OSL sampling transect (profile A in Figure 1 a and Figure 3) shows a remarkably steady rate of ridge progradation (Figure 8) from ~3600 to ~1400 years ago indicated by seven consecutively younger ages taken from topographically higher ridges across the barrier. The rate of progradation across profile A in Figure 3 is approximately 0.4 m per year with a 'ridge lifetime' of around 105 years. Seaward of the ridge dated 1390 ± 70 along profile A (Figure 3) there are two more distinct ridges landward of the deflation hollow which formed in conjunction with the large transgressive dune. Profile B in Figure 3 traverses this dune which is around 17 m high at this location. An OSL age from 1 m deep in the dune crest returned an age of 60 ± 5 years ago. This age corresponds closely with the timing of dune stabilisation due to the planting of Marram grass during the 1950's at this location and there is little evidence for ongoing dune mobility. The upper portion of the ridges seaward of the age 1390 ± 70 in profile A have been reworked by the deflation activity; however, the barrier must have prograded to at or near the present shoreline position before the deflation activity and dune building occurred. This is an additional 360 m of barrier width representing approximately 900 years of additional progradation (assuming the rate of 0.4 m/yr indicated by the OSL age succession). Therefore this large transgressive dune is likely to have formed in last ~500 years. Further dating of the beachface sediments at the base of the deflation hollow close to the present shoreline could constrain the timing of the dune activity more precisely.

5. Discussion

OSL dating, GPR, LiDAR topography and sedimentological analysis have enabled the reconstruction of the Holocene coastal evolution at Seven Mile Beach in southeast Tasmania shown schematically in Figure 9. The OSL results presented in this study

demonstrate that the marine quartz sands of this region of Tasmania have excellent luminescence properties. Very low overdispersion values indicate the high sensitivity of the quartz grains in aeolian sands, also demonstrated by Fitzsimmons et al. (2010), and confer confidence in final age determinations. More broadly, the OSL ages conform to the general character of quartz from southeastern Australia, reflected in successful dating of prograded barriers in this region (Goodwin et al. 2006; Murray-Wallace et al. 2002; Oliver et al. 2015; Oliver & Woodroffe 2016). The comparable ages determined for two samples collected along the same ridge 3.4 km apart also demonstrate the suitability of optical dating for determining the age of Holocene marine and coastal sediments in Australia. That these two samples from the same ridge had comparable ages, also confirms that the ridge building occurred contemporaneously along the shoreline configuration, rather than as a result of longshore processes, reaffirming the planform configuration of the barrier to modal wave climate and refraction patterns into Frederick Henry Bay (Figure 1 c) as emphasised by Davies (1958; 1959) who built on the work of Jennings (1955) (see also recent discussion in Oliver et al. 2016). Despite this, the planform configuration of the preserved ridges shows a substantial shift in shoreline orientation between ~7500-6500 years ago (Figure 9 b, c), which may be due to modal wave climate redistributing the aeolian terrestrial dune sediments within Frederick Henry Bay. Bowman et al. (1986) explained the ridge alignment shifts at Rheban Spit on the east coast of Tasmania as due to changing wave refraction patterns as sediment were redistributed in the region. Re-alignments of ridge orientation in northern NSW have been attributed to the interaction of wave climate and sediment availability with the antecedent topography and shifts in dominant wind direction associated with phases of increased dune building (Goodwin et al. 2006).

Progradation appears to have been limited for a period of up to 3000 years between ~6500 and ~3500 years ago as indicated by the OSL ages. This hiatus deserves additional consideration as depositional hiatuses in coastal progradation have been linked to changes in storminess (Reimann et al. 2011) or the interplay of wave energy, sea-level change and

sediment supply (Fruegaard et al. 2015a). During this time period, only two slightly larger ridges are preserved and there is a low-angle truncation in ridge alignment. One explanation for this pause in progradation is the extinguishing of the terrestrial aeolian dunes as localised sediment source before sufficient shoreface sediments were worked into Frederick Henry Bay to supply sand for barrier progradation from ~3500 years onwards (Figure 9d). The importance of localised sediment supply controlling ridge progradation has been emphasised by several studies (Anthony 1995; Hein et al. 2016; Kinsela et al. 2016; Timmons et al. 2010). As the Seven Mile Beach prograded barrier is located at the upper end of a deep bedrock embayment, there is limited potential for new sediment sources to drive ongoing progradation once local sources are extinguished. However, the reactivation of progradation from between ~3500 years to around ~500 years ago requires a new sand source entering Frederick Henry Bay during this time. A source of sediment partially accounting for the renewed progradation from ~3500 ago is the material eroded from the Five Mile Beach shoreline, which may have been moved into Frederick Henry Bay through the development of a flood tide delta as the tidal channel connecting Pitt Water to the ocean constricted resulting in more energetic tidal flow (Figure 9 d).

