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First recorded evidence of subaqueously-deposited late Pleistocene interstadial (MIS 5c) coastal strata above present sea level in Australia

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Keywords

Late Pleistocene sea level, MIS 5c, Amino acid racemization, Australia, Emergent beach facies

Disciplines

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First recorded evidence of subaqueously-deposited late Pleistocene interstadial (MIS 5c) coastal strata above present sea level in Australia

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Abstract

Significant differences in the elevation of late Pleistocene interstadial coastal strata have been noted at the global scale resulting from the combined effects of tectonism, proximity of field sites to Pleistocene ice sheets, and the variable effects of glacio-hydro-isostatic adjustment processes. Here we report the first recorded example of subaqueously deposited late Pleistocene interstadial coastal sediments above present sea level in Australia, in a far-field location to Pleistocene ice sheets and characterised by minimal to modest rates of vertical crustal movements. Located at Port MacDonnell, in southern Australia, the sedimentary succession is represented by a flint conglomerate beach facies with interstratified shells. An optically stimulated luminescence (OSL) age of 53 ± 4 ka for an aeolianite unit that unconformably overlies the shelly deposit indicates that the beach facies is older than early MIS 3. OSL analysis also confirms that the MacDonnell Range, located 7 km inland from the present coastline, is of last interglacial age (124 ± 10 ka; MIS 5e). Radiocarbon dating on the operculum of *Turbo undulatus* from the shelly conglomerate yielded a minimum age of 47,905 ± 2106 yr BP [Wk-34733]. The extent of amino acid racemization (AAR) for *Turbo* sp. from the shelly unit beneath the aeolianite suggests an interstadial age (102 ± 16 ka). Uplift-corrected palaeo-sea level at the time of deposition of the shelly flint conglomerate was at least -14 m during MIS 5c. These results are consistent with palaeo-sea level estimates from other far-field settings as well as oxygen isotope-inferred sea levels for this interval and further highlight the regional tectonic stability of Australian coastal landscapes in a global context.

Keywords: late Pleistocene sea level; MIS 5c; amino acid racemization; Australia; emergent beach facies

1. Introduction

The last interglacial *sensu lato* is characterised by three sea-level highstands; ~125 ka (MIS 5e), ~105 ka (MIS 5c) and ~80 ka (MIS 5a) as defined by oxygen isotope records from deep sea sediments (Shackleton and Opdyke, 1973) and ice-cores (e.g. EPICA community members, 2004). Sea level during MIS 5e is suggested to have been 2-6 m above present (e.g. Chappell and Shackleton, 1986; Murray-Wallace and Belperio, 1991; Dutton and Lambeck, 2012), while sea level during interstadials MIS 5c and MIS 5a is thought to have been up to 20 m lower than present (e.g. Schellmann and Radtke, 2004).

At a continental scale, Australia shows a high degree of tectonic stability, due to its intra-plate setting and the widespread occurrence of cratons, absence of active volcanism and generally low-magnitude earthquakes confined to restricted areas (Quigley et al., 2010). While Australia has not experienced the rates of uplift commonly associated with plate boundaries, evidence for subtle neotectonic uplift has been reported from several locations in south-eastern Australia (e.g. Coorong Coastal Plain and Fleurieu Peninsula in South Australia, as well as Tasmania and the Bass Strait Islands; Murray-Wallace and Geode, 1995; Kiernan and Lauritzen, 2001) based on the identification and dating of coastal facies relating to the last interglacial maximum (MIS 5e, 132-118 ka). However, emergent subaqueously-deposited coastal facies of late Pleistocene interstadial age have not been reported from Australia. In this paper we document evidence for coastal emergence based on the identification of interstadial sediments and show that the strata correlate with MIS 5c (~105 ka).

