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COASTAL ABORIGINAL SHELL MIDDENS AND THEIR PALAEOENVIRONMENTAL SIGNIFICANCE, ROBE RANGE, SOUTH AUSTRALIA

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Summary

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Two superposed and stratigraphically distinct shell deposits, located at the seaward edge of Robe Range within Little Dip Conservation Park, southeastern South Australia, are identified as Aboriginal middens. The lower midden consists of *Katelysia* shells and megascopic charcoal, within a terra rossa soil, developed on calcarenite of the Pleistocene Bridgewater Formation. Radiocarbon dates of 8270±80yr cal B.P. and 7910±140yr cal B.P. were obtained for charcoal and shell respectively. Amino acid racemisation values confirm an early Holocene age for the *Katelysia* shells and also suggest relatively recent exhumation of the midden materials. The upper midden consists of *Turbo* shells, flint fragments and finely comminuted charcoal within a Holocene sand dune. A radiocarbon date of 470±160yr cal B.P. was obtained for these shells. Amino acid racemisation values confirm that the *Turbo* shells are only slightly older than modern. The midden features, and their established timeframes, together conform to the constraints of the time-cultural archaeostratigraphic Early Horizon and Late Horizon of Aboriginal sites in southeastern South Australia. Accordingly, the middens site is here proposed as a type archaeological locality and type archaeostratigraphic section for the Luebbers Early Horizon and Late Horizon time-cultural units. Shells of the older midden were probably derived from an intertidal marine lagoon that occupied the low lying corridor between the Robe and Woakwine ranges at the culmination of the Holocene transgression. Alternatively, near the peak of Holocene sea level, a similarly protected sandy environment may have hosted *Katelysia* seawards of Robe Range. Shells of the younger midden are equivalent to those extant on the rocky shoreface of Robe Range. The established time difference between the two episodes of human occupation of the site provides a valuable timeframe for Holocene geomorphic changes within the study area.

KEY WORDS: amino acid racemisation, Australian Aborigine, archaeostratigraphy, Early Horizon, Late Horizon, Holocene, Pleistocene, Bridgewater Formation, St Kilda Formation, Glanville Formation, radiocarbon, Mollusca, midden, Robe, Woakwine, South Australia

Introduction

This paper is primarily concerned with sediments and landforms that resulted from the Holocene transgression in southeastern South Australia, and with the impact of that transgression on populations of coastal Aboriginal people. The investigation is centred on areas close to the town of Robe and includes the Robe and Woakwine ranges and the low lying inter-dune corridor (Fig. 1). This area is part of the Robe-Naracoorte coastal plain, which provides a unique record of Quaternary sea level changes. Successive high stands of sea level resulted in the construction of beach/dune barrier complexes on a steadily uplifting coastal plain. The result is a series of low altitude ranges, approximately parallel to each other, and to the present coastline, and generally increasing in age landwards.

The Holocene sea transgressed the continental shelf and reached present sea level about 7000yr B.P. Unconsolidated, mostly bioclastic carbonate sands were driven shorewards by the persistent high energy waves of the southern ocean, and redistributed by the wind to form a blanket of transgressive dunes. Sea water flooded the low lying corridor between the late Pleistocene Robe and Woakwine ranges, thus forming a sheltered coastal lagoon. Subsequent coastal sedimentation, upwards shoaling of lagoon sediments and continued uplift of the coastal plain has transformed the lagoon to a series of shallow lakes.

Late Pleistocene populations of Aboriginal people presumably lived on tracts of coastal land that are now inundated by the Holocene sea. Such populations, adapted to a gatherer economy in a coastal regime, would have moved landwards with the Holocene transgression. Thus, the oldest sites of Aboriginal occupation along the coast are contemporary with the peak of Holocene sea level and contain the remains of molluscan fauna harvested from the inter-range lagoon. Younger sites contain shells of molluscs which favour a rocky open ocean shoreface.

The palaeoenvironmental significance of these

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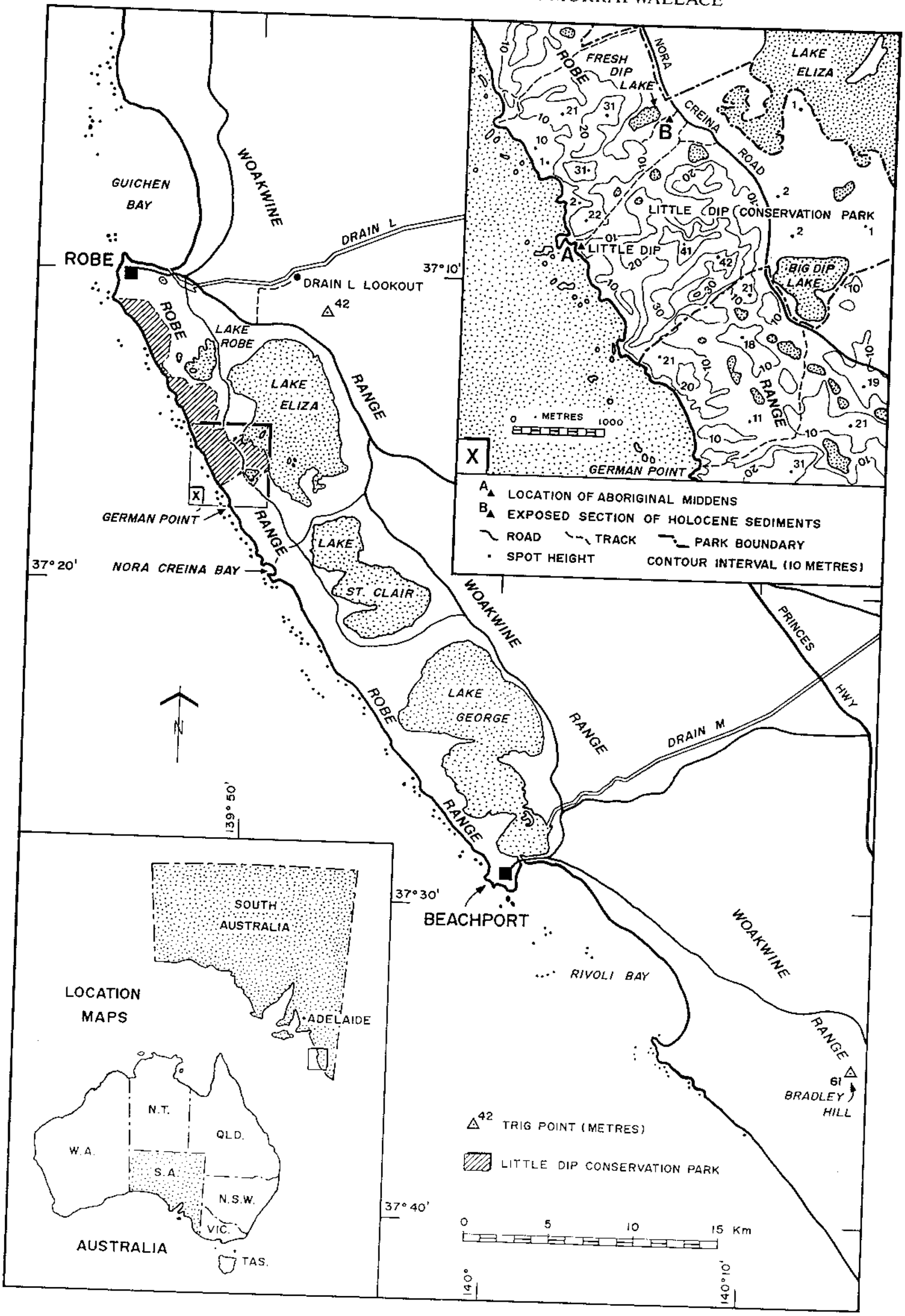