Alternatively, changes in sea-level may have driven shoreface adjustments and hence the pause in shoreline progradation. If a sea level slightly higher than present occurred in the mid-Holocene then a subsequent fall to present level could have driven shoreline progradation through forced regression (Kinsela et al. (2016). However, Kinsela et al. (2016) has demonstrated with morphodynamic modelling that a sea-level fall from a 1.5 m highstand only exerted a minor influence on barrier growth for the Forster-Tuncurry barrier compared to the influence of an inherited disequilibrium shoreface profile. Evidence for higher Holocene sea levels around Tasmania is limited with some evidence for a +0.5 m highstand around 3500-2500 years ago (Lewis et al. 2013) and other evidence suggesting sea levels were lower than present for much of the Late Holocene (Gehrels et al. 2012). However, uplift rates inferred from raised MIS 5e marine deposited sediments around

Tasmania (+11 m above present MSL at minimum) (Murray-Wallace & Belperio 1991) means that marine sediments 7500 years old might be expected to be +0.66 m above present MSL assuming a continuing average uplift rate of 0.088 mm/yr. This uplift rate needs to be considered in future investigations of Holocene sea-level changes in Tasmania.

Changes in sediment budget and changes in sea level have been suggested as important factors controlling barrier evolution over the Holocene on other energetic sandy coastlines around the world (Fruergaard et al. 2015b; Hein et al. 2014; 2016; Timmons et al. 2010). In contrast, Moore et al. (2016) infer that periodic ridge-building may be driven by autocyclic processes related to ridge topography and vegetation, and caution against speculating about external causes despite acknowledging the critical importance of shoreline progradation rate and lateral dune growth rate which cannot be controlled by internal dune dynamics. Also, Moore et al. (2016) considered comparatively short term dune growth with ridges forming over just 5-6 years, whereas at Seven Mile Beach in Tasmania ridges form over ~100 years which is comparable to other sites in southeastern Australia (Oliver et al. 2015). It appears that at this location ridge building and shoreline progradation is strongly controlled by sediment availability in the embayment.

From around 3500 – 500 years ago a steady rate of progradation (0.4 m/yr) is inferred from the pattern of OSL ages taken along a ~1 km long GPR transect in the eastern portion of the barrier. This rate of progradation is in close accord with rates determined for other prograded barriers on the Australian mainland (see Table 3 in Oliver et al. 2015). The sedimentology and GPR-imaged subsurface structures also indicate the accumulation of beach and dune sediments with regressive beachfaces demarcating storm cut and recovery preserved under positive sediment budget conditions (Figure 9e). In the past 500 years, substantial changes have occurred to the seaward portion of the barrier with the development of a large hummocky transgressive dune (Figure 9f). This transgressive dune and the generally higher foredune in the western portion of the Seven Mile Beach barrier resembles the morphology of many prograded barriers in southern NSW (see Fig. 4 in Oliver et al. 2016) and northern

NSW (e.g. Fens embayment, Hesp 2013). The timing of the development of these higher foredunes has been determined at some sites e.g. Guichen Bay (Murray-Wallace et al. 2002), Moruya (Oliver et al. 2015), Callala (Oliver and Woodroffe 2016) and Wonboyn (Oliver 2016) and it appears that these foredunes have formed in the last 500 years and most likely in the past 200 years. At Fens, NSW a prevailing SE wind exposure gradient from south to north has resulted in a large deflation hollow and associated transgressive dune forming in the north of the barrier reworking relict foredune ridges (Hesp 2013). The cause of such features on many prograded barriers in southeastern Australia is not yet known but may be linked with land clearing and grazing on coastal barriers during early European settlement (Chappell & Thom 1986). At Seven Mile Beach Tasmania a strengthening of the westerly circulation during the past 500 – 150 years may also be responsible for increased dune building (Shulmeister et al. 2004). This change in barrier morphology is significant considering the demonstrated importance of sediment delivery regime as a fundamental control on barrier evolution and ridge morphology (Nott 2012; Hein et al. 2016). Multiple lines of evidence suggest that limited progradation has occurred in the past ~500 years implying that the shoreface has reached an equilibrium condition with respect to modal wave energy with no new sand sources entering the bay to enable further shoreline progradation.