2. Regional setting and stratigraphical framework

The Mount Gambier coastal plain in southern Australia is dominated by the coastal dune barrier sequences of the Bridgewater Formation, a Pleistocene succession of aeolianites which extend sub-parallel with the modern coastline (Sprigg, 1952; Boutakoff, 1963; Fig.1). The barriers are correlatives of the dune ranges of the coastal plain between Robe and Naracoorte, where at least thirteen well-preserved high-wave energy barrier shoreline successions and their back-barrier lagoon facies provide a long record of Pleistocene interglacial sea levels (Hossfeld, 1950; Sprigg, 1952; Murray-Wallace et al., 2001; Murray-Wallace and Woodroffe, 2014). The barriers increase in age landwards from the modern/Holocene Younghusband Peninsula to the East Naracoorte Range 90 km inland, the latter deposited following the Brunhes-Matuyama magnetic reversal at 780 ka (Idnurm and Cook, 1980). The coastal successions are well-preserved due to slow epeirogenic uplift (0.07mm yr^{-1}at Robe, 0.13 mm yr^{-1} in the Mount Gambier region) which has resulted in physically distinct barriers (Murray-Wallace et al., 1996). Pervasive calcrete development has further protected the dune facies from regional denudation.

The modern beach at Port MacDonnell is characterised by a shore platform developed on Oligo-Miocene Gambier Limestone. Pod-like flint lenses, several metres wide and 20 cm thick, are exposed on the limestone platform, providing the source of flint cobbles for the beaches along the local coastline such as Racecourse Bay 5 km east of Port MacDonnell (Fig.1). At Port MacDonnell the modern beach is backed by a raised Holocene flint cobble and shelly beach facies and is unrelated to the Pleistocene shelly conglomerate that is the focus of this study.

West of Port MacDonnell, aeolianite cliffs up to 10 m high trend along the modern coastline. The aeolianites extend for 300 m to Cape Northumberland and occur as small islands (up to 30 m wide) 50 m offshore (Fig.1b). High angle trough cross-bedding occurs within the deposits and the aeolianite is vertically separated into two units by a thick, calcrete palaeosol.