GUICHEN BAY
ROBE
WOAKWINE
DRAIN L
DRAIN L LOOKOUT
37°10'
42
ROBE
LAKE ROBE
LAKE ELIZA
RANGE
X
GERMAN POINT
RANGE
LAKE
ST. CLAIR
37°20'
NORA CREINA BAY
WOAKWINE
ROBE
LAKE GEORGE
RANGE
DRAIN M
PRINCES HWY
N
139° 50'
RANGE
37°30'
BEACHPORT
RIVOLI BAY
WOAKWINE
RANGE
61
BRADLEY HILL
LOCATION MAPS
SOUTH AUSTRALIA
ADELAIDE
N.T.
QLD.
W.A.
S.A.
N.S.W.
VIC.
TAS.
AUSTRALIA
37°40'
42 TRIG POINT (METRES)
LITTLE DIP CONSERVATION PARK
0 5 10 15 Km
140°
140°10'
FRESH DIP LAKE
NORA CREINA ROAD
LAKE ELIZA
B
A
LITTLE DIP
LITTLE DIP CONSERVATION PARK
BIG DIP LAKE
RANGE
0 METRES 1000
GERMAN POINT
A LOCATION OF ABORIGINAL MIDDENS
B EXPOSED SECTION OF HOLOCENE SEDIMENTS
ROAD
TRACK
PARK BOUNDARY
SPOT HEIGHT
CONTOUR INTERVAL (10 METRES)

middens is evaluated here within a timeframe of radiocarbon and amino acid racemisation (AAR) dates obtained from shells and charcoal.

Previous investigations

COASTAL ABORIGINAL OCCUPATION IN SOUTHEASTERN SOUTH AUSTRALIA

A mounting body of archaeological evidence suggests that aboriginal populations were established in southern Australia between 40,000 and 30,000yr B.P. (e.g. Allen 1989; Cosgrove 1989). From approximately 45,000 and 30,000yr B.P. in southern Australia sea levels fluctuated between -30 to -22m (Cann *et al.* 1988, in press). During the last glaciation sea levels were some 130 to 150m below present mean sea level (Chappell 1983; Chappell & Shackleton 1986), while the ensuing transgression reached present sea level 7000 to 6000yr B.P. It has been calculated that Holocene sea levels rose as rapidly as 1.5 to 2.4 cm/yr (Woodroffe *et al.* 1988; Belperio in press). This rise in sea level and the associated environmental changes are likely to have significantly affected those Aboriginal populations, with hunter/gatherer economies, reliant on coastal resources. It has been argued by some that this most recent and extreme rise in sea level would have forced all populations on the now submerged continental shelf to retreat inland (Ross 1985). It is clear that the earliest dates that can be expected for emergent sites of coastal aboriginal occupation in southeastern South Australia will approximate to the peak of the Holocene transgression.

The most comprehensive work detailing early Aboriginal sites in the southeast is that of Luebbers (1978)[1]. The significance of this largely unpublished study can be gauged by the extent to which it has been cited by other researchers (e.g. Pretty *et al.* 1983; Ross 1985; Head 1986; Godfrey 1988, 1989; Egloff *et al.* 1989; Bourman & Murray-Wallace 1990). Luebbers (1978)[1] established a chronology for Aboriginal occupation in the southeast, identifying two discrete episodes of occupation which he termed Early Horizon and Late Horizon. The term 'horizon', in this context, is used in a time-cultural sense rather than in reference to the physical materials of the sites.

Aboriginal middens of the Early Horizon occur in terra rossa soils developed on exposed surfaces of late Pleistocene dunes, such as the Robe Range. Luebbers (1978)[1] described material from two such middens, one from Cape Martin and another from Bevilaqua Cliffs, about 5km southeast of Cape Buffon (Fig. 1). The Cape Martin site contained shells of *Katelysia* and *Mytilus*, charcoal and flint tools. Charcoal yielded a radiocarbon date which Luebbers considered questionable. The other site contained 'a small number of nondescript tools' together with shells of *Plebidonax* and charcoal. Dates of 8250±60 and 6350±100yr B.P. were reported for charcoal and shell respectively.

For these sites and another inland, Luebbers (1978)[1] remained unsatisfied with the stratigraphic control and believed it was possible that younger overlying material, perhaps from a more recent occupation, had been incorporated into the lower terra rossa soil. Thus, no specific site was designated as an archaeological type locality for his Early Horizon.

Late Horizon sites occur in unconsolidated sand and in places, such as at Bevilaqua Cliffs, may stratigraphically overlie an Early Horizon site. Luebbers (1978)[1] subdivided his Late Horizon into an Early Phase and a Late Phase. Middens of the Early Phase range in age from 5800 to 1300yr B.P., contain small numbers of tools and 'monospecific deposits of *Plebidonax* or *Brachidontes*.' Middens of the Late Phase are younger than 1300yr B.P., contain numerous flint implements and shells of *Turbo* (= *Subninella*) and other gastropods extant on southern Australian rocky foreshores.

Recent work by Egloff *et al.* (1989) in southeastern South Australia has revealed abundant *Turbo* shells in middens, dated by radiocarbon on charcoal, as old as 2560±120 and 3060±230yr B.P. These dates call into question the Luebbers (1978)[1] subdivision of the Late Horizon time-cultural unit on the basis of the types of shells preserved in coastal middens.

GEOLOGIC AND GEOMORPHIC FRAMEWORK

The landscape of southeastern South Australia is characterised by a series of low altitude ranges, sub-parallel to each other and to the present coastline. Between Naracoorte and Robe thirteen geomorphically distinct ranges can be identified on the otherwise gently seawards sloping coastal plain (Sprigg 1952; Schwebel 1983). The region has undergone steady regional uplift of about 0.07mm/yr throughout the late Pleistocene (Schwebel 1983; Belperio in press). In general terms, the ranges are geomorphic features associated with palaeoshorelines and they increase in age away from

[1] Luebbers, R. A. (1978) Meals and menus: a study in prehistoric coastal settlements in South Australia. Ph.D. thesis, A.N.U. Canberra, unpublished.

Fig. 1. Map of study area and surrounding region indicating locations of sites and features referred to in text.

Robe towards Naracoorte. The geological origin of these features has been attributed to Quaternary sea level changes (e.g. Tindale 1933; Sprigg 1952; Cook *et al.* 1977; Schwebel 1978[2], 1983; Belperio in press). The ranges were termed 'stranded coastal dunes' by Sprigg (1952), though he recognised that at least some ranges had been constructed during several episodes of marine transgression and that they incorporated sediments of beach, dune and lagoonal palaeoenvironments.

Sediments composing the ranges are predominantly aeolian bioclastic calcarenites with some seaward horizons of shelly limestones in which the fossil molluscs can be associated with rocky foreshore sedimentation. This complex of Pleistocene sediments has been termed the Bridgewater Formation (Boutakoff 1963). Between the ranges closest to the present coastline, sediments are lagoonal and lacustrine bioclastic to muddy limestones. Fossil molluscs in the lagoonal sediments indicate clearly a variety of shallow subtidal and intertidal palaeoenvironments.

In the work reported here, the coastal Robe Range, the adjacent Woakwine Range, and the lagoonal sediments confined by these two features, provide an important geomorphic and palaeoenvironmental framework (Fig. 1).

[2] Schwebel, D. A. (1978) Quaternary stratigraphy of the south east of South Australia. Ph.D. thesis, Flinders University, Adelaide, unpublished.