6. Conclusion

OSL dating, GPR and sedimentological analysis of Holocene coastal deposits at Seven Mile Beach reveal a complex history involving the preservation of sediments of terrestrial and marine origin. The Seven Mile Beach Holocene prograded barrier is backed by a terrestrial aeolian dune system with multiple phases of activity in MIS 3 and MIS 2 in accord with other dated terrestrial aeolian dunes around Tasmania. The landward-most ridge was welded on to the terrestrial aeolian dune system ~7300 years ago when sea level reached at or near present following the Post-Glacial Marine Transgression. An initial phase of shoreline

progradation from ~7300 to ~6500 years ago occurred and a series of ridges built seawards into Frederick Henry Bay, preserving changes in shoreline alignment. Shoreline progradation virtually ceased between ~6500 years and ~3500 years ago as only two slightly larger ridges developed. This depositional hiatus appears to have resulted from the extinguishment relict terrestrial dune sediments as a local sand source for progradation with new sources of barrier sand from the floor of Frederick Henry Bay required to explain progradation from ~3500 years ago until at least ~1400 years ago at a steady rate of 0.4 m/yr. This new sand source driving progradation from ~3500 onwards may have been due to Late-Holocene sea-level fall from a high-stand in the mid Holocene. Transgressive dune activity in the past ~500 years has reworked the frontal portion of the barrier which includes the ridges deposited after ~1400 years ago. This dune activity is the morphological expression of another significant hiatus in barrier deposition in the past 500 years. The relict foredune ridges are strongly configured in planform to the modal wave refraction patterns as suggested by Davies (1958; 1959). The chronology of Seven Mile Beach in Tasmania is significantly different to reported chronologies for the Australian mainland which have not exhibited substantial pauses in deposition. Further investigation of Late Quaternary coastal deposits around Tasmania holds considerable potential for understanding the relative influence of key drivers of coastal barrier development and this study re-opens the debate on Holocene sea-level change in Tasmania.

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References

- Anderson, A., Vilumaa, K., Tonisson, H., Kont, A., Ratas, U., Suuroja, S., 2014. Geomorphology of coastal formations on present and ancient sandy coasts. *Journal of Coastal Research* SI 70, 90–95.
- Anthony, E.J., 1995. Beach-ridge development and sediment supply: examples from West Africa. *Marine Geology* 129, 175–186.
- Bacon, C.A., Calver, C.R., Boreham, C.J., Leaman, D.E., Morrison, K.C., Revill, A.T., Volkman, J.K., 2000. The petroleum potential of onshore Tasmania: a review. *Bulletin of the Geological Survey of Tasmania* 71, 93 p.
- Bowman, G.M., 1986. The Holocene Evolution of Rheban Spit, Tasmania 1. Age structure, geomorphic development and sediment characteristics. *Papers and Proceedings of the Royal Society of Tasmania* 120, 23-32.
- Bristow, C., 2009. Ground penetrating radar in aeolian dune sands, in: Jol, H.M. (Ed.), *Ground Penetrating Radar, Theory and Applications*. Elsevier Science, Amsterdam, pp. 273–297.
- Bristow, C.S., Chroston, N.P., Bailey, S.D., 2000. The structure and development of foredunes on a locally prograding coast: Insights from ground-penetrating radar surveys, Norfolk, UK. *Sedimentology* 47, 923–944.

- Brooke, B., Ryan, D., Pietsch, T., Olley, J., Douglas, G., Packett, R., Radke, L., Flood, P., 2008. Influence of climate fluctuations and changes in catchment land use on Late Holocene and modern beach-ridge sedimentation on a tropical macrotidal coast: Keppel Bay, Queensland, Australia. *Marine Geology* 251, 195–208.
- Chappell, J., Thom, B. G. 1986. Coastal morphodynamics in North Australia: review and prospect. *Australian Geographical Studies* 24, 110–127.
- Clark, K., Cochran, U., Mazengarb, C., 2011. Holocene coastal evolution and evidence for paleotsunami from a tectonically stable region, Tasmania, Australia. *The Holocene* 21, 883–895.
- Clemmensen, L. B., and Nielsen, L. 2010. Internal architecture of a raised beach ridge system (Anholt, Denmark) resolved by ground-penetrating radar investigations. *Sedimentary Geology*, 223, 281–290.
- Cromer, W., 1980. Groundwater investigations at Seven Mile Beach for the Royal Hobart Golf Club. Department of Mines, Tasmania, p. 86.
- Cromer, W., 2006. A hydrological review of the Seven Mile Beach spit, southeastern Tasmania. *Mineral Resources Tasmania*, Tasmania.
- Davies, J.L., 1958. Wave refraction and the evolution of shoreline curves. *Geographical Studies* 5, 1–14.
- Davies, J.L., 1959. Sea level change and shoreline development in South-Eastern Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 93, 89–95.
- Davies, J.L., 1961. Tasmanian beach ridge systems in relation to sea level change. *Papers and Proceedings of the Royal Society of Tasmania* 95, 35–41.

