ANU RADIOCARBON DATE LIST VII

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Along SE coast of Australia a variety of Holocene barriers composed of siliceous sand and shell detritus occur within bedrock-confined embayments. On basis of morphostratigraphy 4 barrier types are recognized: prograded, stationary, receded and episodic transgressive dunes. Several subtypes are also distinguished. Composite bay barriers involving partial eolian reworking of a prograded barrier constitute most complex examples of Holocene depositional sequences on this coast. The present list is a preliminary attempt at defining the age structure of a group of such barriers (excepting receded type). Ages are reported in *conventional years* BP. Text references to ages and age ranges are *environmental effect corrected* ages BP* and yr* (as recommended by Stuiver and Polach, 1977), using 450 ± 35 yr as postulated by Gillespie and Polach (in press) in order to relate Australian oceanic environment shells to terrestrial environment wood. $\delta^{13}C$ errors, where based on measurement, are always $\pm 0.2\%$ and are not shown in the text; when based on estimated values (*Est*) the error is given.

Samples were obtained by power-auger drilling, coll by **B G Thom**, Dept Biogeog and Geomorph, Australian National University and **G M Bowman**, Geography Dept, Sydney University, and subm by Dept Biogeog and Geomorph. Except where noted, cleaned shelly sand or shell sample was hydrolyzed with HCl under vacuum and released CO_2 recovered for further processing prior to ^{14}C analysis.

Reworking of mollusks and their redeposition at a later date in the sediment body in a dynamic nearshore or beach face environment have been considered by Bernard *et al* (1962) and Curray *et al* (1969). These workers have designated certain samples "anomalously old". However, in this list, consistency of pattern is prime guide to assessing reworking effect. In areas studied in detail (eg, Moruya, see fig 1), failure to find young dates below upper shoreface deposits limits the likelihood of all dates being reworked; all Holocene dates are assumed to date the period of deposition unless otherwise stated.

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work of the laboratory's senior staff, John Head and John Gower, made
this report possible.

Prograded Barriers

Moruya series

Located N of Moruya R, New South Wales (35° 53′ S, 150° 09′ E).
Narrow drainage basins sculptured into folded Palaeozoic metasediments,
which are locally capped by Tertiary basalts and fluvial gravels, are
blocked by bay-head barrier which is composed of 40-50 beach ridges.
Four ^{14}C dates on shell hash and organic muds were obtained from the
transgressive facies. Eighteen ^{14}C dates on shell fragments were obtained
from nearshore regressive unit, from which 5 age groups (4 relic, 1 modern) have been id (fig 1).

ANU-1117.   D^{14}C = −531.9 ±**4.4**‰   **6100 ± 80**
                                                        $\delta^{13}C = +1.1$‰

Shell hash (1240 min count).

ANU-1118.   D^{14}C = −521.7 ±**4.4**‰   **5920 ± 70**
                                                        $\delta^{13}C = +1.1$‰

Shell hash (1320 min count).

ANU-1197.   D^{14}C = −518.0 ±**4.3**‰   **5860 ± 70**
                                                        $\delta^{13}C = +0.6$‰

Shell hash (1460 min count).

ANU-1119.   D^{14}C = −515.2 ±**5.5**‰   **5820 ± 90**
                                                        $\delta^{13}C = +1.3$‰

Shell hash (760 min count).

ANU-1198.   D^{14}C = −515.9 ±**4.3**‰   **5830 ± 70**
                                                        $\delta^{13}C = +1.2$‰

Shell hash (1480 min count).

ANU-1200.   D^{14}C = −542.8 ±**4.6**‰   **6290 ± 80**
                                                        $\delta^{13}C = +0.6$‰

Shell hash (1180 min count).

ANU-1116.   D^{14}C = −458.8 ±**4.5**‰   **4930 ± 70**
                                                        $\delta^{13}C = +1.2$‰

Shell hash (1300 min count).

ANU-1199.   D^{14}C = −471.1 ±**5.0**‰   **5120 ± 80**
                                                        $\delta^{13}C = +1.1$‰

Shell hash (1100 min count).

ANU-1400.   D^{14}C = −489.9 ±**5.4**‰   **5410 ± 90**
                                                        $\delta^{13}C = +1.1$‰

Shell hash (880 min count).

ANU-1138.   D^{14}C = −475.5 ±**4.1**‰   **5180 ± 60**
                                                        $\delta^{13}C = +0.8$‰

