A DIVERSE HOLOCENE MOLLUSCAN FAUNA, INCLUDING *ANADARA TRAPEZIA*, FROM ROYAL PARK, LAUNCESTON, TASMANIA

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(with three tables and two text-figures)

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Estuarine sediments exposed during road construction at Royal Park in the City of Launceston, northern Tasmania, were found to contain a diverse molluscan fauna with some 40 species identified. An unusual occurrence was the presence of six specimens of *Anadara trapezia*, a species not previously encountered *in situ* in Quaternary marine or estuarine deposits in Tasmania. Amino acid racemisation and electron spin resonance, calibrated against radiocarbon dating, point to a late Holocene age for this estuarine sequence. A numeric age of 2600 ± 400 yrs BP was derived for a specimen of *A. trapezia*, based on the extent of leucine and valine racemisation. Electron spin resonance data are consistent with this age assessment. The presence of *A. trapezia* in late Holocene sediments at Launceston may imply slightly warmer water temperatures during the late Holocene.

Key Words: Holocene, estuarine molluscs, amino acid racemisation, electron spin resonance, Tasmania.

INTRODUCTION

The shell bed was discovered during excavations for the Wellington Street overpass and drawn to the attention of the Queen Victoria Museum and Art Gallery by the site engineer (fig. 1). The material was collected by Mr Ron Kershaw and Dr Bob Green, in or about 1980, and lodged with the Museum collections.

A note with the collection stated that the material was recovered c. 3.6 m below the surface during excavations for the extension overpass. There is no stratigraphic description, but a significant amount of shelly sand matrix was collected. No record was kept of the overlying sediments, and it is not known to what extent they represent estuarine infilling or urban landfill.

The discovery was recorded by Van de Geer (1981), who tentatively suggested a Pleistocene age. He pointed out that *Anadara trapezia* has never been recorded from Holocene marine deposits in Tasmania, but is widely reported from coastal deposits of Last Interglacial age in the southern mainland states of Australia (Ludbrook 1984), in contrast with a more restricted geographic coverage during the Holocene. The considerable overburden reported from the site, if natural, also appeared consistent with a late Pleistocene age, based on geomorphological reasoning and known rates of estuarine sedimentation.

R.C. Kershaw (pers. comm., 1988) indicated that the site was at the outer edge of the existing floodplain of the Tamar River, and that the bank sloped steeply upwards from this position (fig. 2). The site was reported to be 40 m northwest from the northwest corner of the Supreme Court building and 225 m due east of the Tamar Estuary (grid ref. 511050mE, 5412565mN). The surface of the site was less than 1 m above high tide level and is known to have been subject to flooding during historical times.

A full description of the species content is given, together with an account of the palaeoecological conditions. Two Quaternary dating techniques calibrated against the radiocarbon method were also applied to specimens of *Anadara trapezia* and *Katelysia rhytiphora* from this deposit. These dating methods have previously been applied to several other Tasmanian Quaternary coastal fossil shell localities (Murray-Wallace & Goede 1991).

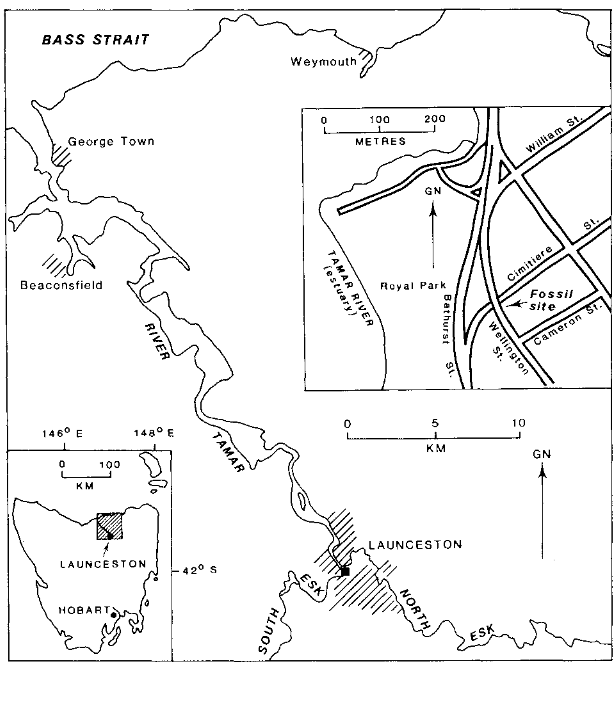

FIG. 1 — Locality map of Launceston area with inset map showing position of fossil site.