- Dillenburg, S. R., Tomazelli, L. J., Hesp, P. A., Barboza, E. G., Clero, L. C. P., da Silva, D. B. 2004. Stratigraphy and evolution of a prograded transgressive dunefield barrier in southern Brazil. *Journal of Coastal Research*, SI 39, 132–135.
- Donaldson, P., 2010. Facies Architecture and Radar Stratigraphy of the Seven Mile Spit Complex, Tasmania, School of Earth Sciences. University of Tasmania, Hobart, p. 147.
- Dougherty, A.J., 2014. Extracting a record of Holocene storm erosion and deposition preserved in the morphostratigraphy of a prograded coastal barrier. *Continental Shelf Research* 86, 116–131.
- Duller, G.A.T., 2003. Distinguishing quartz and feldspar in single grain luminescence measurements. *Radiation Measurements* 37, 161–165.
- Duller, G.A.T., Augustinus, P., 1997. Luminescence studies of dunes from north-eastern Tasmania. *Quaternary Science Reviews* 16, 357–365.
- Duller, G.A.T., and Augustinus, P.C., 2006. Reassessment of the record of linear dune activity in Tasmania using optical dating. *Quaternary Science Reviews* 25, 2608–2618.
- Engel, M., May, S.M., Scheffers, A., Squire, P., Pint, A., Kelletat, D., Brückner, H., 2015. Prograded foredunes of Western Australia's macro-tidal coast - implications for Holocene sea-level change and high-energy wave impacts. *Earth Surface Processes and Landforms* 40, 726–740.
- Fitzsimmons, K. E., Rhodes, E. J., Barrows, T. T., 2010. OSL dating of southeast Australian quartz: A preliminary assessment of luminescence characteristics and behaviour. *Quaternary Geochronology*, 5, 91–95.
- Foster, M., 1997. Pittwater - Progress Report. Louisa Mining Corporation.

- Fruergaard, M., Andersen, T. J., Nielsen, L. H., Johannessen, P. N., Aagaard, T., Pejrup, M., 2015a. High-resolution reconstruction of a coastal barrier system: impact of Holocene sea-level change. *Sedimentology*, 62, 928–969.
- Fruergaard, M., Møller, I., Johannessen, P.N., Nielsen, L.H., Andersen, T.J., Nielsen, L., Sander, L., Pejrup, M., 2015b. Stratigraphy, Evolution, and Controls of a Holocene Transgressive – Regressive Barrier Island under Changing Sea Level : Danish North Sea Coast. *Journal of Sedimentary Research* 85, 820–844.
- Galbraith, R., Roberts, R., Laslett, G., Yoshida, H., Olley, J., 1999. Optical dating of single and multiple grains of quartz from Jinmium rock shelter, northern Australia: Part I, experimental design and statistical models. *Archaeometry* 41, 339–364.
- Gehrels, W.R., Callard, S.L., Moss, P.T., Marshall, W.A., Blaauw, M., Hunter, J., Milton, J.A., Garnett, M.H., 2012. Nineteenth and twentieth century sea-level changes in Tasmania and New Zealand. *Earth and Planetary Science Letters* 315-316, 94–102.
- Goodwin, I., Stables, M., Olley, J., 2006. Wave climate, sand budget and shoreline alignment evolution of the Iluka–Woody Bay sand barrier, northern New South Wales, Australia, since 3000 yr BP. *Marine Geology* 226, 127–144.
- Guedes, C.C.F., Giannini, P.C.F., Sawakuchi, A.O., DeWitt, R., Nascimento, D.R., Aguiar, V.A.P., Rossi, M.G., 2011. Determination of controls on Holocene barrier progradation through application of OSL dating: The Ilha Comprida Barrier example, Southeastern Brazil. *Marine Geology* 285, 1–16.
- Guérin, G., Mercier, N., Adamiec, G., 2011. Dose-rate conversion factors: Update. *Ancient TL* 29, 5–8.
- Hede, M. U., Sander, L., Clemmensen, L. B., Kroon, A., Pejrup, M., Nielsen, L., 2015. Changes in Holocene relative sea-level and coastal morphology: A study of a raised

beach ridge system on Samso, southwest Scandinavia. *The Holocene*, 25, 1402–1414.