Shell hash (1820 min count).
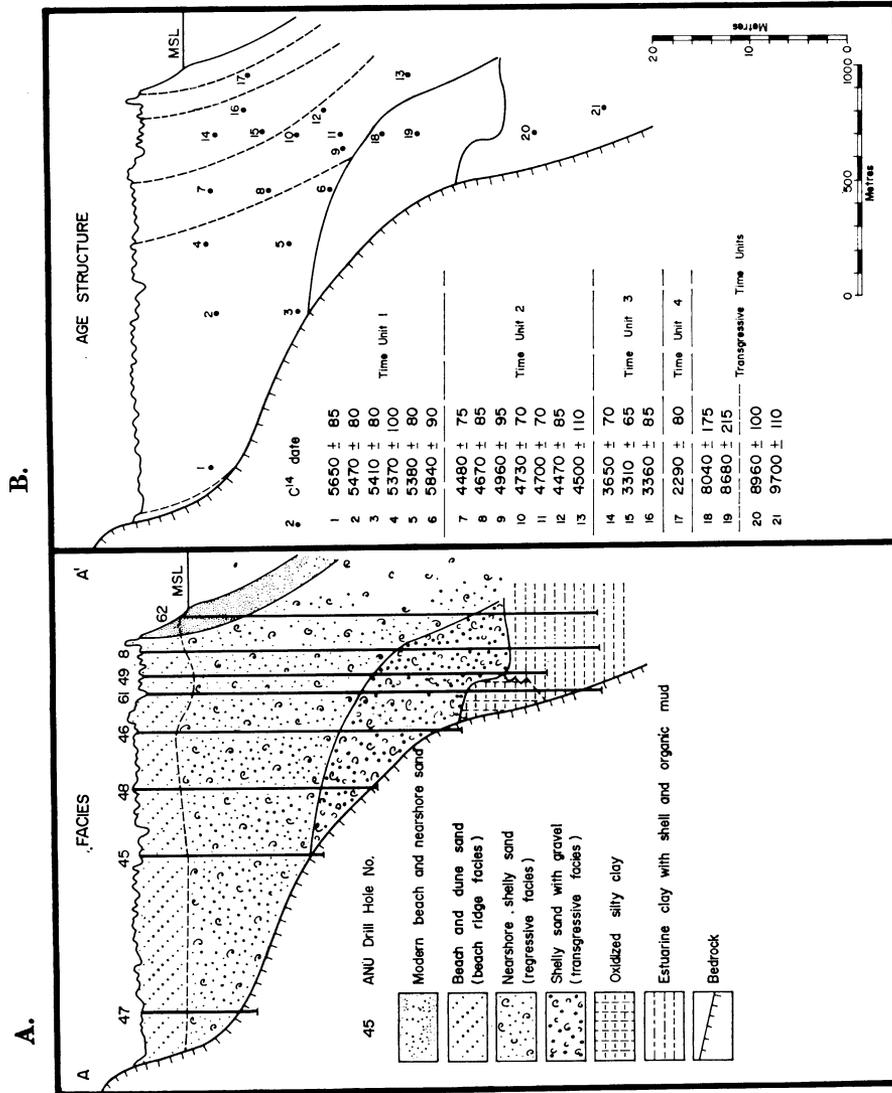
Fig. 1. Cross section of Moruya beach-ridge plain showing (A) facies and (B) ages structure. Time-lines are estimated on basis of ¹⁴C dates from uppermost shelly sand samples. All dates listed in (B) are environmentally corrected ¹⁴C ages BP* except organic matter dates, Nos. 20 & 21.

ANU-1139.   D^{14}C = −473.2 ±4.0‰   **5150 ± 60**
$$\delta^{13}C = +1.1‰$$

Shell hash (1960 min count).

ANU-1398.   D^{14}C = −458.3 ±5.5‰   **4920 ± 80**
$$Est\ \delta^{13}C = +1.0\ ±0.5‰$$

Shell hash (900 min count).

ANU-1399.   D^{14}C = −460.2 ±6.9‰   **4950 ± 100**
$$\delta^{13}C = +1.1‰$$

Shell hash (680 min count).

ANU-1115.   D^{14}C = −399.9 ±4.7‰   **4100 ± 60**
$$\delta^{13}C = +1.1‰$$

Shell hash (1320 min count).

ANU-1137.   D^{14}C = −374.0 ±4.3‰   **3760 ± 60**
$$\delta^{13}C = +1.0‰$$

Shell hash (1920 min count).

ANU-1114.   D^{14}C = −377.4 ±6.1‰   **3810 ± 80**
$$\delta^{13}C = +1.0‰$$

Shell hash (1080 min count).

ANU-1397.   D^{14}C = −289.4 ±6.1‰   **2740 ± 70**
$$\delta^{13}C = +0.7‰$$

Shell hash (880 min count).

ANU-1140.   D^{14}C = −652.4 ±7.4‰   **8490 ± 170**
$$\delta^{13}C = +0.4‰$$

Shell hash. Dilution, 40% sample (1980 min count).

ANU-1141.   D^{14}C = −678.9 ±8.1‰   **9130 ± 210**
$$\delta^{13}C = +0.9‰$$

Shell hash. Dilution, 39% sample (2000 min count).

ANU-1133.   D^{14}C = −672.1 ±4.0‰   **8960 ± 100**
$$Est\ \delta^{13}C = −24.0\ ±2.0‰$$

Organic mud, boiled in 2N HCl (1740 min count).

ANU-1132.   D^{14}C = −700.8 ±3.9‰   **9700 ± 110**
$$Est\ \delta^{13}C = −24.0\ ±2.0‰$$

Organic mud, boiled in 2 N HCl (1720 min count).