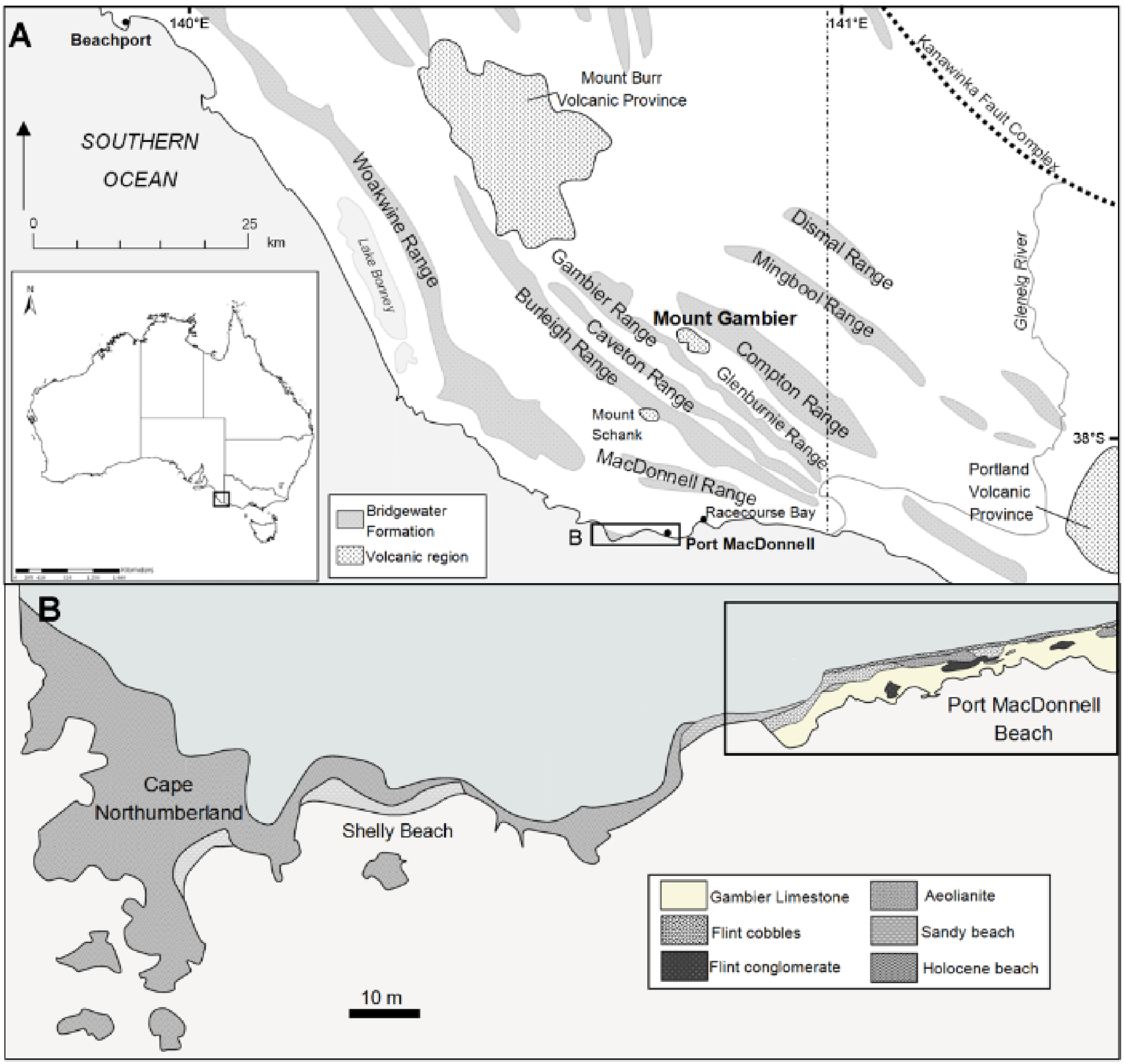

Figure 1: The Mount Gambier coastal plain, southern Australia A: Barrier successions of the Bridgewater Formation on the Mount Gambier coastal plain with sub-crop map highlighting study location. B: Modern shoreline of the Port MacDonnell region and sedimentary units on Port MacDonnell Beach.

MacDonnell Range is an inferred correlative of Woakwine Range (Fig.1), a prominent barrier found to trend largely uninterrupted, sub-parallel to the present coast for over 300 km between the Mount Gambier region and the River Murray mouth. Although a composite structure, volumetrically the relict barrier shoreline is predominantly of last interglacial age (MIS 5e) as revealed by AAR and thermoluminescence dating at numerous sites (Huntley et al., 1994; Murray-Wallace et al., 1999; Murray-Wallace et al., 2010). MacDonnell Range is a two armed structure, 3 km wide in cross-section, approximately 20 m higher than the surrounding regional land surface, and located 7 km inland from the modern coastline. As a working hypothesis, we correlate the aeolianite successions of the modern coastal cliffs with Robe Range due to their proximity to the present shoreline, their seaward position from the inferred last interglacial barrier and the presence of two distinct aeolianite units of similar morphostratigraphical character to Robe Range in its type area. Schwebel (1978; 1984) described Robe Range as an interstadial aeolianite complex in the Robe region, 130 km north-west of the present study area. He suggested that Robe Range is a composite barrier structure having formed during three successive sea-level highstands and labelled the modern Holocene dunes that drape the complex as Robe I, and MIS 5a and MIS 5c deposits as Robe II and Robe III respectively.

Several outcrops of a conglomerate unit dominated by flint cobbles and shell fragments within a well-cemented calcite matrix were identified along Port MacDonnell Beach. The pitted surface of the conglomerate and the presence of a 2 cm thick calcrete within the conglomerate indicate subaerial exposure of the deposit. The strongly cemented conglomerate unconformably overlies the Gambier Limestone and occurs beneath highly eroded aeolianite of the late Pleistocene Bridgewater Formation. The unconformity is part of a marine abrasion surface more widely exposed between Port MacDonnell and Mount Gambier (Belperio et al., 1996; Murray-Wallace and Cann, 2007). Outcrops of the eroded aeolianite that unconformably overlie the cemented conglomerate, correspond stratigraphically with the lower of two aeolianite units identified in the coastal cliffs 100 m to the west and are similar in physical attributes (including colour, particle size and trough cross-bedding).

A composite cross-section was constructed (Fig.2) based on mapping the morphostratigraphical relationships of the sedimentary units at the western end of Port MacDonnell Beach. Eight transects were recorded where outcrops of eroded aeolianite, flint conglomerate and Gambier Limestone were found to be stratigraphically superposed. Figure 2 illustrates the aeolianite units of Robe Range at Port MacDonnell and the nearby flint conglomerate as stratigraphical crosssections. It is hypothesised that the aeolianites would have overlain the flint conglomerate before removal by erosion. The upper unit is approximately 7-8 m thick and capped by a rubbly calcrete. The two aeolianite units are separated by a 75 cm thick calcrete and red-brown palaeosol, suggesting a significant depositional hiatus. The lower unit is approximately 2-3 m thick. While the contact of this unit with the underlying Gambier Limestone is not visible within the cliffs it is assumed to be a similar elevation to the contact between the two units observed on the beachface 100 m farther east. The lower unit was inferred to be an equivalent of Robe III for mapping purposes (using terminology of Schwebel, 1978; 1984) before undertaking geochronological analyses.