Hein, C.J., Fitzgerald, D.M., De Souza, L.H.P., Georgiou, I.Y., Buynevich, I.V., Da, A.H., Klein, F., Thadeu De Menezes, J., Cleary, W.J., Scolaro, T.L., 2016. Complex coastal change in response to autogenic basin infilling: An example from a sub-tropical Holocene strandplain. *Sedimentology*.

Hein, C.J., FitzGerald, D.M., Thadeu de Menezes, J., Cleary, W.J., Klein, A.H.F., Albernaz, M.B., 2014. Coastal response to late-stage transgression and sea-level highstand. *Geological Society of America Bulletin* 126, 459–480.

Hesp, P. A., 2006. Sand Beach Ridges: Definitions and Re-Definition. *Journal of Coastal Research*, SI 39, 72–75.

Hesp, P.A., 2013. A 34 year record of foredune evolution, Dark Point, NSW, Australia. *Journal of Coastal Research* 65, 1295–1300.

Hesp, P. A., Dillenburg, S. R., Barboza, E. G., Clerot, L. C. P., Tomazelli, L. J., Norberto Ayup Zouain, R., 2007. Morphology of the Itapeva to Tramandai transgressive dunefield barrier system and mid- to late Holocene sea level change. *Earth Surface Processes and Landforms*, 32, 407–414.

Jennings, J.N., 1955. The influence of wave action on coastal outline in plan. *Australian Geographer* 6, 36–44.

Kinsela, M.A., Daley, M.J.A., Cowell, P.J., 2016. Origins of Holocene coastal strandplains in Southeast Australia: Shoreface sand supply driven by disequilibrium morphology. *Marine Geology* 374, 14–30.

- Lewis, D., 2006. Modern and Recent Seafloor Environments (Sedimentary, Foraminiferal and Ostracode) of the Pitt Water Estuary, South-east Tasmania. PhD Thesis, University of Tasmania, p 215
- Lewis, S.E., Sloss, C.R., Murray-Wallace, C.V., Woodroffe, C.D., Smithers, S.G., 2013. Post-glacial sea-level changes around the Australian margin: a review. *Quaternary Science Reviews* 74, 115–138.
- McIntosh, P.D., Eberhard, R., Slee, A., Moss, P., Price, D.M., Donaldson, P., Doyle, R., Martins, J., 2012. Late Quaternary extraglacial terrestrial deposits in low and mid-altitude Tasmania and their climatic implications. *Geomorphology* 179, 21–39.
- McIntosh, P.D., Price, D.M., Eberhard, R., Slee, A.J., 2009. Late Quaternary erosion events in lowland and mid-altitude Tasmania in relation to climate change and first human arrival. *Quaternary Science Reviews* 28, 850–872.
- McIntosh, P.D., Price, D.M., Grove, S., Slee, A.J., 2013. Reply to Murray-Wallace et al. (2013): Comments on a paper by Slee et al. (2012). A reassessment of Last Interglacial deposits at Mary Ann Bay, Tasmania. *Quaternary Australasia* 30, 6–8.
- Moore, L.J., Vinent, O.D., Ruggiero, P., 2016 . Vegetation control allows autocyclic formation of multiple dunes on prograding coasts. *Geology* 44, 1–4.
- Murray, A., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32, 57–73.
- Murray-Wallace, C.V., Banerjee, D., Bourman, R.P., Olley, J.M., Brooke, B.P., 2002. Optically stimulated luminescence dating of Holocene relict foredunes, Guichen Bay, South Australia. *Quaternary Science Reviews* 21, 1077–1086.
- Murray-Wallace, C.V., Belperio, A.P., 1991. The last interglacial shoreline in Australia — A review. *Quaternary Science Reviews* 10, 441–461.