Woakwine Range

The internal structure of Woakwine Range has been exposed in the Drain L and Woakwine cuttings, excavations through the range to effect drainage of wet lands to the northeast. These cuttings reveal a complex Quaternary stratigraphy which resulted from perhaps as many as five separate stands of high sea level. The deposits of each high sea level are separated by conglomerates, soils, calcretes and strong carbonate cementation (Schwebel 1983). Basal transgressive sediments in the Woakwine cutting consist of shelly and pebbly horizons that include flint cobbles, up to 10cm diameter, derived from the underlying Tertiary Gambier Limestone. These are overlain in turn by seaward dipping subtidal sands, beach sediments and landward dipping sands of the transgressive dune facies (Belperio in press).

In the Drain L cutting Sprigg (1952) observed that several exposed planes of marine erosion were immediately overlain by sediments containing 'a typical reef fauna' fossil assemblage (Fig. 2). Blocks of excavated shelly limestone, corresponding to this facies, can be observed today on the roadside overlooking this cutting. Significant faunal components are fossils of abalone and *Turbo* (Fig. 3), species which are characteristic of modern rocky foreshores. Sprigg (1952) deduced that the dune sediments had been substantially lithified during subaerial exposure. Thus they had remained as a coherent geomorphic feature and provided a rocky

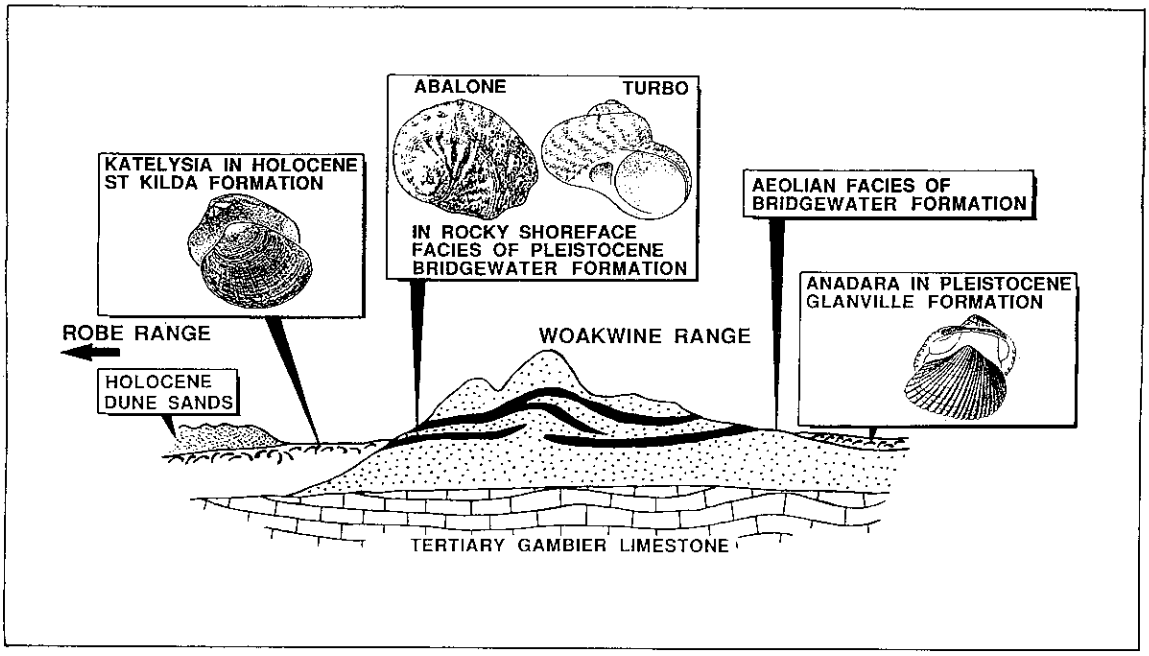


Fig. 2. Diagrammatic section through Woakwine Range (after Sprigg 1952) illustrating stratigraphic distribution of distinctive fossil molluscs. Both *Anadara* and *Katelysia* are characteristic of lagoon facies sediments.

Fig. 3. Fossil gastropods within rocky shoreface facies of the Bridgewater Formation, Drain L cutting, Woakwine Range: A. *Turbo* shell B. Abalone shell.

substrate following marine inundation. On this basis he was able to recognise three episodes of marine regression followed by transgression in the construction of the Woakwine Range.

Fossils of the bivalve *Anadara trapezia* occur in some of the lagoonal sediments onlapping the landward side of Woakwine Range (Fig. 2). This species is characteristic of the late Pleistocene Glanville Formation (Cann 1978; Murray-Wallace *et al.* 1988a) and similiar marine sediments of earlier Pleistocene age (Murray-Wallace *et al.* 1988b).

Robe Range

Robe Range is the youngest of the emergent stranded coastal dunes. Within the study area it outcrops as an erosional rocky shoreline with numerous irregular stacks and islands in which aeolian bedding structures are clearly evident (Fig. 4). Basal sediments of this range rest unconformably on Tertiary Gambier Limestone 10–15m below present sea level and there are no horizons of fossiliferous rocky foreshore facies such as were recognised in the Woakwine complex (Sprigg 1952).

Schwebel (1983) identified three stages of development for Robe Range. The late Pleistocene constructional stages were equated with oxygen isotope sub-stages 5c and 5a. Equivalent marine sediments were deposited in Spencer Gulf at sea level maxima of -8m and -14m respectively (Hails *et al.* 1984). The most recent deposition has resulted from the Holocene transgression, during which there was extensive build up of dune sands over the older components of the Robe Range. These Holocene sands remain essentially unlithified.

Inter-range sedimentation

Despite the steady regional uplift, maximum sea level of the Holocene transgression was sufficient to flood the low lying corridor between the Robe and Woakwine ranges. Numerous road cuttings and other shallow excavations reveal a wealth of Holocene fossil molluscs characteristic of relatively protected (lagoonal) shallow subtidal and intertidal marine environments (Fig. 5). The floor of Lake Robe (Fig. 1), for example, is littered with the shells of oysters, scallops and cockles, particularly the intertidal *Katelysia*. These richly fossiliferous Holocene sediments belong to the St Kilda Formation, in the sense of Cann & Gostin (1985).

Present Investigation

The work reported here centres on the Little Dip Conservation Park southeast of Robe (Fig. 1). The area includes coastal exposures of the late Pleistocene Robe Range (Fig. 4) and Holocene shell beds deposited in the low lying areas between the Robe and Woakwine ranges. These features are to a large extent covered by transgressive Holocene sand dunes, some of which are fixed by modern vegetation, while others are little vegetated and subject to present day erosion. The gastropod *Turbo* is extant on the rocky foreshore and its shells are easily collected at the waters edge (Fig. 6).

The Aims of the investigation are three fold:

1. to evaluate critically the cultural-chrono-stratigraphic concept adopted by Luebbers (1978)[1] within a framework of chronologic, palaeontologic and geomorphic investigation;
2. to propose a type section for the Early Horizon and Late Horizon cutural sites;
3. to document the palaeoenvironmental significance of the type area.