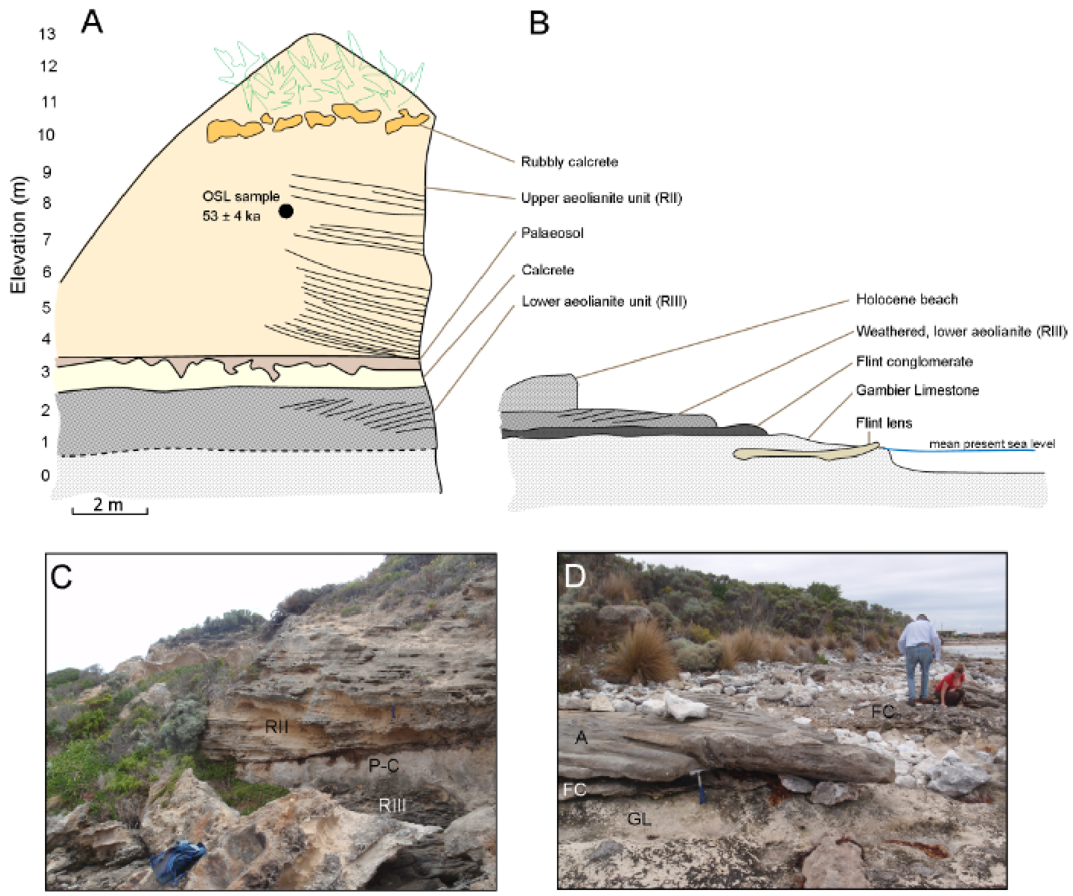

Figure 2: The sedimentary units of Port MacDonnell Beach, South Australia A: Composite stratigraphical cross-section of the aeolianite cliffs at the western end of Port MacDonnell Beach. The toe of the lower aeolianite within the cliffs was not identified due to the presence of boulders but is presumed to be a similar elevation to the contact between the remnant aeolianite and Gambier Limestone 100 m east on the beach. B: Composite stratigraphical cross-section of sedimentary deposits on Port MacDonnell Beach. C: Cliff face at the western end of Port MacDonnell Beach, highlighting two aeolianite units of Robe II (RII) and Robe III (RIII) separated by a distinct palaeosol and calcrete unit (P-C). Boulders of aeolianite eroded from the cliff face are seen in the foreground. D: Weathered aeolianite (A) overlying the flint conglomerate (FC) remnant palaeo-beach facies which in turn overlies the Gambier Limestone (GL) on Port MacDonnell Beach, 100 m east of the aeolianite cliffs.

