Aboriginal occupation on Rottnest Island, Western Australia, provisionally dated by Aspartic Acid Racemisation assay of land snails to greater than 50 ka

Patrick A. Hesp[1], Colin V. Murray-Wallace[2] and C. E. Dortch[3]

The generally accepted age for the earliest human occupation of Australia is about 60,000 years (e.g. Chappell et al. 1996), with many dates centred around 30,000 to 40,000 years (e.g. Pearce and Barbetti 1981; Dortch 1984; Allen and Holdaway 1995; Dortch and Dortch 1996). Recent, but disputed, archaeological evidence at Jinmium in the Northern Territory indicates a much earlier date of occupation of 116,000 years (Fullagar et al. 1996; Spooner 1998) in line with palaeoecological evidence (e.g. White 1994; Roberts and Jones 1994; Thorne et al. 1999). We present independent evidence from Rottnest Island, Western Australia, which provisionally suggests a Late Pleistocene (and possibly Last Interglacial?) age for Aboriginal occupation in Western Australia.

Rottnest Island lies 19 km offshore of Perth in south-western Western Australia and consists mostly of Pleistocene aeolian calcarenite (Tamala Limestone) and Holocene, partially lithified to unlithified dunes (Hesp et al. 1983; Playford 1983). The Island was last separated from the Western Australian mainland by glacio-eustatic sea level rise about 6500 years ago (Fig. 1; Playford 1983, 1988). The island forms the westernmost portion of a calcarenite barrier system, assumed to be at least, in part, upper Pleistocene in age, which was connected to the mainland and is now predominantly a shallow submarine ridge around 10 m or less in depth (Fig. 1).

Rottnest prehistoric record

The island's prehistoric record consists solely of three stone flakes, two collected in 1984, and the third in 1992, and one feldspar pebble interpreted as a probable manuport,