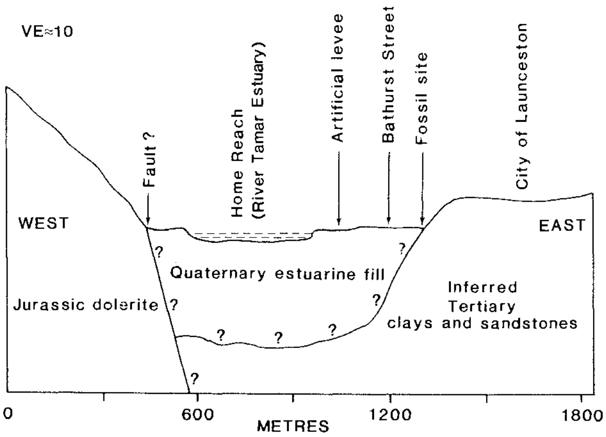

FIG. 2 — Cross-sectional diagram showing relationships of site to topography and geological substrate.

SEDIMENT CHARACTERISTICS

The host sediment is represented by poorly sorted, pale orange-brown quartz sands of mixed fluvial and marine provenance. Grain size ranges from very fine to medium sand size, and the sediment comprises a heterogeneous mixture of coarser-grained, subrounded quartz grains, with frosted surfaces, and finer-grained, angular quartz, with either a vitreous lustre or milky surfaces. Approximately 3% of the sediment consists of coarse (c. 2 mm long axis) shell fragments of unrecognisable affinity and a few prismatic grains of mica. Some micro-gastropods are also present.

SPECIES COMPOSITION AND ECOLOGY

The diverse molluscan fauna recovered from the site is listed in table 1. Some species are represented only by a few fragments, the majority by one to six specimens, while only five species were abundant: *Bittium granarium, Diala lauta, Batillaria australis, Katelysia scalarina* and *K. rhytiphora.*

The fossil assemblage indicates that during deposition the site represented a marginal marine environment characterised by tidal sand and mudflats. A beach may have been present.

Virtually all species are consistent with Holocene and modern populations found in similar environments in Tasmania. An exception is *Anadara trapezia.* Living specimens have not been recorded from Tasmanian waters, although shells are occasionally found washed up on beaches (Sutherland & Kershaw 1971).

Ecological preferences of species are also shown in table 1. The majority are tidal sand or mudflat dwellers, which either browse or filter-feed on the sandy floor or burrow just below the surface of the sand. They are typical of species which prefer quiet, sandy, sheltered bays, inlets and estuaries. Such environments are usually dominated by bivalves, but several gastropods are also found browsing on seagrass or scavenging around tidal sand and mudflats. The presence of littorinid and trochid species indicates that the immediate area was partially rocky, with associated rockpools. Other species present may live on rocks, on algae, in crevices or under rocks. Mudflats are indicated by the presence of some species *(Batillaria australis, Nassarius* spp., *Anadara trapezia* and *Spisula trigonella)* and are the only indication of a freshwater influence.