Fossil shell within the conglomerate is dominated by the gastropods *Turbo undulatus* and *Thias orbita*. These species are similar to those found on the modern beach at Port MacDonnell, and suggest that the conglomerate is a palaeo-beach deposit formed in a rocky, high energy environment.

3. Geochronological methods

Radiocarbon analyses were undertaken at the University of Waikato Radiocarbon Dating Laboratory and involved accelerator mass spectrometry. Opercula of the marine gastropod *Turbo undulatus* were analysed. One specimen was obtained from the strongly indurated flint conglomerate while a second was obtained from the Holocene gravel beach facies at Port MacDonnell. The surfaces of the opercula were cleaned in an ultrasonic bath, lightly etched with 0.1 N HCl, rinsed in distilled water and dried. XRD revealed the carbonate to be primary aragonite. Measured $\delta^{13}C$ values are consistent with marine carbonate (2.3 ± 0.2 ‰ for the Holocene and 2.1 ± 0.2 ‰ for the Pleistocene shells respectively).

Samples for OSL analysis were collected from the upper aeolianite unit within the coastal cliffs at Port MacDonnell that stratigraphically overlies the cemented shelly conglomerate (Fig.2), and from the MacDonnell Range, an older barrier, of inferred last interglacial age (MIS 5e), 7 km inland from the modern coastline. Sediment samples were prepared following the standard procedures outlined in Jacobs (2010). Extracted quartz grains (180-212 μm size fraction) were analysed as 1 mm diameter multi-grain aliquots using a Risø OSL/TL-DA-15 luminescence reader, and optical stimulation was performed using blue LEDs (470 ± 30 nm) for 40 s at 125°C. Protocols for analysis followed Murray and Wintle (2000) and Wintle and Murray (2006). Environmental dose-rates were estimated using thick-source alpha counting and Geiger Müller beta counting (Aitken, 1985, 1998; Bøtter-Jensen and Mejdahl, 1998; Jacobs, 2004), and the dose-rate conversion factors of Guérin et al. (2011). Ages for the OSL samples were obtained by dividing the Central Age Model

(CAM) (Galbraith et al., 1999) D_e value by the adjusted total environmental dose-rate (Fig. 3; Table 1).

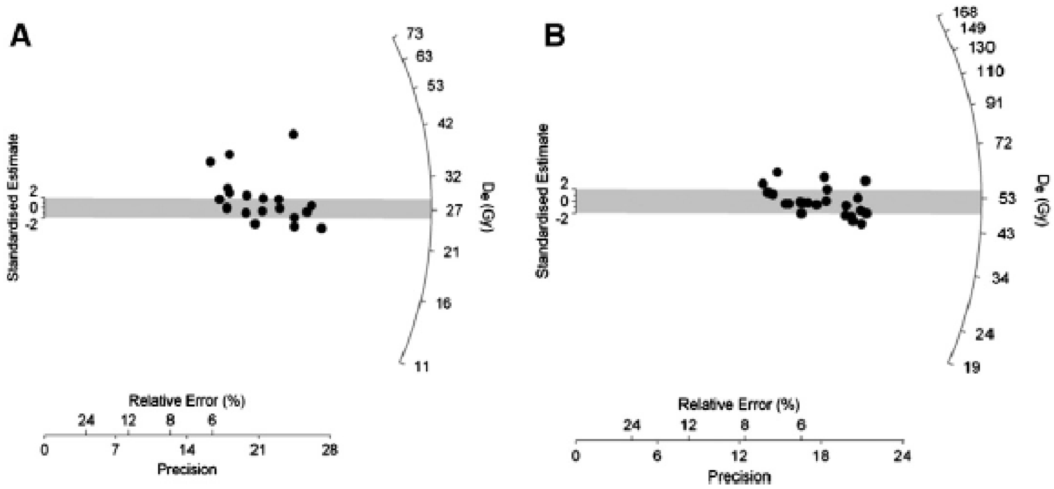

Figure 3: Single-aliquot OSL equivalent dose (D_e) distributions (as radial plots) for A: Robe II centred on CAM 27.04 ± 0.72 Gy, and B: MacDonnell Range centred on CAM 51.98 ± 1.36 Gy. Three upper values were excluded from the CAM for the Robe II sample, due to the possibility that a significant percentage of poorly bleached grains were present within these aliquots. No aliquots were rejected from the MacDonnell Range sample. Over-dispersion was relatively low (<20%) which supports the assumption of a single-dose population.