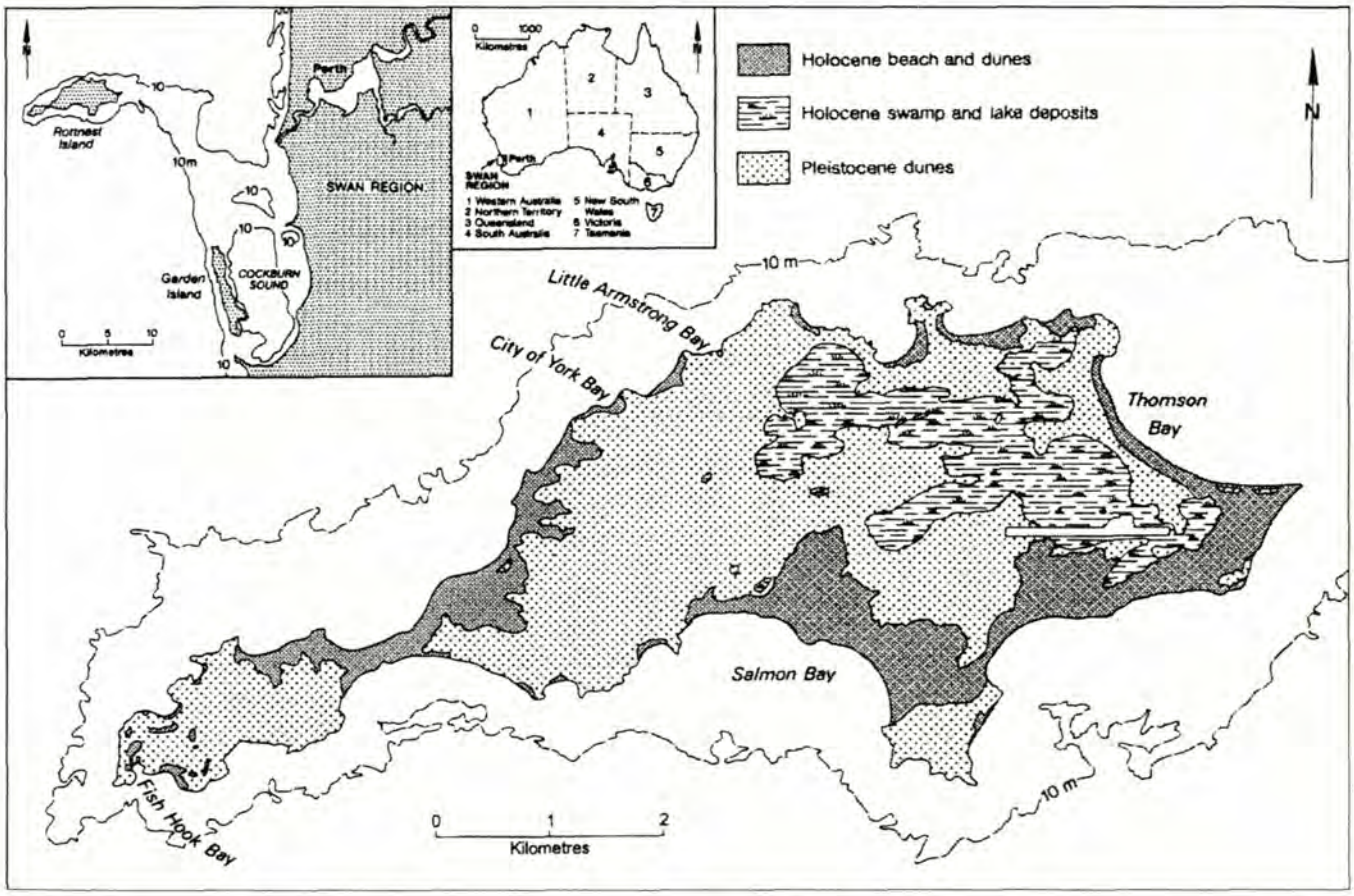

Figure 1 Rottnest island and the Swan Region, Western Australia, showing the 10 m bathymetric depth contour. Detailed locality map and simplified geology.

1 Geography, School of Global Studies, Massey University, Private Bag 11222, Palmerston North, New Zealand. P.A.Hesp@Massey.ac.nz
2 School of Geosciences, University of Wollongong, Northfields Avenue, Wollongong, NSW, 2522, Australia.
3 Anthropology Department, Western Australian Museum, Francis Street, Perth, WA, 6000, Australia.

collected in 1992. A small quartz pebble found *in situ* at Little Armstrong Bay in 1992 may also be a manuport but could simply be a bird crop stone and of no archaeological importance (Table 1; Dortch and Hesp 1994).

One of the two stone artefacts found on Rottnest in 1984 is an Eocene fossiliferous chert flake (Fig. 2:1) collected from

Specimen	Find Location	W.A. Museum
1984		
Eocene chert flake	Fish Hook Bay	B 5612 S02099
Calcrete flake		B 3123 S02099
1992		
Feldspar pebble	City of York Bay	B 7712 S02276
Eocene chert flake	Little Armstrong Bay	B 7713 S02276
Quartzite pebble[1]	Little Armstrong Bay	B 7746

Table 1 1984 and 1992 Rottnest Island prehistoric and other finds. [1] Possible, but unlikely artefact.

limestone rubble exposed by the deflation of one or more dune soils (Dortch and Morse 1984) on an eroding Tamala Limestone cliff-top overlooking Fish Hook Bay (Fig. 1). The second 1984 find was a deeply weathered calcrete flake (Fig. 2:2; Dortch 1991) and was found in a siliceous dune blow-out on the limestone cliff summit about 300 m east of Fish Hook Bay.

A 1992 survey carried out by one of us (CED) covered an estimated 50% of the aeolian calcarenite palaeosols exposed on the summits and in the faces of the island's coastal cliffs and headlands, and 30% of the eroded surfaces of dunes comprised of aeolian calcarenite and palaeosol remnants on the island. The two 1992 prehistoric finds are from aeolian calcarenite cliffs at City of York Bay, and at Little Armstrong Bay, 1100 m further north-eastward along the northern shore of the island (Fig. 1, Table 1). A prominent palaeosol intercalated between aeolian calcarenite units is featured in each cliff face.