- Murray-Wallace, C.V., Colhoun, E.A., Goede, A., Quilty, P.G., 2013. Comments on Slee et al. (2012). A reassessment of Last Interglacial deposits at Mary Ann Bay, Tasmania. *Quaternary Australasia* 29: 4-11. *Quaternary Australasia* 30, 4–6.
- Murray-Wallace, C.V., Goede, A., 1991. Aminostratigraphy and electron spin resonance studies of late Quaternary sea level change and coastal neotectonics in Tasmania, Australia. *Zeitschrift fur Geomorphologie* 35, 129–149.
- Murray-Wallace, C. V., Goede, A. 1995. Aminostratigraphy and electron spin resonance dating of Quaternary coastal neotectonism in Tasmania and the Bass Strait islands. *Australian Journal of Earth Sciences*, 42, 51–67.
- Murray-Wallace, C.V., Goede, A., Picker, K., 1990. Last interglacial coastal sediments at Mary Ann Bay, Tasmania and their neotectonic significance. *Quaternary Australasia* 8, 26–32.
- Neal, A., Roberts, C., 2000. Applications of ground-penetrating radar (GPR) to sedimentological, geomorphological and geoarchaeological studies in coastal environments. *Geological Society Special Publications* 175, 139–171.
- Nott, J., 2012. Storm Tide Recurrence Intervals - A Statistical Approach Using Beach Ridge Plains in Northern Australia. *Geographical Research*, 50, 368–376.
- Nott, J., Smithers, S., Walsh, K., Rhodes, E., 2009. Sand beach ridges record 6000 year history of extreme tropical cyclone activity in northeastern Australia. *Quaternary Science Reviews* 28, 1511–1520.
- Oliver, T.S.N., 2016. Holocene depositional history of three coastal sand ridge plains, southeastern Australia. PhD Thesis, University of Wollongong, Wollongong p. 216

- Oliver, T.S.N., Dougherty, A.J., Gliganic, L.A., Woodroffe, C.D., 2015. Towards more robust chronologies of coastal progradation: Optically stimulated luminescence ages for the coastal plain at Moruya, south-eastern Australia. *The Holocene* 25, 536–546.
- Oliver, T.S.N., Thom, B.G., Woodroffe, C.D., 2016. Formation of Beach-Ridge Plains: An Appreciation of the Contribution by Jack L. Davies. *Geographical Research* Accepted, In Press.
- Oliver, T.S.N., Woodroffe, C.D., 2016. Chronology, Morphology and GPR-imaged Internal Structure of the Callala Beach Prograded Barrier in Southeastern Australia. *Journal of Coastal Research* SI 75, 318–322.
- Otvos, E.G., 2000. Beach ridges — definitions and significance. *Geomorphology* 32, 83–108.
- Prescott, J.R., Hutton, J., 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements* 23, 497–500.
- Reimann, T., Tsukamoto, S., Harff, J., Osadczuk, K., Frechen, M., 2011. Reconstruction of Holocene coastal foredune progradation using luminescence dating — An example from the Świna barrier (southern Baltic Sea, NW Poland). *Geomorphology* 132, 1–16.
- Rémillard, A. M., Buylaert, J.-P., Murray, A. S., St-Onge, G., Bernatchez, P., Hétu, B., 2015. Quartz OSL dating of late Holocene beach ridges from the Magdalen Islands (Quebec, Canada). *Quaternary Geochronology*, 30, 264-269.
- Roy, P.S., Cowell, P.J., Ferland, M.A., Thom, B.G., 1994. Wave Dominated Coasts, in: Carter, R.W.G., Woodroffe, C.D. (Eds.), *Coastal Evolution: Late Quaternary Shoreline Morphodynamics*. Cambridge University Press, Cambridge, pp. 121–186.

- Shulmeister, J., Goodwin, I., Renwick, J., Harle, K., Armand, L., McGlone, M. S., Cook, E., Dodson, J., Hesse, P.P., Mayewski, P., Curran, M. (2004). The Southern Hemisphere westerlies in the Australasian sector over the last glacial cycle: A synthesis. *Quaternary International* 118–119, 23–53.
- Sharples, C., Mount, R., Hemer, M.A., Puotinen, M., Dell, M., Lacey, M., Harries, S., Otera, K., Benjamin, J., Zheng, X., 2012. The ShoreWave Project: Development of a methodology for coastal erosion risk analysis under climate change, integrating geomorphic and wave climate data sets. Report to Commonwealth Department of Climate Change and Energy Efficiency, by the University of Tasmania, Hobart, Tasmania., 11th April 2012, 285 p.
- Shin, J., 2013. Stratigraphy and geochronology of quaternary marine terraces of Tasmania, Southeastern Australia: Implications on neotectonism. *Geosciences Journal* 17, 429–443.
- Slee, A.J., McIntosh, P.D., Price, D.M., Grove, S., 2012. A reassessment of Last Interglacial deposits at Mary Ann Bay, Tasmania. *Quaternary Australasia* 29, 4–11.
- Stacey A.R. and Berry, R. F., 2004. The structural history of Tasmania; a review for petroleum explorers. Petroleum Exploration Society of Australia Eastern Australasian Basins Symposium II, Adelaide.
- Tamura, T., 2012. Beach ridges and prograded beach deposits as palaeoenvironment records. *Earth-Science Reviews* 114, 279–297.
- Tamura, T., Murakami, F., Nanayama, F., Watanabe, K., Saito, Y., 2008. Ground-penetrating radar profiles of Holocene raised-beach deposits in the Kujukuri strand plain, Pacific coast of eastern Japan. *Marine Geology* 248, 11–27.
- Taylor, M., and Stone, G. W., 1996. Beach-Ridges: A Review. *Journal of Coastal Research*, 12, 612–621.