TABLE 1
Species list of subfossil shells from Royal Park, Launceston, and their ecological preferences

Taxon	Ecological Preference
GASTROPODA	
Alaba monile (A. Adams, 1862)	algae, sea grass
Astralium (Micrastraea) aurea (Jonas, 1844)	on rocks
Batillaria lawleyanum (Crosse, 1863)	mud
B. australis (Quoy and Gaimard, 1834)	mud
Bembicium auratum (Quoy and Gaimard, 1834)	on rocks
B. melanostoma (Gmelin, 1791)	on rocks
Bittium granarium (Kiener, 1842)	sand, weed
Bulla quoyi (Gray, 1827) (syn. *Bullaria botanica)*	sand, mud, weed
Cominella eburnea (Reeve, 1846)	sand, rockpools
C. lineolata (Lamarck, 1809)	sand, rockpools
Conuber conicus (Lamarck, 1822)	sand, mud
Dentimitrella tayloriana (Reeve, 1859)	under rocks at low water
Dentimitrella sp. (fragment)	under rocks at low water
Diala lauta (A. Adams, 1862)	algae, sea grass
Gibbula (Cantharidella) tiberiana (Crosse, 1863)	algae, sea grass
Monodonta (Austrocochlea) constricta zebra (Menke, 1829)	sea grass
Nassarius burchardi (Philippi, 1851)	sand, mud
N. nigellus (Reeve, 1854)	sand, mud
N. pauperatus (Lamarck, 1822)	sand, mud
N. pyrrhus (Menke, 1843)	sand, mud
Phasionella sp.	algae
Pleuroploca australasia (Perry, 1811)	sand
Salinator sp.	sand, mud
Seila sp. (probably *S. insignis* (May, 1911))	deep water
Zeacumantus diemenensis (Quoy and Gaimard, 1934)	sand, mud, weed
BIVALVIA	
Anadara trapezia (Deshayes, 1840)	mud
Eumarcia fumigata (Sowerby, 1853)	sand, sandy mud
Fulvia tenuicostata (Lamarck, 1819)	sand, mud
Irus crenatus (Lamarck, 1818)	on rocks, in cavities
Katelysia rhytiphora Lamy, 1937	sand, mud
K. scalarina (Lamarck, 1818)	sand, sandy mud
Notolepton sp.	algae, sea grass
Ostrea angasi Sowerby, 1871	on rocks, sand, mud
Sanguinolaria biradiata (Wood, 1815)	sand
Spisula trigonella (Lamarck, 1818)	sand, sandy mud
Tawera sp. (fragments)	sand
Tellina deltoidalis Lamarck, 1818	sandy mud
T. mariae Tenison Woods, 1876	sand
Venerupis anomala (Lamarck, 1818) (syn. *Pullastra fabagella)*	gravelly sand
Wallucina assimilis (Angas, 1867)	sand

Four species are essentially estuarine on the basis of the definitions used by Wells (1984). In addition, *Bembicium melanostoma* should also be regarded as such in a Tasmanian context (R.C. Kershaw, pers. comm.). The remaining 34 species are adapted to the marine aspect of the estuarine biota. Many were recorded by Kershaw (1958) as intertidal species at Kelso and Greens Beach, close to the estuary mouth. The present distribution of this fauna indicates a downstream shift of some 40 km in the marine-dominated estuarine environment, subsequent to the accumulation of the Royal Park sediments.

European settlement is certain to have changed the area beyond all recognition, due to land reclamation and filling, dredging, accelerated erosion in the catchments of the South Esk and North Esk Rivers, agricultural drainage, stormwater run-off and the introduction of new species of plants and animals.

METHODS

Amino acid racemisation (AAR)

This method involves analysis of the amino acid content of the shells. Amino acids persist for lengthy periods after death but undergo structural and chemical changes, which are predominantly a function of the diagenetic temperature history and other time-dependent parameters.

In the protein of all living organisms, amino acids occur almost exclusively in the L (laevo rotatory or left-handed) configuration. This is due to a variety of enzymic reactions, which prevent the development of D-amino acids during life. However, following the death of an organism, these enzymic reactions cease, and amino acids undergo a slow change to the D (dextro rotatory or right-handed) configuration until equilibrium (i.e. 50:50 mixture of L- and D-amino acids). This change is known as racemisation. Dating requires measurement of the D/L ratio, which is determined by gas chromatography. The higher the D/L ratio, the greater the age of a fossil. Advantages of the method include the wide timespan it serves and the fact that small samples (<1 g) may be analysed. Analytical techniques and sampling strategies are described by Kimber & Griffin (1987) and by Murray-Wallace & Kimber (1987). Analyses are reported for several enantiomeric amino acids that include valine (VAL), leucine (LEU), proline (PRO), aspartic acid (ASP), phenylalanine (PHE) and glutamic acid (GLU). Isoleucine results are not reported here because of poor baseline resolution during chromatography.