The feldspar pebble (Fig. 2:3) was found *in situ* in the City of York Bay palaeosol (Fig. 3). The smaller end of the pebble has a fracture surface along a cleavage plane that was broken after the stone was rounded; no archaeological significance is attributed to this fracture. The nearest known sources of feldspar pebbles deriving from the Yilgarn Craton are mainland alluvial gravels in the vicinity of the Darling Fault, 50 km east of Rottnest Island (Fig. 1). This feldspar pebble (mass 12.41 g, maximum length 33 mm) is within the size range of the very largest observed emu cropstones (pers. comm. 1992: R. Johnstone of the Department of Terrestrial Vertebrates, W. A. Museum). However, the relatively great distance between Rottnest Island and the nearest known feldspar sources seems to strengthen the case for this specimen being a manuport (i.e. an object transported through human agency) rather than a bird cropstone.

The chert flake from Little Armstrong Bay was not found *in situ*, but resting on a 10 cm-thick deposit of fine carbonate sand covering a calcarenite ledge at the foot of the prominent palaeosol exposed in a 1 to 1.3 m-high section in this cliff face (Fig. 3; Dortch and Hesp 1994). This sand closely resembles that in the palaeosol, and has almost certainly fallen from the palaeosol section, as did the chert flake. Less likely derivations for the flake are the summit of the cliff, or the aeolian calcarenite deposit that forms a 1 m-wide overhang above the fossil soil section. An even less likely possibility is that someone had left the flake on the surface of the loose sand a short time before it was found. Sieving of approximately 100 litres of the loose sand yielded no archaeological finds, although it did reveal small calcareous nodules, rhizotubules and land snails (*Austrosuccinea* sp.), as found within the palaeosol. Like the 1984 chert flake (Fig. 2:1), the 1992 flake appears to have been buried in a stable deposit for most of the time since it was discarded (cf. Dortch and Morse 1984).

The two Eocene chert flakes listed in Table 1 presumably derive from chert outcrops on the submerged shelf, quarried during times of glacio-eustatic low sea level. Eocene fossiliferous chert artefact assemblages distributed throughout the emergent Perth Basin and Leeuwin Block (Fig. 1; Glover 1984) are interpreted as deriving from a 'concealed western provenance', i.e. quarry-factories centred on chert outcrops totally or mostly submerged by glacio-eustatic sea level rise (Glover and Lee 1984:16). These onshore chert assemblages comprise 'the most extensive material record in Australia directly relating to human activities (minimally chert quarrying and knapping) on the now-submerged continental shelves' (Dortch 1991:40). The presence of two of these distinctive chert artefacts on Rottnest Island, as well as two others from Garden Island 20 km to the South (Fig. 1; Dortch and Morse 1984:40), strongly support a human presence on this part of the continental shelf during glacio-eustatic low sea levels in the Late Pleistocene.

A weathered quartzite pebble (B7746) was collected *in situ* in the palaeosol at Little Armstrong Bay 1 m east of the find spot of the chert flake. This piece could be a manuport, although it is so small (weight 1.26 g; maximum dimension 16 mm), that it could also be a cropstone from any of a number of bird species. The nearest outcrops of quartzite are presumably in the Yilgarn Block, 50 km east of Rottnest Island.

Stratigraphy and previous estimated age of the 1992 find sites

The palaeosols at the City of York Bay and Little Armstrong Bay find spots are pedogenically very similar, and their stratigraphic positions within the cliff face, and heights