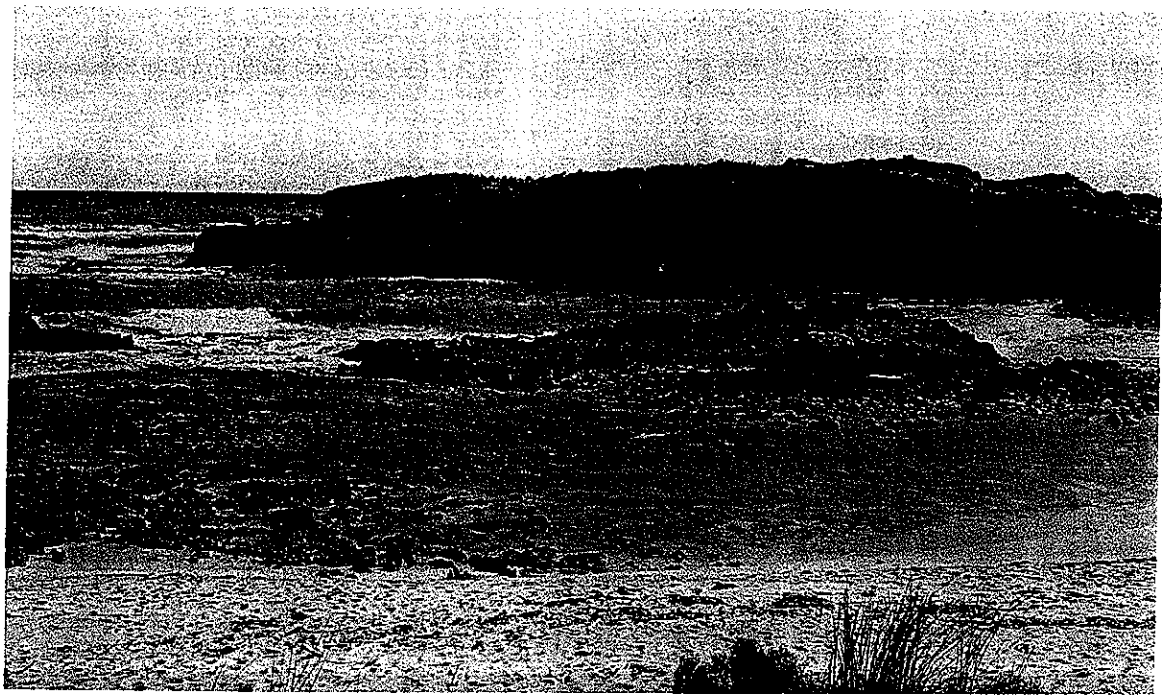


Fig. 4. Erosional rocky shoreface of Robe Range at Little Dip (Location A, Fig. 1).

Observations and Methods

ABORIGINAL MIDDENS

At the study site (Fig. 1, location A) a poorly vegetated coastal dune immediately overlooks the foreshore. The seaward side of this dune has been subjected to wind deflation and a lag deposit of abundant shells and opercula of *Turbo*, together with numerous fragments of flint, litters and surface (Figs 7A, B). Some opercula are chipped or fractured and are more numerous in some areas than others, as if selectively sorted. Above the lag deposit there are numerous conspicuous *Turbo* shells in a greyish, poorly consolidated horizon of the dune (Figs 7A, C). The shell and flint appear to have been derived from this layer which, on field evidence, is interpreted as an Aboriginal midden belonging to the Late Phase of the Late Horizon as defined by Luebbers (1978)[1]. Shell from this midden was taken for radiocarbon and amino acid racemisation dating.

On the landward side of the dune the Holocene sand sharply overlies a well consolidated red-brown terra rossa soil developed on the Bridgewater Formation of the Robe Range (Fig. 8A). Embedded within this palaeosol are numerous shells of the bivalve *Katelysia* and fragments of charcoal (Figs 8B, C; 9A, B). Although no flint fragments were observed, a human origin is also proposed for this material. This assertion is based on the following observations.

a. The shells are disarticulated, lack any preferred orientation and many are severely broken. It is difficult to imagine a natural sedimentary environment that would cause such fracturing of shells, but had they been naturally transported under conditions of high wave or current energy, the shells would have been deposited predominantly convex upwards and tightly imbricated and also show signs of attrition. Such a fabric can be seen in some of the Holocene shell beds between Robe and Woakwine ranges (Fig. 5B). Where shells have not been actively transported their valves usually remain more or less paired (Fig. 5C).

b. Characteristic 'drill' holes, inflicted by predatory gastropods, were not observed in any of the exposed

Fig. 5. Fossil molluscs of Holocene St Kilda Formation between Robe and Woakwine Ranges: A. Oyster shells on the floor of Lake Robe. B. Predominantly shells of *Katelysia*, disarticulated and convex upwards, signifying moderate energy transportation; small roadside excavation, Princes Highway. C. Predominantly shells of *Katelysia*, mostly articulated, signifying little or no transportation. An intertidal environment of deposition is inferred. (Location B, Fig. 1). D. *Katelysia* showing the characteristic "drill" hole inflicted by predatory gastropods. (Location B, Fig. 1).