Electron Spin Resonance (ESR)

This method is based on the fact that many natural materials, of either mineral or biological origin, tend to accumulate radiation defects over time. Dating requires the measurement of concentrations of ionised particles that build up in different kinds of traps within the crystalline lattice of the material. The radiation dose has two components. An internal dose is generated by the presence of radioactive isotopes within the sample (mainly U, Th and K). The external dose is due predominantly to radioactive impurities in the immediate environment of the sample, predominantly within 300 mm radius, with a small contribution from cosmic radiation.

The absorbed radiation dose or gamma equivalent dose (ED) is measured in gray (Gy) and can be determined using an ESR spectrometer. Details of the technique and of the sample preparation procedures can be found in Goede & Hitchman (1987) and Goede (1989). Approximately 10 g of material is required for analysis.

If both the internal and external annual dose rate are determined, it is possible to obtain a numerical age since

$$\text{Age} = \text{ED}/\text{annual dose rate}$$

In practice, numerical estimates involve several assumptions which cannot be verified, and it has been argued that the method is better suited as a relative dating method (Goede 1988); this approach is followed here.

DATING

Amino Acid Racemisation

Parts of the hinge region of a single shell of *Anadara trapezia* were used to assess the extent of AAR. Analytical results are shown in table 2 and compared with analyses from two other Tasmanian Holocene shell sites. The latter have also been dated, using radiocarbon methods (Murray-Wallace & Goede 1991). The Royal Park amino acid data are also compared with modern and Last Interglacial (c. 125 000 yrs BP) specimens of *A. trapezia* from southern mainland states of Australia.

Comparison of these results indicates clearly that the *Anadara* sample from Royal Park is of late Holocene age (i.e. <6000 yrs BP by analogy with the radiocarbon dated samples [table 2]). Most of the amino acids in the sample show significantly lower D/L ratios than samples from the other two Holocene sites and therefore imply a Holocene age for the specimen of *A. trapezia* (table 2).

Similarly, the extent of racemisation of amino acids in the Last Interglacial specimens of *A. trapezia* from South Australia and in the modern sample from Quarantine Bay in southern New South Wales, effectively bracket the Royal Park data, and show conclusively that the *Anadara* from Royal Park is not Last Interglacial in age.

A numerical age assessment for the *Anadara* specimen from Royal Park was undertaken, using the integrated rate expression for racemisation (Schroeder & Bada 1976). Radiocarbon-dated specimens of *Glycymeris (Tucetilla) striatularis* (6100 ± 180 cal BP: SUA-2833) from Shell Pitts Point in northwestern Tasmania (Murray-Wallace and Goede 1991) were used as a framework to calibrate the amino acid data for the Royal Park *Anadara.* An empirically derived racemisation rate constant (k) of 1.16×10^{-5} was determined on this basis and a numerical age of 2600 ± 400 yrs BP is indicated for the *Anadara* specimen from Royal Park. The numerical age assessment is based on the extent of leucine and valine racemisation.

Electron Spin Resonance

Attempts were made to analyse two shell samples, one consisting of two valves of *Anadara trapezia* and another of three valves of *Katelysia rhytiphora.* It proved to be impossible to obtain an ED value for *Anadara,* as analysis did not yield a characteristic ESR aragonite spectrum. Remains of a third *Anadara* shell, partly used for AAR analysis, were examined by X-ray diffraction, and the material was found to be aragonite. The unusual spectrum of the *Anadara* ESR sample remains unexplained.