- Thom, B.G., 1983. Transgressive and regressive stratigraphies of coastal sand barriers in southeast Australia. *Marine Geology* 56, 137–158.
- Thom, B.G., Bowman, G.M., Gillespie, R., Temple, R., Barbetti, M., 1981a. Radiocarbon dating of Holocene beach-ridge sequences in South-East Australia. Department of Geography, University of New South Wales at Royal Military College, Duntroon, ACT, Australia, p. 36.
- Thom, B.G., Bowman, G.M., Roy, P.S., 1981. Late Quaternary evolution of coastal sand Barriers, Port Stephens-Myall Lakes Area, central New South Wales, Australia. *Quaternary Research* 15, 345–364.
- Thom, B.G., Hesp, P., Bryant, E., 1994. Last glacial “coastal” dunes in Eastern Australia and implications for landscape stability during the Last Glacial Maximum. *Palaeogeography, Palaeoclimatology, Palaeoecology* 111, 229–248.
- Timmons, E.A., Rodriguez, A.B., Mattheus, C.R., DeWitt, R., 2010. Transition of a regressive to a transgressive barrier island due to back-barrier erosion, increased storminess, and low sediment supply: Bogue Banks, North Carolina, USA. *Marine Geology* 278, 100–114.

Figure captions

Figure 1: a) Map of the Seven Mile Beach barrier derived from airborne LiDAR showing the major geomorphic features, OSL ages and GPR transect locations, b) map of Tasmania showing location of Frederick Henry Bay, c) inset map showing Frederick Henry Bay wave refraction patterns and resultant shoreline alignment of Seven Mile Beach relict ridges and other sandy beaches (bold lines) within the bay; modified after Davies (1958) and Oliver et al. (2016).

Figure 2: Results of preheat plateau test on sample SMB-T-1 (see Table 1) showing various pre-heat and cut-heat combinations for sets of three aliquots with measured De. The central age model (CAM) (Galbraith et al. 1999) for all 24 aliquots is represented by the dashed line.

Figure 3: Three topographic profiles A,B and C (see Figure 1 for locations) across the Seven Mile Beach prograded barrier with OSL ages plotted with respect to sample location and depth. All axes are in metres.

Figure 4: GPR transects BR1 and BR2 collected with a 100 MHz antenna showing raw data and interpreted reflectors (see Figure 1 for location) with OSL ages plotted with respect to sample location and depth. See Donaldson (2010) for a 250 MHz profile of this transect.

Figure 5: GPR transect BR5 (see Figure 1 for location) collected using a 50 MHz antenna showing transition from landward to seaward dipping reflectors at the landward margin of the ridge sequence.

Figure 6: GPR transect BR6 (see Figure 1 for location) collected using a 100 MHz antenna traversing the change in ridge truncation and shoreline realignment evident at the landward margin of the barrier (see Figure 1). See Donaldson (2010) for a 250 MHz profile of this transect.

Figure 7: GPR transect BR3-4 (see Figure 1 for location) collected using a 100 MHz antenna showing continuation of seaward dipping clinoforms out to the present shoreline. See Donaldson (2010) for a 250 MHz profile of this transect.

Figure 8: OSL ages for the Seven Mile Beach prograded barrier plotted against barrier width as a percentage showing substantial pause in deposition and strong linear pattern of shoreline progradation between ~3500 and ~1400 years ago.

Figure 9: Planform depositional model of the Seven Mile Beach prograded barrier from 8000 years to present.

Figure 1

Figure 2

Figure 3

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Table 1: Optically stimulated luminescence ages for sand ridges across the Seven Mile Beach prograded barrier, Tasmania.