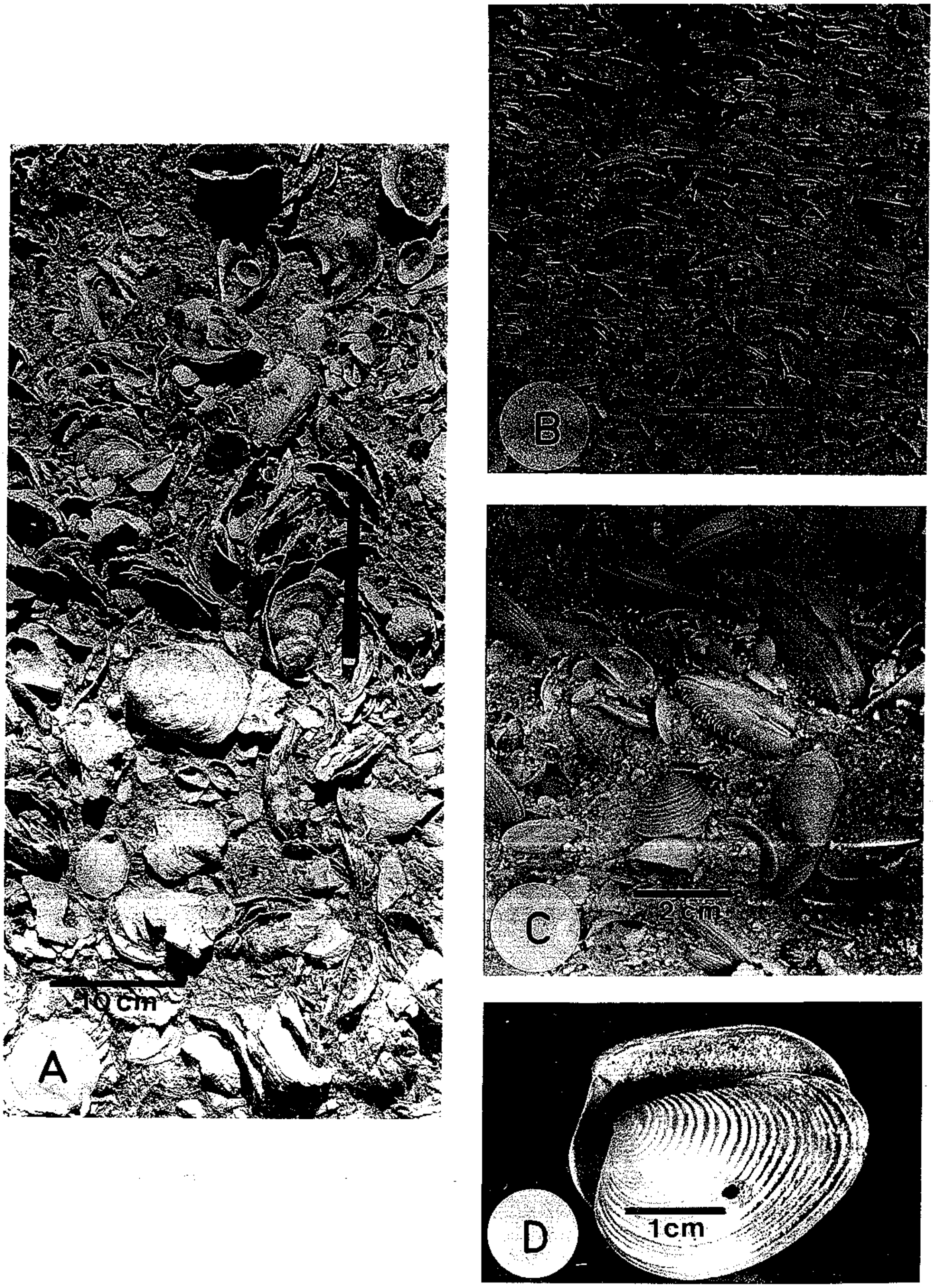

A
10 cm
B
C
2 cm
D
1cm

Fig. 6. Shells of *Turbo*, extant on the Rocky foreshore of Robe Range at Little Dip. (Location A, Fig. 1).

Katelysia valves, yet within the nearby Holocene shelly sediments such valves with 'drill' holes are numerous (Fig. 5D). Clearly some form of selective process has operated to eliminate bivalves affected by this type of predation. Selection also seems to have favoured larger individuals.

c. Sand enclosed by paired *Katelysia* valves from the Holocene lagoonal sediments was microscopically examined and found to contain species of Foraminifera also known from intertidal sandflats of Gulf St Vincent (Cann & Gostin 1985). Species included *Elphidium crispum*, *E. macelliforme* and *Miliolinella labiosa*. Gill *et al.*

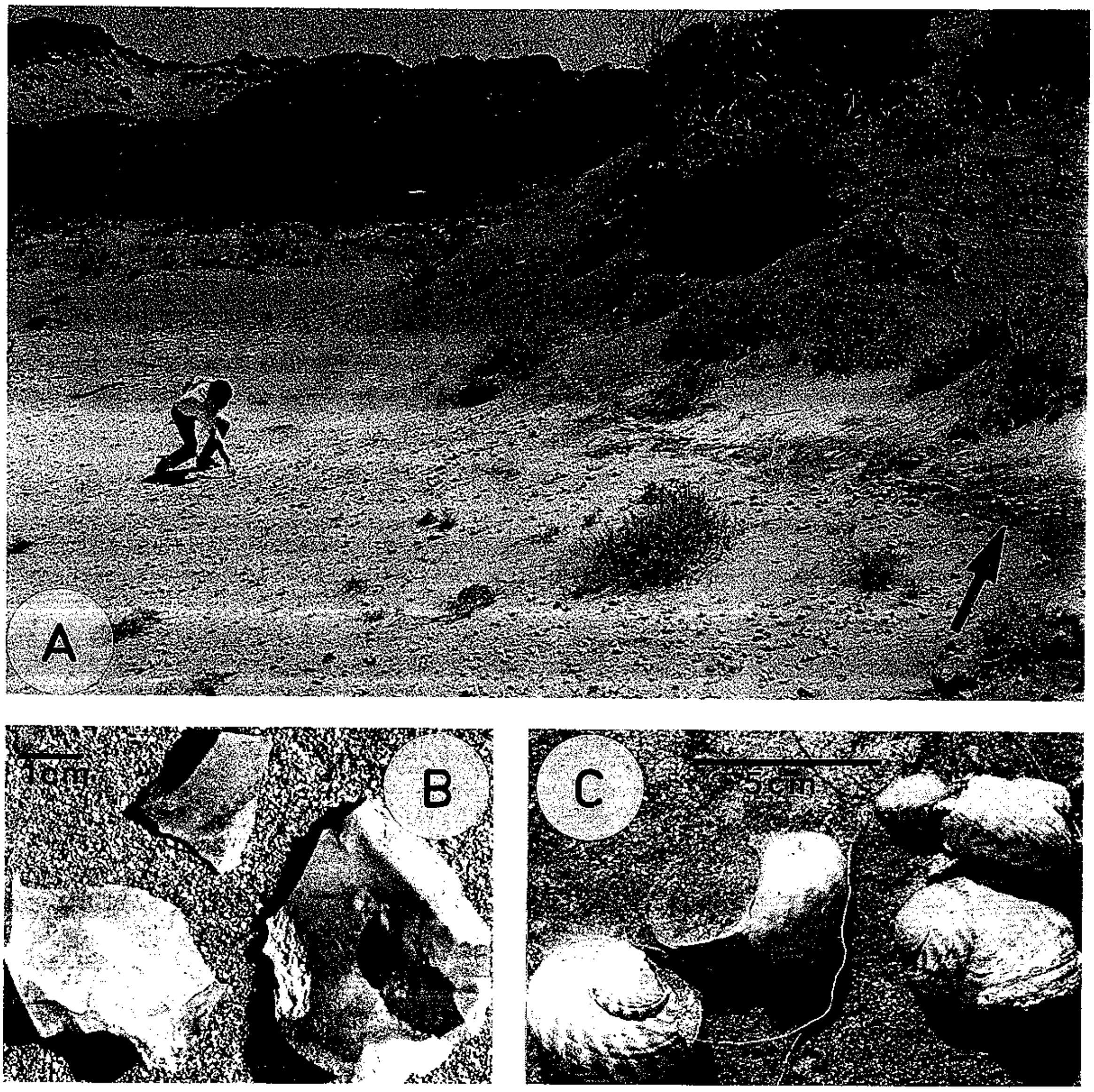


Fig. 7. A. Lag deposit of *Turbo* shells and flint fragments apparently derived from stratum indicated by arrow. This deposit is interpreted as a Late Horizon Aboriginal midden. (Location A, Fig. 1). B. Flint fragments from the lag deposit. C. *Turbo* shells within the stratum indicated by the arrow in A.

(1991), used the abundance of Foraminifera in a shell deposit at Warrnambool to show that it was a natural estuarine deposit and not of human origin. Microscopic examination of the terra rossa matrix enclosing the *Katelysia* shells revealed no Foraminifera within the deposit under present discussion.

d. Stratigraphic elevation of the *Katelysia* deposit at the crest of Robe Range makes natural sedimentation implausible if these shells are to be correlated with those undisputedly deposited in the Holocene lagoon between Robe and Woakwine ranges. It is also possible that *Katelysia* could have occupied relatively sheltered intertidal seaward environments that probably existed immediately prior to the culmination of the Holocene transgression, a suggestion favoured by Luebbers (pers. comm. 1991).

(Although there is abundant charcoal, both within and surrounding the shell deposit, and unambiguously embedded within the terra rossa soil, there are no clear signs of localisation that might be easily interpreted as camp fires. Thus, for this site, the presence of charcoal does not necessarily, in itself, constitute evidence of human occupation).

Thus the deposit is interpreted as an Aboriginal midden belonging to the Early Horizon as defined by Luebbers (1978)[1]. Shell and charcoal from this midden were taken for radiocarbon assessment. Additional shell was taken for amino acid racemisation dating. Paired *Katelysia* valves from the nearest accessible deposit of Holocene lagoonal sediments (Fig. 1, location B), were taken for comparative AAR dating.