Excellent results were obtained for *Katelysia rhytiphora.* An ED value of 5.3 Gy was determined with 95% confidence limits of 1.9 and 8.8. In table 3 this value is compared with ED values obtained for nine samples drawn from four other Tasmanian sites. The ED value is significantly lower than those for three of the other Tasmanian sites, including the Shell Pits Point and The Spit sites, both radiocarbon dated with calculated ages of c. 6500 yrs BP. The Royal

TABLE 2
Extent of amino acid racemisation ("total acid hydrolysate") in Holocene mollusca from Tasmania, compared with modern and late Pleistocene specimens of *Anadara trapezia* from the southern mainland states of Australia

Locality	Species	Lab code	Conventional age (BP)	Calibrated age (cal BP)*	Amino acid D/L ratio					
					VAL	LEU	PRO	ASP	PHE	GLU
Quarantine Bay, southern NSW	*Anadara trapezia*	–	(modern)	–	0.02	0.03	–	0.11	–	0.08
Royal Park, Launceston	*Anadara trapezia*	–	–	–	0.04 ± 0.003	0.07 ± 0.03	0.05± 0.005	0.17 ± 0.001	0.11 ± 0.002	0.05 ± 0.002
"The Spit", Ralphs Bay	*Katelysia scalarina*	SUA-2294R	6150 ± 60	6580 ± 160	0.05 ± 0.002	0.14 ± 0.02	0.18 ± 0.01	0.28 ± 0.001	0.11 ± 0.001	0.09 ± 0.006
"The Spit", Ralphs Bay	*Fulvia tenuicostata*	SUA-2294R	6150 ± 60	6580 ± 160	0.11 ± 0.01	0.16 ± 0.01	0.11 ± 0.01	0.19 ± 0.01	0.12 ± 0.02	0.11 ± 0.01
Shell Pits Point, NW Tasmania	*Glycymeris (Tucetilla) striatularis*	SUA-2833	5700 ± 70	6100 ± 180	0.09 ± 0.01	0.17 ± 0.01	–	0.33 ± 0.01(?)	0.16 ± 0.05	0.15 ± 0.01
Woakwine Range, (lagoon facies) Robe SA	*Anadara trapezia*		(late Pleistocene: c. 125 000 yrs BP)		0.20 ± 0.01	0.35 ± 0.01	–	0.47 ± 0.003	0.42 ± 0.01	0.32 ± 0.01

* Calibrated radiocarbon ages (cal BP) include a correction for the marine reservoir effect for southern Australian coastal waters. This involved the subtraction of 450 ± 35 years from the conventional radiocarbon age (Libby half-life of 5568 years) according to the principles outlined by Gillespie & Polach (1979). Radiocarbon calibration is after Stuiver *et al.* (1986).

TABLE 3
Summary of ESR analytical data on Holocene molluscan shells from Tasmanian deposits

Sample No.	Species	ED (Gy)	95% conf. limits
Royal Park, Launceston			
T20	*Katelysia rhytiphora*	5.3	1.9–8.8
Shells Pits Point, NW Tasmania			
T10	*Fulvia tenuicostata*	26	21–30
T16	*Katelysia rhytiphora*	18	14–21
Perkins Island, NW Tasmania			
T7	*Fulvia tenuicostata*	20	16–24
T12	*Glycymeris (T) striatularis*	15	10–20
The Spit, Ralphs Bay			
T15	*Katelysia scalarina*	13	10–16
F74 (1)	*Fulvia tenuicostata*	19	16–22
F79 (1)	*Katelysia scalarina*	13	12–15
Shelly Beach, Ralphs Bay			
F68 (1)	*Fulvia tenuicostata*	6.4	4.6–8.2
F68 (2)	*Fulvia tenuicostata*	10	8–13

Park ED value is comparable to two ED values obtained at Shelly Beach, South Arm Peninsula, for *Fulvia tenuicostata.* This site has a radiocarbon age of 2930 ± 80 cal BP (SUA-2293). Thus, the Royal Park sample appears to be of similar age. This is in good agreement with the age estimated by AAR. A z-score test indicates that the AAR derived age is not significantly different to this radiocarbon age ($z = 0.809$).