Sample Code	-----Radionuclide Concentrations-----			-----Dose Rates-----				D _e (Gy)	Over-dispersion (%)	OSL Age (yrs)
	U (ppm)	Th (ppm)	K (%)	Beta (Gy/ka)	Gamma (Gy/ka)	Cosmic (Gy/ka)	Total Dose Rate (Gy/ka)			
SMB-T-1	0.23 ± 0.01	0.84 ± 0.01	0.30 ± 0.01	0.26 ± 0.01	0.13 ± 0.002	0.18 ± 0.02	0.60 ± 0.03	0.83 ± 0.01	6.4 ± 1.1	1390 ± 70
SMB-T-2	0.22 ± 0.01	0.88 ± 0.04	0.27 ± 0.01	0.24 ± 0.01	0.13 ± 0.002	0.18 ± 0.02	0.58 ± 0.03	1.07 ± 0.01	4.2 ± 0.9	1850 ± 90
SMB-T-3	0.23 ± 0.01	0.89 ± 0.04	0.31 ± 0.01	0.27 ± 0.01	0.14 ± 0.002	0.18 ± 0.02	0.62 ± 0.03	1.43 ± 0.01	10.5 ± 1.6	2310 ± 120
SMB-T-4	0.22 ± 0.01	0.90 ± 0.04	0.34 ± 0.01	0.28 ± 0.01	0.16 ± 0.002	0.18 ± 0.02	0.64 ± 0.03	1.69 ± 0.01	2.9 ± 0.8	2640 ± 120
SMB-T-5	0.26 ± 0.01	1.14 ± 0.05	0.47 ± 0.01	0.39 ± 0.01	0.19 ± 0.003	0.18 ± 0.02	0.79 ± 0.03	2.13 ± 0.05	11.6 ± 1.8	2690 ± 130
SMB-T-6	0.23 ± 0.01	0.85 ± 0.03	0.36 ± 0.01	0.30 ± 0.01	0.15 ± 0.002	0.18 ± 0.02	0.66 ± 0.03	2.12 ± 0.03	5.1 ± 0.9	3210 ± 150
SMB-T-7	0.24 ± 0.01	0.98 ± 0.04	0.40 ± 0.01	0.33 ± 0.01	0.16 ± 0.003	0.18 ± 0.02	0.70 ± 0.03	2.31 ± 0.03	5.4 ± 1.0	3280 ± 150
SMB-T-8	0.25 ± 0.01	0.96 ± 0.04	0.42 ± 0.01	0.34 ± 0.01	0.17 ± 0.003	0.18 ± 0.02	0.72 ± 0.03	2.62 ± 0.03	4.3 ± 0.9	3620 ± 160
SMB-T-10	0.23 ± 0.01	0.89 ± 0.04	0.32 ± 0.01	0.27 ± 0.01	0.14 ± 0.002	0.18 ± 0.02	0.62 ± 0.03	0.04 ± 0.003	25 ± 7.0	60 ± 5
SMB-T-11	0.25 ± 0.01	1.68 ± 0.07	0.15 ± 0.003	0.17 ± 0.01	0.14 ± 0.003	0.18 ± 0.02	0.52 ± 0.02	12.7 ± 0.21	7.4 ± 1.3	24 250 ± 1280
SMB-T-12	0.28 ± 0.01	1.12 ± 0.04	0.35 ± 0.01	0.30 ± 0.01	0.16 ± 0.003	0.18 ± 0.02	0.68 ± 0.03	4.56 ± 0.10	10.6 ± 1.6	6720 ± 330
SMB-T-13	0.22 ± 0.01	1.12 ± 0.04	0.20 ± 0.004	0.19 ± 0.01	0.12 ± 0.002	0.18 ± 0.02	0.53 ± 0.02	3.54 ± 0.05	5.8 ± 1.0	6770 ± 350
7MB#2	0.37 ± 0.01	1.57 ± 0.06	0.36 ± 0.01	0.33 ± 0.01	0.20 ± 0.004	0.18 ± 0.02	0.74 ± 0.03	2.39 ± 0.03	6 ± 1.1	3250 ± 150
5MB#1	0.96 ± 0.03	9.50 ± 0.38	0.17 ± 0.003	0.43 ± 0.02	0.57 ± 0.02	0.18 ± 0.02	1.21 ± 0.04	8.89 ± 0.18	9.2 ± 1.5	7320 ± 330

Highlights:

- OSL dating of barrier sediments reveal shoreline progradation commenced ~7300 years ago and continued to near present.
- Terrestrial aeolian dune active during MIS 2 and MIS 3 supplied sediment for initial shoreline progradation.
- A ~3000 year pause in deposition was evident between 6700 and 3600 years ago linked to sediment supply.
- GPR and OSL datasets reemphasise planform configuration of ridges to modal wave refraction pattern and ridge building resulting from beach and dune accretion.
- Transgressive dune activity and vertical frontal dune building near the modern shoreline suggests another pause in shoreline progradation.