Table 1: Results of single-aliquot regenerative dose OSL analysis (SAR) of quartz grains within aeolianite at Port MacDonnell and the MacDonnell Range, South Australia.

Lab Code	Sample Code	Total dose rate (Gy/ka^{-1})[a, b]	N/σ_d (%)[c]	D_e (Gy)[d]	Age (ka)[b,e]
UOW-848	MGCP 23	0.515 ± 0.037	17 / 9.9 ± 2.1	27 ± 1	53 ± 4
UOW-849	MGCP 24	0.418 ± 0.031	24 / 11.4 ± 2.1	52 ± 1	124 ± 10

[a] Includes an assumed internal alpha dose rate of 0.03 ± 0.01 Gy/ka; cosmic ray dose-rates estimated as a function of geomagnetic latitude, elevation, and depth, after Prescott and Hutton (1994); dose-rates are adjusted for water content and beta attenuation (Aitken, 1985, 1998; Brennan, 2003; Nathan and Mauz, 2008)
[b] Mean ± total uncertainty (68 % confidence interval), calculated as the quadratic sum of the random and systematic uncertainties
[c] Number of aliquots used in the final D_e estimation (N) / relative standard deviation of D_e distribution after accounting for measurement uncertainties (overdispersion, σ_d)
[d] Central age model (CAM) D_e (Galbraith et al. 1999)
[e] Uncertainty includes a systematic component of ± 2 % associated with laboratory beta-source calibration

Amino acid racemization (AAR) analyses were conducted on sub-samples of the same *Turbo undulatus* opercula analysed for radiocarbon dating. The analytical methods follow those set out in Kaufman and Manley (1998) and Murray-Wallace et al. (2010). Six individual *Turbo* sp. opercula were analysed from the modern beach face at Port MacDonnell, 12 opercula from the Holocene beach deposit, and 8 opercula fragments from the indurated flint conglomerate. Results are reported for the total hydrolysable amino acids and free amino acids.

Table 2: Comparison of AAR D/L values of *Turbo undulatus* from Port MacDonnell modern beach, Holocene back beach deposit, flint conglomerate palaeo-beach facies and Traeger's Quarry, Goolwa, South Australia.

Sample site	Mollusc species	Lab code (UWGA)	*n*-replicates	Amino acid D/L value ASP	GLU	VAL	LEU
Port MacDonnell modern beach face	*Turbo undulatus* (opercula)	9856A,B,C,E and 9811C-D	6	T: 0.153 ± 0.053	T: 0.063 ± 0.017	T: 0.019 ± 0.08	T: 0.039 ± 0.017
Port MacDonnell Holocene cobble beach deposit	*Turbo undulatus* (opercula)	9840, 9841 and 9847A-D, 9840, 9841	12	T: 0.308 ± 0.037 F: 0.586 ± 0.061	T: 0.133 ± 0.017 F: 0.255 ± 0.03	T: 0.069 ± 0.015 F: 0.206 ± 0.035	T: 0.101 ± 0.021 F: 0.261 ± 0.079
Port MacDonnell flint conglomerate (Holocene)	*Turbo undulatus* (opercula)	9851, 10058, 10061, 10062	4	T: 0.345 ± 0.023 F: 0.597 ± 0.019	T: 0.137 ± 0.01 F: 0.258 ± 0.021	T: 0.062 ± 0.012 F: 0.145 ± 0.013	T:0.095 ± 0.009 F:0.279 ± 0.094
Port MacDonnell flint conglomerate (Late Pleistocene)	*Turbo undulatus* (opercula)	9852, 10057, 10059, 10060	4	T: 0.650 ± 0.075 F: 0.822 ± 0.076	T: 0.443 ± 0.069 F: 0.618 ± 0.016	T: 0.353 ± 0.052 F: 0.534 ± 0.022	T: 0.487 ± 0.082 F: 0.864 ± 0.024
Traeger's Quarry, Goolwa	*Turbo undulatus* (opercula)	5387A-E	5	T: 0.730 ± 0.012	T: 0.480 ± 0.010	T: 0.415 ± 0.010	

n= number of replicates from separate individuals. ASP = aspartic acid, GLU = glutamic acid, VAL = valine, LEU = leucine