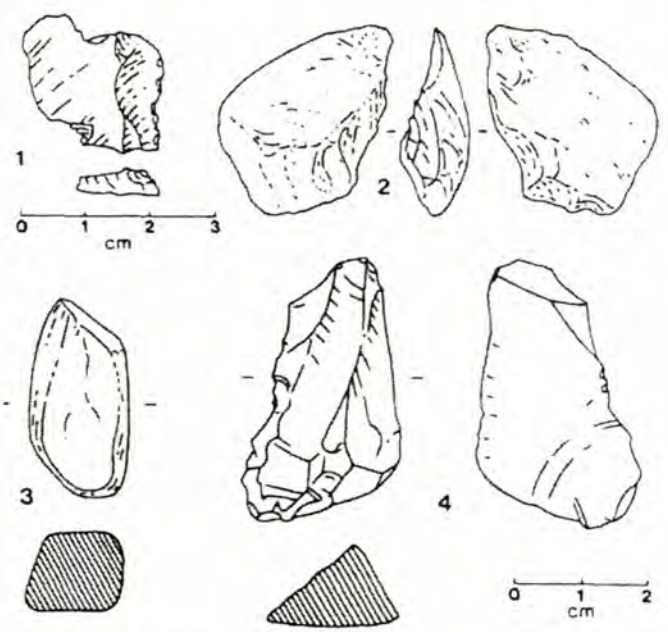

Figure 2 Prehistoric finds from Rottnest Island. 1984 specimens: 1. Eocene fossiliferous chert flake from Fish Hook Bay; 2. Calcrete flake from 300 m East of Fish Hook Bay. 1992 specimens: 3. Feldspar pebble from City of York Bay; 4. Eocene fossiliferous chert flake from Little Armstrong Bay.

above sea level are similar (Table 2; Fig. 3). While the palaeosols cannot be traced laterally very far (300 m maximum), the two sites may be parts of the same palaeosol unit. Similar palaeosols occur at many sites around the island.

The palaeosols at both these find spots display moderately deep (ca. 0.6 m), light-grey A horizons with diffuse contacts to a lower C horizon; no B horizon is present. The A and C horizons in the Little Armstrong Bay palaeosol are formed in fine carbonate sand, with a very small fraction of fine-medium quartz grains dispersed throughout. The City of York Bay palaeosol has an A horizon that is 60% fine carbonate sand and 40% fine-medium quartz sand; its C horizon consists of equal amounts of fine-medium carbonate sand and medium-coarse, well-rounded quartz grains. In both palaeosols, small carbonate nodules and rhizotubules (maximum dimension 1 cm) are present in frequencies estimated at 100 per 1 m^3. Fossil land snails (*Austrosuccinea* sp.) are common in the upper two thirds of the A horizon of each palaeosol. Limited organic development takes place in the A horizon, presumably due to low rainfall (ca. 715 mm p.a.), high exposure, semi-arid vegetation with limited turnover, a Mediterranean climate and limited soil fauna.

Dortch and Hesp (1994) estimated the age of The City of York Bay and Little Armstrong Bay palaeosols at 50 ka to 15 ka old. This estimate was based on the following criteria:

1. the strongly lithified condition of the dunes forming these seaward-facing cliffs is typical of Pleistocene dunes in the Perth Basin, whereas Holocene dunes are poorly lithified or unconsolidated;
2. the palaeosols exposed in these seaward-facing cliffs are overlain by truncated, lithified, aeolian lee slope and slipface (foreset) beds. If dune crests and windward (backset) beds were added and projected seawards, the toe of the windward slopes would extend well below sea level;
3. the palaeosols are not the youngest unit present. They are overlain by another lithified aeolian calcarenite dune unit, which is overlain by Holocene units.

This indicates that the dunes are probably older than 10,000 years (Holocene dunes are largely unlithified), and could only have formed at times of lower sea level (topset and foreset beds are truncated and would project well seawards). Thus, by reference to glacio-eustatic models of sea level change, the degree of cementation, and their position within the limestone units, the aeolian dunes above the palaeosol could only have developed within the interval of approximately 50 to 15 ka.

The oldest known Tamala Limestone on Rottnest Island is exposed just at and below mean sea level at Fairbridge Bluff in Salmon Bay (Fig. 1). Here Tamala Limestone