DATING METHODS: RADIOCARBON DATING

Charcoal and *Katelysia* shell were carefully removed from the terra rossa matrix of the Late Horizon midden and packed in clean plastic bags. Similarly, *Turbo* shells were taken from the Early Horizon midden (Fig. 1, location A). These materials were forwarded to the radiocarbon laboratories of the Australian National University and the University of Sydney for radiocarbon dating. Conventional radiocarbon dating followed the methods of Gupta & Polach (1985).

DATING METHODS: AMINO ACID RACEMISATION ANALYSES

The following materials were collected for AAR analysis for the purpose of age determination:

a. disarticulated shells of *Katelysia rhytiphora* and *K. scalarina* from the Early Horizon midden (Fig. 1, location A);

b. articulated shells of *K. scalarina* from Holocene lagoon sediments (= St Kilda Formation) within the Robe-Woakwine corridor (Fig. 1, location B);

c. articulated shells of *K. scalarina* from late Pleistocene lagoon sediments (= Glanville Formation) on the landward side of the Woakwine Range, exposed in a small quarry adjacent to Princes Highway;

d. shells of *Turbo* sp. from the Late Horizon midden, and from the immediately adjacent modern shoreface sediments (Fig. 1, location A).

AAR analyses were undertaken on all the collected shell materials. Data obtained from the *Katelysia* shells of the Early Horizon midden were compared and contrasted with the extent of racemisation in specimens obtained from the Holocene and late Pleistocene lagoon sediments. As the nature of racemisation kinetics in *Turbo* spp. shells is not well documented, the significance of AAR analysis of shells from the Late Horizon midden was assessed with reference to data derived from radiocarbon dating of an adjacent midden shell and AAR analysis of modern specimens.

Amino acid analyses were for the 'total acid hydrolysate', complex peptide mixture of varying molecular weights, and followed the methods outlined by Kimber & Griffien (1987). Analyses of the N-pentafluoropropionyl D, L-amino acid 2-propylesters were undertaken using a 25m fused silica Chirasil-L-Val capillary column and Hewlett Packard model 5890A gas chromatograph with a flame ionisation detector and helium carrier gas. The integrity of the analytical procedures undertaken using the AAR technique was evaluated by analysing international interlaboratory comparison samples of Wehmiller (1984a). Results were within two standard deviations of the grand mean of the international comparison.

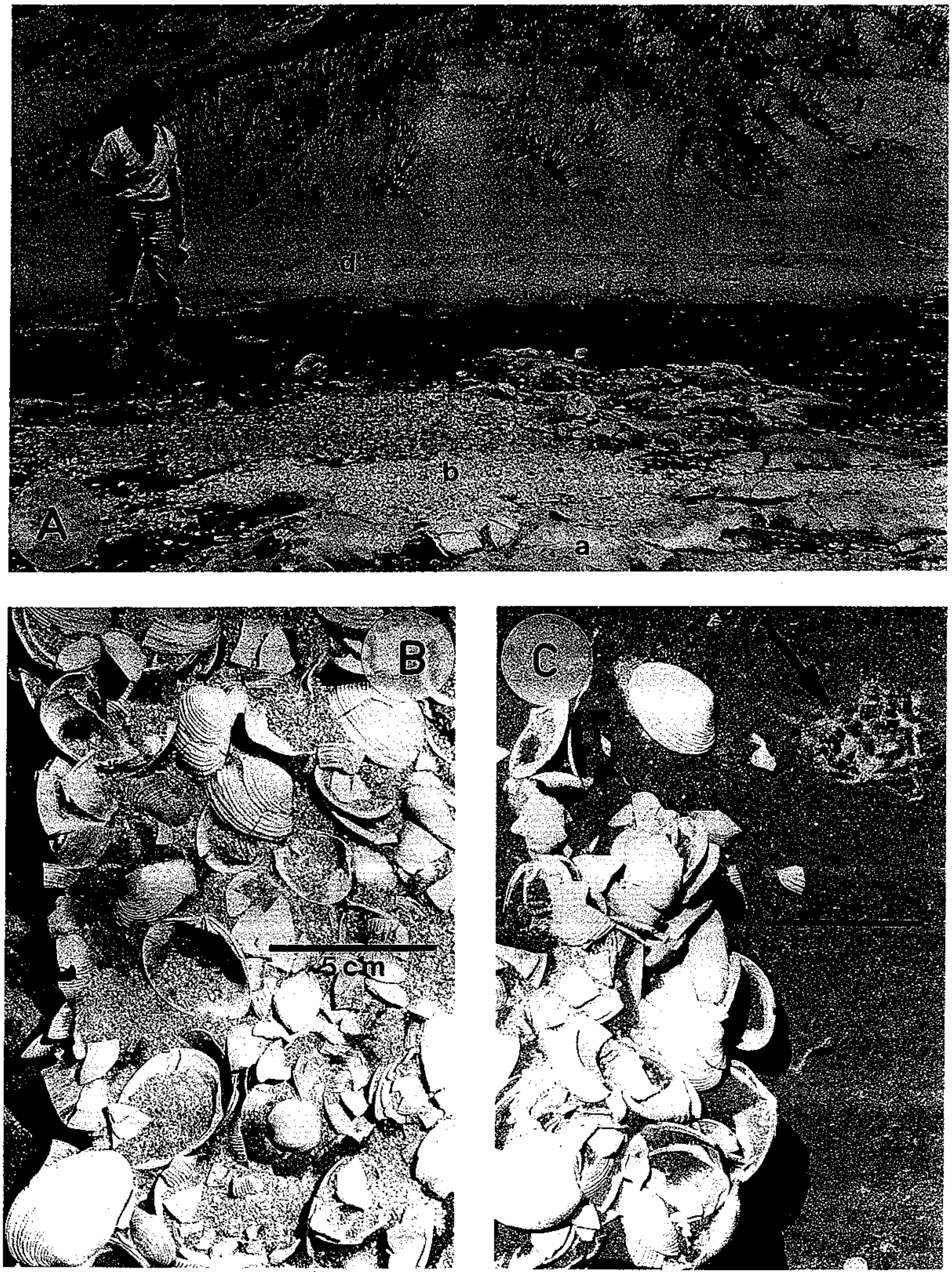
The hinge region of each *Katelysia* shell was analysed as the highest concentration of residual protein occurs within this region. The columella was analysed in the *Turbo* specimens. In excess of 20% by weight for each shell was analysed by AAR to reduce variability which may potentially arise when analysing small fragments (Wehmiller 1984b).

Amino acid D/L ratios were compared with calendric radiocarbon ages (cal B.P.), converted from marine reservoir corrected radiocarbon years (B.P.: Libby half-life) according to the methods outlined by Gillespie & Polach (1979) and Stuiver *et al.* (1986) (Table 1).