T= Total hydrolysable amino acids, F= Free amino acids

Current mean annual temperature (CMAT) at Traeger's Quarry, Goolwa is 15.5°C, and CMAT at Port MacDonnell is 14.04°C

4. Results and discussion

Radiocarbon dating of the *Turbo undulatus* operculum within the indurated flint conglomerate at Port MacDonnell yielded a 'finite' minimum age of 47,905 ± 2106 yr BP [Wk-34733]. Although we regard this as a minimum age, it precludes a Holocene age for the fossil shells within this deposit. Radiocarbon analysis of *Turbo undulatus* operculum from the Holocene cobble-gravel deposit yielded an age of 2473 ± 25 yr BP [Wk-34195] and precludes a late Pleistocene age for the gravel beach facies.

OSL analysis suggests that the upper aeolianite unit within the Port MacDonnell coastal cliffs was deposited 53 ± 4 ka, during the earlier portion of MIS 3 (25-60 ka). The MacDonnell Range, located 7 km north of the present study area, yielded an age of 124 ± 10 ka confirming it is an extension of the last interglacial (MIS 5e) Woakwine Range (Fig.1). The indurated flint conglomerate at Port MacDonnell is therefore not related to this structure.

As the flint conglomerate lies stratigraphically below outcrops of the eroded aeolianite dated at 53 ± 4 ka it must predate the early stages of MIS 3. Accordingly, the aeolianite unit at Port

MacDonnell post-dates Robe II *sensu* Schwebel (1978) which formed during MIS 5a. These findings are consistent with Banerjee et al. (2003) who used (SAR) OSL to date the sediments of Robe II near the township of Robe and reported an age of 61 ± 3.6 ka. The findings from Port MacDonnell, some 80 km south-east of Robe, confirm that Robe II cannot be a local deposit as suggested by Banerjee et al. (2003) and has much wider stratigraphic expression. Bathymetric data suggest that if sea level during MIS 3 was 40 to 65 m lower than present (Lambeck and Chappell, 2001), the shoreline would have been approximately 13 km from that of present at Port MacDonnell (Geoscience Australia, 2009). It is plausible that with strong winds reactivated sands may have blown this far inland. Similar aeolian reworking of skeletal carbonate sands during the late Pleistocene has been noted on the Swan Coastal Plain (Price et al., 2001).

The well-defined, 75 cm thick, calcrete palaeosol between aeolianite units at the west of Port MacDonnell Beach (Fig.2) indicates a significant hiatus in sediment deposition. If the upper aeolianite unit correlates with Robe II described by Banerjee et al. (2003), then the lower aeolianite unit may represent a correlative of Robe III of MIS 5c (~105 ka) age. This is in accord with the previously derived thermoluminescence (TL) age of 116 ± 6 ka for Robe III near the type locality at Robe (Huntley et al., 1994).

AAR analysis of *Turbo undulatus* opercula from the flint conglomerate unit at Port MacDonnell reveals two periods of shell deposition within the conglomerate (Table 2). Of the eight opercula fragments analysed, 4 yielded GLU D/L values of 0.137 ± 0.01 which is directly comparable to D/L values within the Holocene cobble deposit. The other 4 fragments yielded GLU D/L values of 0.443 ± 0.037 and indicate a late Pleistocene age for these fossils, similar to MIS 5e GLU D/L values reported by Murray-Wallace et al. (2010) from the Glanville Formation at Traeger's Quarry, Goolwa (Table 2). On closer examination, samples deriving a Holocene age are less well-cemented into the conglomerate and are of a more pristine condition compared with late Pleistocene samples which display slight pitting on their outer surface. It is suggested that the flint conglomerate is late

Pleistocene warm interstadial in age and has been exposed by the uplifting coastal plain. The younger shells appear to have been cemented onto the upper surface of the conglomerate during the Holocene sea-level highstand, which also eroded much of the overlying aeolianite. At this time sea level was up to 1 m APSL (Lewis et al., 2013).