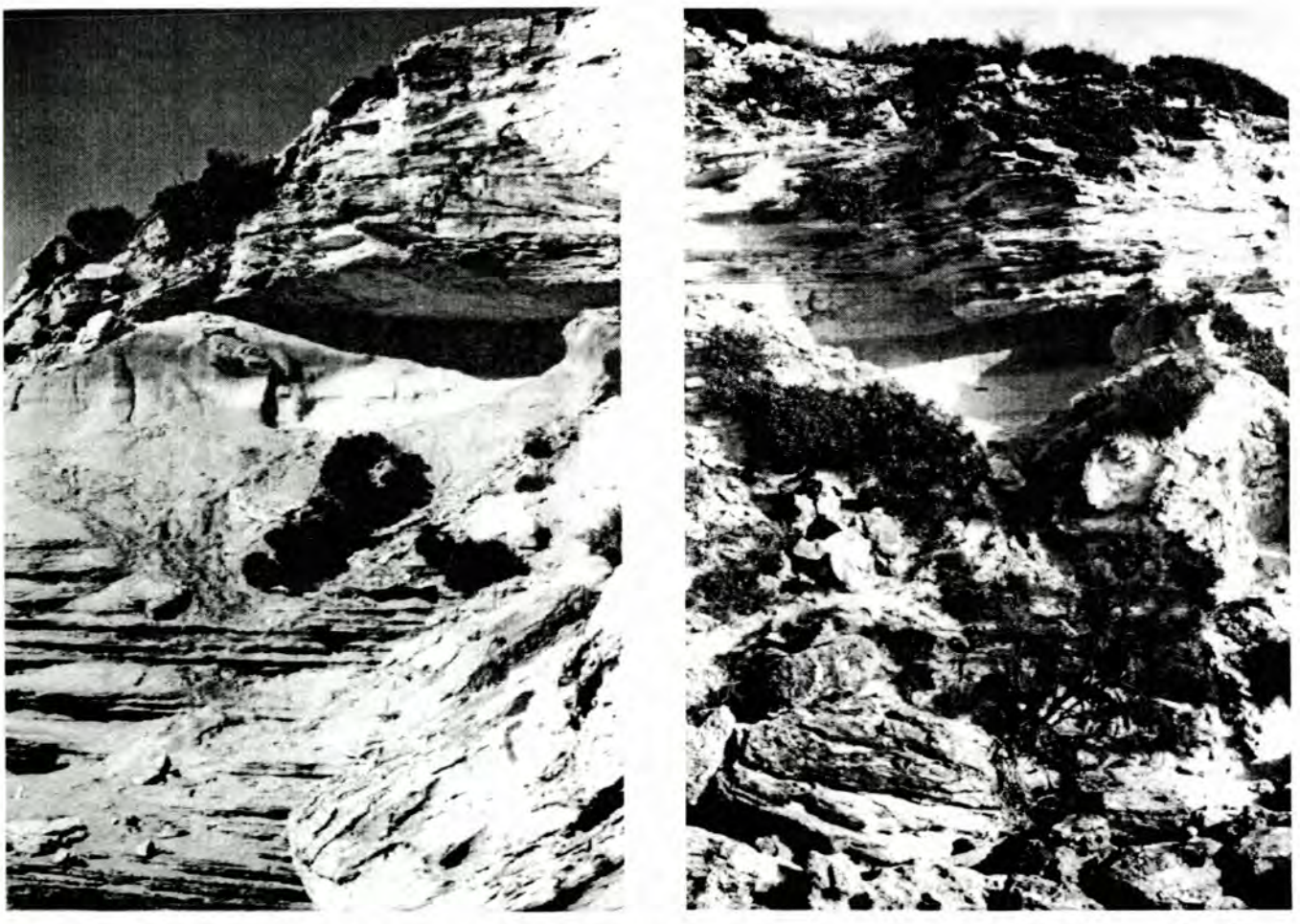

Figure 3 Tamala Limestone cliffs on Rottnest Island, showing cross-bedded aeolian calcarenite and intercalated palaeosols: a. City of York Bay, the position of the feldspar pebble (Fig. 2:3) found *in situ* is in the shaded area beneath the calcarenite overhang; b. Little Armstrong Bay, 15 cm scale in centre of palaeosol section.

Species/Location	D/L ratio	C.M.A.T. (°C)*	Age	Reference
Austrosuccinea sp. West End, Rottnest Island	0.66	18.4	>50 ka	This study
Austrosuccinea sp. Little Armstrong Bay, Rottnest Island	0.59	18.4	>50 ka	This study
Austrosuccinea sp. City of York Bay, Rottnest Island	0.65	18.4	>50 ka	This study
Austrosuccinea sp. Rockleigh Formation, South Australia	0.52	16.0	>>8 ka	Gatehouse and Murray-Walker 1989
Katelysia sp. Herschell Limestone, Rottnest Island	0.37	18.4		Murray-Wallace and Kimber 1989
Katelysia rhytiphora Gulf St., Vincent, South Australia	0.45	17.0	~50 ka	Murray-Wallace et al. 1993
Katelysia rhytiphora Tamala Limestone, Western Australia	0.61	18.5	~125 ka	Murray-Wallace and Kimber 1989