Results

RADIOCARBON DATES

Charcoal from the Early Horizon midden (lab. code ANU-7448) yielded a radiocarbon age of 8270±80yr cal B.P. *Katelysia* shell, also from the


d
c
b
A
a
B
5 cm
C

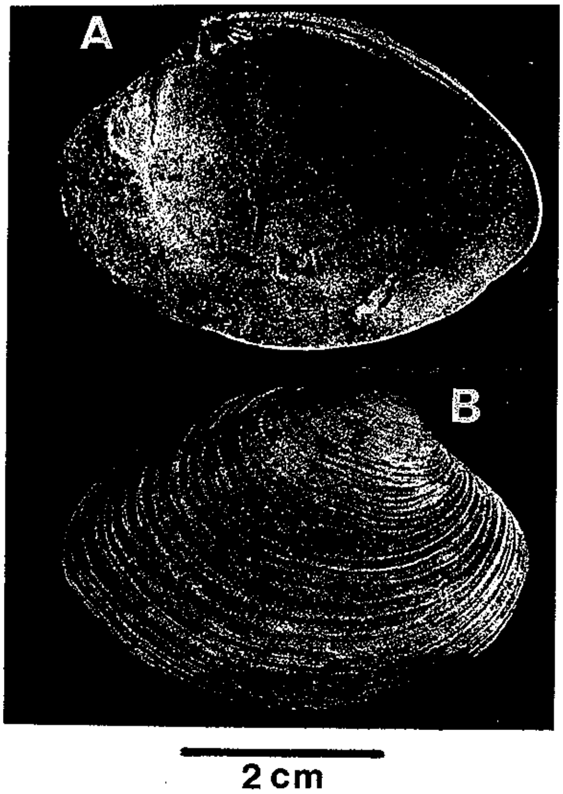


Fig. 9. Selected valve from the Early Horizon midden showing (A) internal and (B) external features of *Katelysia*.

older midden (lab. code SUA-2613), was determined to have a marine reservoir corrected age of 7910±140yr cal B.P. *Turbo* shell from the overlying Late Horizon midden (lab. code ANU-7447) had a radiocarbon age, again corrected for the marine reservoir effect, of 470±160yr cal B.P.

AMINO ACID RACEMISATION ANALYSES

The relative extent and degree of racemisation for the different amino acides in *Katelysia* spp. and *Turbo* spp. is in accord with other radiocarbon dated Holocene fossils in southern Australia (for example, Murray-Wallace *et al.* 1988c; Murray-Wallace & Bourman 1990) and the theoretically predicted differential rates of amino acid racemisation (Table 1).

The similarity in extent of racemisation of amino acids in *Katelysia scalarina* obtained from lagoonal sediments and molluscs from the Early Horizon midden points to a common age given the assumption that they have experienced equivalent diagenetic temperature histories. The validity of this assumption is strengthened by the close proximity of these two sites. The location of the lagoonal facies close to the feather edge of the Holocene transgressive sediments, which have elsewhere been dated at approximately 7000yr B.P., also points to a common age for these two sites.

A calibrated radiocarbon age of 7910±140yr cal B.P. was obtained on *Katelysia* from the Early Horizon midden (Table 1). These data are significant, for they document Aboriginal coastal occupation during an early transgressive phase of the post glacial Holocene marine transgression. To evaluate the amino acid data of the Early Horizon midden, these results are compared with a sequence of similar age at Smoky Bay, Eyre Peninsula (Table 1). A z-score, according to the methods of Gupta & Polach (1985), indicates that these two calibrated radiocarbon dates are not significantly different at the 5% level (z-score of 1.55). Although contemporary mean annual temperatures (CMAT) between these two sites differ by approximately 2.2°C, it is unlikely that the diagenetic temperature differences will be detected for the Holocene record. In contrast, such temperature differences are significant for last interglacial fossils (for example, Murray-Wallace *et al.* 1991).

The similarity in extent of racemisation for the radiocarbon calibrated Holocene *Katelysia* from Smoky Bay indicates that the *Katelysia* shells of the Early Horizon midden were buried for a significant portion of their diagenetic temperature history. Had the shells been subaerially exposed for much of their diagenetic history, the extent of racemisation of amino acids would be significantly higher (compare Murray-Wallace *et al.* 1988c). The suggestion, independently based on AAR data, that the Early Horizon midden had been buried, then exhumed, is consistent with the geomorphic evidence of the site, that is, recent dune deflation. This clearly represents a novel application of AAR in the recognition of exhumed sequences.

The lower extent of AAR in *Turbo* sp. from the Late Horizon midden, than in *Katelysia* spp. from the Early Horizon midden, is consistent with a younger age, as independently determined by radiocarbon dating. However, as this is the first

Fig. 8. A. Early Horizon Aboriginal midden within terra rossa palaeosol on Bridgewater Formation, Robe Range. (Location A, Fig. 1). a. Karstified rocky outcrop of Bridgewater Formation. b. *Katelysia* shells of the Early Horizon midden. c. Terra rossa palaeosol. d. Holocene sand dune which includes the Late Horizon *Turbo* midden (Fig. 6). Note the sharp contact between this and the underlying terra rossa palaeosol. B. Detail of *Katelysia* shells within the midden. Note that shells are disarticulated, lack preferred orientation and none shows signs of gastropod predation. C. Detail of part of the midden in which charcoal, indicated by arrow, is embedded in the terra rossa palaeosol.

TABLE 1. *Extent of amino acid racemisation ('total acid hydrolysate') in late Quaternary Mollusca from the south east of South Australia.*

Location/ description	Depth of burial (m)	Species	CMAT+ (°C)	Age PB* & [lab code]	Amino acid D/L ratio# VAL	LEU	ASP	PHE	GLU
Robe Beach	surface	*Turbo* spp.	14.7	modern	0.02 ± 0.001	0.02 ± 0.004	—	0.03 ± 0.005	0.04 ± 0.01
Robe midden (Late Horizon)	surface (exhumed)	*Turbo* spp.	14.7	(840±80) 470±160 [ANU-7447]	0.04 ± 0.002	0.07 ± 0.01	0.18	0.12 ± 0.002	0.09 ± 0.01
Robe midden (Early Horizon)	surface (exhumed)	*Katelysia* spp.	14.7	(7480±70) 7910±140 [SUA-2613]	0.05 ± 0.01	0.09 ± 0.03	0.28 ± 0.01	0.22 ± 0.02	0.11 ± 0.01
Robe/Holocene lagoon facies	1	*Katelysia scalarina*	14.7	—	0.06 ± 0.02	0.08 ± 0.02	0.32 ± 0.01	0.16 ± 0.04	0.12 ± 0.01
Woakwine Range/ Back barrier lagoon facies	>1	*Katelysia scalarina*	14.7	last interglacial 125 000	0.20 ± 0.02	0.35 ± 0.01	0.54 ± 0.06	—	0.31 ± 0.03
Smokey Bay, Eyre Peninsula/coastal sediments[1]	1.82 1.88-	*Katelysia rhytiphora*	16.9	(6940±170) 7410±290 [CS-450]	0.08 ± 0.02	0.16 ± 0.02	0.23	—	0.10 ± 0.004

+ C.M.A.T. — Contemporary mean annual temperature (atmospheric).
* Conventional radiocarbon age indicated in parentheses with associated error term (1δ). Marine reservoir corrected sidereal ages without parentheses with 2δ error term. See text for discussion on marine reservoir correction and calibration of radiocarbon ages to sidereal years.
# amino acids: VAL — valine; LEU — leucine; ASP — aspartic acid; PHE — phenylalanine and GLU — glutamic acid. Error terms indicate analytical precision and intershell amino acid D/L ratio variation (1δ).
[1] data of Murray-Wallace *et al.* (1988c).

AAR analysis on *Turbo* spp. from southern Australia, it is not possible to evaluate critically the relation of the kinetics of racemisation in *Turbo* to the moderate racemisation rates that are characteristic of *Katelysia.* It is likely that racemisation rates vary between bivalves and gastropods, as noted by Miller & Brigham-Grette (1989). However, the small difference in extent of racemisation of amino acids between *Turbo*, of the Late Horizon midden, and *Katelysia*, of the Early Horizon midden, may also point to a history of subaerial exposure for the former.

The extent of amino acid racemisation in *Katelysia scalarina* from the back barrier lagoon facies of the Woakwine Range barrier complex is consistent with other last interglacial Mollusca (Murray-Wallace *et al.* 1988a) and is in accord with a temperature-geographic latitude kinetic model for last interglacial shell taxa in southern Australia (Murray-Wallace *et al.* 1991).