Based on a model of apparent parabolic kinetics (Mitterer and Kriausakul, 1989) an age of 102 ± 16 ka was derived for the older opercula from the flint conglomerate. The extent of amino acid racemization in *Turbo* specimens of known age from Traeger's Quarry (MIS 5e; derived from AAR analysis by Murray-Wallace et al., 2010), radiocarbon dated opercula from the Holocene beach deposit and modern beach specimens were used in the age calculation. While temperature differences between Traeger's Quarry and Port MacDonnell (Table 2) are acknowledged to potentially account for the lower D/L values derived from Port MacDonnell, these are accounted for within the uncertainty term associated with the numeric age derived for the flint conglomerate. The flint conglomerate at Port MacDonnell is younger that MIS 5e as the barrier shoreline succession of the last interglacial maximum (MIS 5e) is represented by the MacDonnell Range, some 7 km inland from the modern coastline and the outcropping interstadial succession. The aeolianite overlying the flint conglomerate is proposed to correlate with Robe III of MIS 5c age given that the underlying and interstratified flint conglomerate with fossil shell yielded an age of 102 ± 16 ka indicating a correlation with MIS 5c.

At a global scale, significant differences in sea level during late Pleistocene warm interstadials MIS 5a and MIS 5c have been recorded (Murray-Wallace and Woodroffe, 2014). Reported MIS 5c sea-levels range from -8 m on the Northwestern Peninsula, Haiti, -9 ± 3 m on the Huon Peninsula, Papua New Guinea to as low as -10 to -17 m in Barbados (Dumas *et al.* 2006; Chappell and Shackleton, 1986; Gallup et al., 1994; Schellmann and Radtke, 2004). MIS 5c sea level has also been recorded as +2 to +6 m APSL on San Nicolas Island, California (Muhs et al., 2012). Sea levels in regions closer to former glaciated areas, such as North America, may yield more extreme sea-level values as the land isostatically rebounds than areas a greater distance from former ice sheets, such as Australia.

At a continental-scale, Australia shows a high degree of tectonic stability and is located in the far-field from Quaternary ice sheets (Lambeck and Nakada, 1990). As the continent was largely unglaciated in the Quaternary, the effects of glacio-isostasy on shorelines in this region are minimal, and thus inferred palaeo-sea levels are more likely to reflect ice-equivalent sea level with a spatially variable but minor neotectonic overprint for different coastal sectors. Few areas of continental Australia show evidence for crustal uplift during the later Quaternary. Last interglacial (MIS 5e) shallow subtidal shell beds have been identified at 12 m APSL on Fleurieu Peninsula (Bourman et al., 1999), at 8 m APSL on the Coorong Coastal Plain (Murray-Wallace et al., 2001) and up to 22 m APSL in Tasmania (Murray-Wallace and Geode, 1995). Viewed at a wider spatial scale, the geotectonically stable context of the Australian continent explains why emergent late Pleistocene interstadial successions deposited under subaqueous conditions are so uncommon above present sea level and therefore accounts for the novelty of the findings reported here. The uplifted conglomerate unit at Port MacDonnell suggests that minimum sea level during MIS 5c was -14 m ± 2 m. Palaeo-sea level was calculated based on the uplift rate for the Mount Gambier coastal plain of 0.13 mm yr^{-1} (Murray-Wallace et al., 1996) and an inferred sea level of 2 m APSL for MIS 5e derived from Eyre Peninsula, South Australia, where the transgressive feather edge of shoreline successions of this age consistently crop out at 2 m APSL (Murray-Wallace and Belperio, 1991). The derived minimum palaeo-sea level from Port MacDonnell is consistent with other global interstadial sea level indicators from far-field sites such as uplifted coral terraces of Huon Peninsula (Chappell and Shackleton, 1986), and Haiti (Dumas et al., 2006).

5. Conclusions

A flint cobble and shelly conglomerate unit exposed at present sea level on Port MacDonnell Beach, South Australia, is suggested to have been deposited during the sea-level highstand MIS 5c (~105 ka). An AAR age of 102 ± 16 ka was derived for the feature which is located stratigraphically beneath aeolianite of proposed MIS 5c age. OSL analysis confirms that the coastal barrier MacDonnell Range, located 7 km inland from the modern coastline and outcropping interstadial succession, is of last interglacial (MIS 5e) age. The flint conglomerate is the first identified example of a subaqueously deposited interstadial succession above present sea level in Australia. Based on a previously determined uplift rate of 0.13 mm yr^{-1} for the Mount Gambier coastal plain throughout the Quaternary, minimum sea level during MIS 5c is found to be -14 m, which compares well with other MIS 5c sea-level indicators at far-field sites around the globe.

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