Table 2 Extent of aspartic acid racemisation (total acid hydrolysate) in the gastropod *Austrosuccinea*, Rottnest Island, Western Australia, compared with Late Quaternary fossil molluscs from southern Australia. *C.M.A.T. – Current Mean Annual Temperature

underlies the partly-emergent Rottnest Limestone coral-reef unit (Playford 1988), dated by uranium-thorium technique to 132,000±5000 yr BP (Szabo 1979). There are lithified palaeosols (some containing rhizotubules and *Leptopius* weevil pupal cases), sandy sediments and solution pipes at and below sea level at various places around Rottnest, indicating that the oldest Tamala limestone aeolian calcarenites predate the Last Interglacial coral reef unit.

Aspartic and racemisation results

Sampling and Methods

Small (<5 mm) land snails (*Austrosuccinea* sp.) are present within the upper portions of the palaeosols. They occur *in situ* as individual shells scattered throughout the top 40 cm of the soil profile. They appear in the palaeosol face as the palaeosol is weathered and eroded by occasional rain splash following storms, and thus are not subaerially exposed for lengthy periods. The artefacts and finds appear in the same manner.

Several snails were collected from three palaeosol sites on Rottnest; a site at Fish Hook Bay (West End) where charcoal deposits which may be of cultural significance have been found (see Dortch and Hesp 1994), and at the Little Armstrong Bay and City of York Bay palaeosols immediately above the pebble find positions. These were dated utilising aspartic acid racemisation.

Aspartic acid racemisation analyses (total acid hydrolysate) followed methods described in more detail elsewhere (Murray-Wallace 1993). Specimens of the terrestrial gastropod *Austrosuccinea* sp. were cleaned in distilled water in an ultrasonic bath and then given a light etch in 2M HCl to remove the outer surface of the shells. Analysis of the N-pentafluoropropionyl D- and L-aspartic acid 2-propyl esters was undertaken using a Hewlett Packard 5890A Series II gas chromatograph, with a flame ionisation detector and a 25 m coiled, fused silica capillary column with the stationary phase Chirasil-L-Val. Several individuals of *Austrosuccinea* were incorporated in each amino acid sample to obtain the requisite sample mass for analysis (<1 g).

Results

The extent of aspartic acid racemisation, as determined for three samples of the gastropod *Austrosuccinea* sp. from Rottnest Island is presented in Table 2. These data are compared with previously published results for the same species from a Late Pleistocene valley fill deposit in the Adelaide Hills, South Australia (Gatehouse and Murray-Wallace 1984). In view of the paucity of amino acid racemisation data presently available for the genus *Austrosuccinea*, the results for the Rottnest Island fossils are also compared with the extent of aspartic acid racemisation in fossil marine molluscs from a mid-Holocene shell bed on Rottnest Island, a Last Interglacial (oxygen isotope substage 5e; ~125 ka) deposit at Minim Cove in the Swan Estuary and an interstadial marine deposit (oxygen isotope stage 3; ca. 50 ka) from Gulf St Vincent, South Australia (Murray-Wallace et al. 1993; Table 2).

A high extent of aspartic acid racemisation is noted for the three *Austrosuccinea* samples from Rottnest Island. The similarity in the extent of racemisation for the three samples suggests that they are of broadly equivalent age (Table 2). Expression of these ratio data to a numeric age is, however, difficult in view of the little that is presently known about the nature of racemisation kinetics in this genus. In view of this, results for *Austrosuccinea* sp. are compared with the genus *Katelysia* that has been extensively studied from Late Quaternary coastal deposits in southern Australia (Murray-Wallace 1995). Moderate rates of racemisation are apparent for the genus *Katelysia*, and accordingly, provide a generally representative measure of the extent of racemisation likely to be found with respect to fossil age in other genera. *Katelysia* was also selected to evaluate the Rottnest Island *Austrosuccinea* data, as the range of available amino acid data for this genus spans the Quaternary (Murray-Wallace 1995) and the data relate to fossils that have experienced comparable diagenetic temperature histories to the fossil *Austrosuccinea* from Rottnest Island. Slow to moderate rates of racemisation have been documented in other species of fossil gastropods (Miller and Brigham-Grette 1989) and accordingly, comparison with results for *Katelysia* may indicate minimum ages for the *Austrosuccinea* from the Rottnest Island deposits.