DISCUSSION

In Australia, including Tasmania, sea levels appear to have reached their present height c. 6500 ± 250 yrs BP (^{14}C) (Thom & Roy 1985). However, arguments continue concerning the extent of sea-level fluctuations since that time (Hopley 1983, Nakada & Lambeck 1989). Infilling of the Tamar Estuary must have proceeded continuously since that time. It is interesting to note that nearly 4000 years later the marine influence at Royal Park, near the head of the estuary, remained strong, suggesting that estuarine infilling that occurred up to this time had little impact on the ecology. This is believed to reflect low rates of natural denudation in the catchments of the South Esk and North Esk Rivers. The situation may well have continued until historical times.

Today, many of the shell species collected at Royal Park appear to be absent from this section of the modern estuary. Rapid siltation has become a major environmental problem (Foster *et al.* 1986). It has been estimated by Skirving (1989) that, under present-day conditions, the average annual input of suspended sediment into the Tamar Estuary is 56 900 tonnes/year. The bulk of this can be attributed to accelerated erosion due to forestry, mining, farming and road construction activities.

Estuarine silting has been further accelerated by the introduction of the saltmarsh grass *Spartina anglica* into the Tamar Estuary in 1947. It has very successfully colonised the upper third of the intertidal slope in most of the area. Before 1947, this area had been almost completely bare of vegetation. The saltmarsh grass has proved extremely efficient at promoting and stabilising deposition of silt (Phillips 1975, Pringle 1982).

An unusual feature of the site is the occurrence of the bivalve *Anadara trapezia.* This species has not been recorded *in situ* from any Quaternary marine, estuarine or beach deposits in mainland Tasmania or in the Bass Strait Islands (Colhoun *et al.* 1982, Jennings 1959, Sutherland & Kershaw 1971) nor has it been recorded live from Tasmanian coastal waters in historical times, but occasionally shells are washed up on Tasmanian beaches. Sutherland & Kershaw (1971) have recorded the presence of shells at Yellow Beach, south-east Flinders Island.

According to Gill (1977), its present southern limit in the southeastern mainland states is at Port Philip Bay, Central Victoria, where it occurs in small numbers and in smaller size compared with the mid-Holocene population. Gill also claimed that it has occurred in northern Tasmania in warmer times but provided no evidence.

Anadara trapezia first migrated into southern Australia some time during the middle Pleistocene, as penultimate interglacial (oxygen isotope stage 7: c. 220 000 yrs BP) occurrences have been dated from Peppermint Grove in the Swan Estuary, Western Australia (Hewgill *et al.* 1983, Murray-Wallace & Kimber 1989) and from Redcliff in northern Spencer Gulf, South Australia (Murray-Wallace *et al.* 1988). A possible older occurrence of the species has been cited by Gill (1977) in the Hopkins River Estuary at Warrnambool. However, relative ESR dating by Goede (1989) has shown that the site contains shell material of more than one age. The *Anadara trapezia* shell analysed from the site was found to be of Last Interglacial age.

If, as inferred by Gill (1977), the southern limit of the distribution of *Anadara trapezia* is controlled by water temperatures, conditions in the Tamar Estuary are likely to have been somewhat warmer than at present at the time of deposition of the Royal Park sediments. Therefore, the absence of *A. trapezia* in the Tamar Estuary may be related to a late Holocene cooling event. The exact sea level at that time is unknown. It was clearly no higher than today and may well have been lower.

CONCLUSION

Amino acid racemisation and ESR dating calibrated against radiocarbon indicate that estuarine sediments at Royal Park are of late Holocene age and are host to the estuarine bivalve *Anadara trapezia.* The variety and composition of molluscan species indicates a strong marine influence in the upper Tamar Estuary 4000 years after it was flooded by the Post-glacial marine transgression. This is also consistent with the nature of the host sediments.

The extremely high siltation rates observed at the present time are believed to reflect the combined effects of accelerated erosion of the catchment and the introduction of the saltmarsh grass *Spartina anglica.* The presence of *Anadara trapezia* is the first Tasmanian record of this species in a stratigraphic context and may well reflect slightly higher water temperatures than prevail today.

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