These data assist in constraining the time framework for the Aboriginal coastal occupation of southern Australia.

Discussion and Conclusions

THE ARCHAEOLOGICAL SITE: A TYPE LOCALITY

The sharp stratigraphic boundary between the *Katelysia* bearing terra rossa palaeosol of the Bridgewater Formation and the overlying *Turbo* bearing Holocene dune sand is clearly shown in Fig. 7. the palaeosol is well consolidated and has not been contaminated by younger overlying sediment, shells or artifacts.

The two sets of midden materials, as described in this paper, undoubtedly conform to those specified by Luebbers (1978)[1] for his Early Horizon and Late Horizon of aboriginal occupation of southeastern South Australia. Equally, the age determinations of both shells and charcoal, particularly the close agreement of ^{14}C and AAR dates, meet the constraints of time applied to this time-cultural classification.

Given that the site meets these tight stratigraphic, archaeological and time constraints, and given that it is located within the boundaries of a National Conservation Park, it is here confidently proposed as a type locality and type section for the time-cultural Early Horizon and Late Horizon of Luebbers (1978)[1].

OTHER ARCHAEOLOGICAL SITES AND POSSIBLE REFERENCE LOCALITIES

It is likely that future investigations will reveal other sites that will equally illustrate, or futher clarify, the Luebbers (1978)[1] chronology. If appropriate, such sites should be designated as reference localities and reference sections.

In this context, middens within Discovery Bay Coastal Park near Cape Bridgewater in southwestern Victoria seem worthy of further study. Godfrey (1989) differentiated middens in this area into two episodes of occupation, though did not use the Luebbers (1978)[1] terminology.

The older middens, 8490-3860yr B.P., are in terra rossa soils of the Bridgewater Formation and contain mussel shells of a species no longer extant along the present shore. The younger middens are in unconsolidated sand and contain shells of species, such as *Turbo*, which inhabit the present shoreline, together with numerous flint fragments. Dates of 1050-360yr B.P. were reported by Godfrey (1989) for these younger sites.

Environmental history of the study area

The following is an account of the interaction of physical and biological processes, from c.125,000yr B.P. to late Holocene, leading to the evolution and early human exploitation of the study environment.

At 125,000yr B.P., oxygen isotope sub-stage 5e, southern Australian sea level was slightly higher than at present. Various estimates place global sea levels at +4 to +6m, but distribution of late Pleistocene Mambray Formation (=Glanville Formation) in northern Spencer Gulf suggests that the 5e sea level was only +1m (Hails *et al.* 1984). At this time, the seaward side of Woakwine Range formed a rocky coastline and the shoreface was inhabited by molluscs favouring such a substrate in a high energy wave regime. Abalone, limpets and *Turbo* were significant faunal elements. Seawater flooded areas landwards of Woakwine Range forming a coastal lagoon, the sheltered waters of which were extensively colonised by molluscs such as *Katelysia* and *Anadara*.

Following marine regression during oxygen isotope sub-stage 5d, at 105,000yr B.P., sub-stage 5c, marine transgression brought palaeo sea level to -8m (Hails *et al.* 1984; Belperio in press). Robe Range stage III sediments accumulated as unconsolidated beach and dune sands (Schwebel 1983).

During isotope sub-stage 5b, the sea receded allowing subaerial diagenesis and at least partial lithification of the carbonate rich sands of the stage III sediments. Protective calcretes developed on exposed surfaces.

At 80,000yr B.P., isotope sub-stage 5a, marine transgression brought sea level to -14m (Hails *et al.* 1984; Belperio in press). Robe Range stage II sediments were deposited at this time. Sea level was not sufficiently high to erode the earlier formed stage III sediments, which were mantled by the dune facies of the stage II transgression.

Following this peak of sea level, the ocean again regressed across the continental shelf and for the remainder of Pleistocene time the shoreline remained seawards of Robe Range. The carbonate sands thus underwent futher extensive diagenesis and consolidation.

Between 45,000 and 30,000yr B.P., oxygen isotope stage 3, there were fluctuations of sea level between -30m and -22m (Cann *et al.* 1988, in press), but these were insufficient to influence Robe Range. Also, by 30,000yr B.P. the base of the range had undergone about 5m of tectonic uplift, futher compounding the impact of the regression. Early humans may have first appeared in southeastern Australia at this time.

From 30,000 to 18,000yr B.P., during oxygen isotope stage 2, the last glacial regression lowered sea level to -130m (Chappell & Shackleton 1986). Aboriginal populations occupied the emergent continental shelf and in coastal areas probably exploited a variety of sea food resources.

At 18,000yr B.P. sea level began to rise, sometimes as rapidly as 2.4cm/yr, totally submerging the continental shelf by 7,000yr B.P. (Belperio in press). Unconsolidated sands were driven shorewards by the rising seas, mantling seaward outcrops of Robe Range stage II and, where exposed, stage III. Sea water flooded the low lying corridor between Robe and Woakwine ranges, providing sheltered shallow subtidal and intertidal environments in which mollusc populations thrived. Aboriginal people occupied Robe Range, open ocean to one side and sheltered lagoon to the other. At the study site they exploited the intertidal cockle *Katelysia*. Elsewhere, for example at Bevilaqua Cliffs to the southeast, ocean beach cockles, *Plebidonax*, were the prime food source.

Bioclastic sedimentation within the shallow Robe-Woakwine marine lagoon was rapid. Sedimentary sections reveal upward shaoling sequences of subtidal oysters overlain by intertidal *Katelysia* and *Anapella*. Shoaling was further facilitated by tectonic uplift of about 0.5m from the time of stabilisation of Holocene sea level to present.

Meanwhile, on the seaward side of Robe Range, sands continued to accumulate. In the absence of any preferred direction of longshore transport

(Sprigg 1952; Bourman & Murray-Wallace 1990), the strong persistent ocean swell (Gostin *et al.* 1988) moved sands onshore from where they were distributed to form a blanket of dunes. Some sands were also redistributed, both up and down the coast, to the protected areas of Guichen Bay, to the northwest, and Rivoli Bay, to the southeast. Sedimentation in these areas effectively isolated the Robe-Woakwine lagoon from futher marine influence.

At the study site, continued onshore and alongshore migration of the Holocene sands once again exposed the older lithified sediments of Robe Range. Their long subaerial emergence through the late Pleistocene had resulted in a high degree of carbonate cementation and they outcropped as a rugged irregular erosional coastline. A marine mollusc fauna, dominated by the large gastropod *Turbo*, became established along this rocky, high wave energy environment. Thus was repeated, on the Holocene shoreface of Robe Range, ecological events that are recorded by the Pleistocene horizons of 'typical reef fauna' (Sprigg 1952) in the Woakwine Range.

For a second time, Aboriginal people occupied the study site and exploited this newly established food resource.

The two middens at the study site therefore reflect profound changes in landscape. The elapsed time between the two periods of human occupation is a valuable clue to the rate of environmental change.

Conclusions

1. Radiocarbon and AAR dating together confirm an early Holocene age for the Early Horizon Robe Range Aboriginal midden, which is contemporaneous with the culmination of the Holocene transgression. Application of AAR as a palaeothermometer indicates that this early human site has recently been subaerially exposed.
2. This work has demonstrated the importance of an integrated approach to archaeostratigraphic studies through the combined efforts of dating, geomorphology, sedimentology and palaeontology. Such integrated studies can reconcile otherwise seemingly conflicting evidence.
3. The notion of archaeostratigraphic type and reference sections provides a useful approach in the study of Australian prehistory and has potential for wider application.

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