Results for *Austrosuccinea* previously reported from the Rockleigh Formation, a Late Quaternary valley fill sequence in the Adelaide Hills, South Australia (Gatehouse and Murray-Wallace 1984), remain critical for the evaluation of the Rottnest Island amino acid data. Dating of peat from the Rockleigh Formation, although not entirely reliable in view of radiocarbon age reversals in superimposed peats (Grubb 1978), suggests that part of the succession sand from which

the *Austrosuccinea* were sampled is older than 8 ka. The high extent of aspartic acid racemisation for *Austrosuccinea* from the Rockleigh Formation exceeds that theoretically possible for Holocene materials (Murray-Wallace 1995), given the current mean annual temperature and likely diagenetic temperature history of the site. A further example illustrating the effect of diagenetic temperature on racemisation can be seen in specimens of *Katelysia* collected from the crest of a relict foredune in South Australia (Murray-Wallace et al. 1988). The fossil molluscs were collected from the ground surface, a context where accelerated racemisation is known to occur because of the exponential effect of high summer temperatures on surface samples. In contrast, in well-buried situations diagenetic racemisation is primarily influenced by long term temperature variations associated with climate change. The *Katelysia* from the crest of the relict foredune yielded an aspartic acid D/L ratio of only 0.26 after 3100 years of racemisation (Murray-Wallace et al. 1988). Collectively, these data preclude a Holocene age being assigned to the *Austrosuccinea* from Rottnest Island.

The extent of aspartic acid racemisation in the *Austrosuccinea* from Rottnest Island is greater than that apparent for the Holocene and Late Pleistocene (ca. 50 ka) fossil *Katelysia,* but comparable to the last interglacial *Katelysia* from the Tamala Limestone at Minim Cove in the Swan River estuary (Table 2). In view of the paucity of amino acid data concerning the nature of racemisation kinetics in *Austrosuccinea,* a cautious interpretation of the data suggests that the age of the *Austrosuccinea* from Rottnest Island exceeds the range of radiocarbon dating (i.e. >50 ka) and is most likely to fall within the interval of 50 to 125 ka. Further work is required to more accurately define the age of these fossils.

The prehistoric finds from Rottnest are not the only evidence for a possibly very early human presence in the Greater Swan Region (i.e. the Perth metropolitan region and the adjacent continental shelf). Many years ago, the pioneer geologist J. L. Somerville (1920:11) collected a quartz crystal within the Minim Cove marine shell bed which dates to the Last Interglacial (oxygen isotope substage 5e: ca 125 ka) (Table 2; Murray-Wallace and Kimber 1989). Although this quartz crystal has since disappeared, there seems no reason to doubt the validity of its provenance and identification. However this find is similar to the feldspar pebble from City of York Bay in that it is anomalous (i.e. the nearest natural occurrences of quartz crystals are in the Yilgarn Block 30 km to the east of Minim Cove), yet could have a purely natural origin, such as being a bird cropstone. At the same time, like the feldspar pebble, the Minim Cove find could equally be of cultural significance, particularly considering the ubiquitous knapping of quartz by Aboriginal tool makers, and the widespread ritual use of quartz crystals in Australia (McCarthy 1976:65-6).

Conclusion: Significance of the Rottnest finds

The prehistoric artefacts and finds listed in Table 1 do not provide absolute evidence for a human presence on Rottnest Island during the Late Pleistocene. However, the feldspar pebble from City of York Bay (Fig. 2:3) and the Eocene chert flake from Little Armstrong Bay (Figs 2:1 and 2:4) do show that archaeological remains are probably a feature of what may be a single palaesol unit exposed at these two sites. The artefacts clearly pre-date the Holocene since they occur within palaeosols below lithified Pleistocene dunes. The preliminary aspartic acid racemisation dating of the fossil molluscs from the palaeosols suggests that the artefacts are >50 ka in age and may be as old as 125 ka.

These sites provide a significant addition to the archaeological and potential archaeological record for Rottnest Island and for Australia as a whole. They provide additional provisional evidence for Aboriginal occupation of Australia during the Late Pleistocene (>50 ka) and may possibly provide tentative evidence for occupation during the Last Interglacial.

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