ANU-1523.   D^{14}C = −435.4 ±5.3‰   **4590 ± 80**
$$\delta^{13}C = +0.8‰$$

Shell hash (1020 min count).

General Comment (BT): Holocene depositional history of Moruya embayment may be summarized as follows: 1) Between ca 10,000 and 8500 ^{14}C yr* ago a low-relief barrier stood 30 to 40m below present sea level and seaward of present shoreline. Estuarine sediments accumulated be-

hind this transgressing barrier. Vertical and landward growth of barrier may have ceased between ca 8500 and 8000 ^{14}C yr*. 2) Rapid marine transgression from 8000 to 6000 ^{14}C yr* took sandy open-ocean shoreline to the head of the embayment, blocking off narrow drowned valleys in which estuarine shelly muds were rapidly accumulating. 3) From close to 6000 to ca 2500 ^{14}C yr* ago shoreline prograded by mechanism of multiple beach-ridge formation. Pattern of progradation was episodic. Four phases have been recognized. First resulted in deposition of more than half beach-ridge plain. This led to a marked change in environmental conditions in drowned valleys from estuarine to freshwater swamp. 4) Relative shoreline stability has characterized last 2500 ^{14}C yr* in embayment during which a complex hummocky foredune has formed.

Fens series

N of Port Stephens (32° 38′ S, 152° 12′ E), New South Wales. Embayment contains (Pleistocene) Inner and (Holocene) Outer Barriers. Both barriers composed of well-developed sets of beach ridges (Langford-Smith and Thom, 1969, pl III). An interbarrier depression 1 to 2km wide, occupied in part by diverted Lower Myall R, separates 2 barriers. Outer Barrier beach-ridge plain is 1km wide and contains 20 ridges. Dates are on Outer Barrier and interbarrier depression samples.

ANU-1665. $D^{14}C = -492.2 \pm 6.9‰$ **5440 ± 110**

Est δ^{13}C = +1.0 ±1.0‰

Shell hash (1040 min count).

ANU-1527. $D^{14}C = -583.5 \pm 11.2‰$ **7040 ± 220**

δ^{13}C = +1.1‰

Shell hash. Dilution, 27% sample (1520 min count).

ANU-1666. $D^{14}C = -499.4 \pm 6.2‰$ **5560 ± 100**

δ^{13}C = 0.0‰

Shell hash (1040 min count).

ANU-1335. $D^{14}C = -528.2 \pm 30.1‰$ **6030 ± 530**

Est δ^{13}C = +1.0 ±1.0‰

Shell hash. Dilution, 10% sample (1300 min count).

ANU-1336. $D^{14}C = -462.8 \pm 21.7‰$ **4990 ± 330**

δ^{13}C = +0.3‰

Shell hash. Dilution, 14% sample (1500 min count).

ANU-1528. $D^{14}C = -463.3 \pm 6.4‰$ **5000 ± 100**

Est δ^{13}C = +1.0 ±1.0‰

Shell hash (1000 min count).

ANU-1529. $D^{14}C = -595.4 \pm 9.8‰$ **7270 ± 200**

δ^{13}C = +1.0‰

Shell hash. Dilution, 34% sample (1460 min count).

ANU-1531.   D^{14}C = −411.1 ±13.2‰   **4250 ± 180**
$\delta^{13}C = +1.5‰$

Shell hash. Dilution, 25% sample (1440 min count).

ANU-1532.   D^{14}C = −403.7 ±5.4‰   **4150 ± 70**
$\delta^{13}C = +1.6‰$

Shell hash (1040 min count).

ANU-1530.   D^{14}C = −532.0 ±5.0‰   **6100 ± 90**
$\delta^{13}C = +1.5‰$

Shell hash (1000 min count).

General Comment (BT&GB): minimum ANU ^{14}C dates, and others (Thom *et al*, 1978) from nearshore facies show that most Outer Barrier progradation occurred during the period 5000 to 3300 ^{14}C yr BP*. Barrier appears to have ceased growing seaward since that period, or alternatively, has been eroded back to its present position removing later phases of progradation.

Age structure of 'backbarrier' or quiet-water interbarrier deposits suggests near vertical growth between 7000 and 5000 ^{14}C BP*. From mollusk composition a sandy partially enclosed bay is inferred which opened to S toward Port Stephens. Rich shelly facies rise close to present sea level in that direction. At site of section this unit dates 6800 to 6600 ^{14}C yr BP* at 13m below MSL (ANU-1527, -1529), but 4km to S, at −4m MSL a similar fauna dates 4990 ± 115 ^{14}C yr BP* (ANU-1665).

Following stages can be recognized in develop of Outer Barrier at Fens: 1) A low relief barrier that only partially enclosed a faunal-rich sandy bay was initiated within Fens embayment at least 7000 ^{14}C BP*, when sea level was ca 10 to 15m below its present position. 2) After sea level reached its present position, ca 6000 ^{14}C yr BP*, a narrow, low sand barrier probably formed a highly mobile open-ocean shoreline, subjected to periodic washover and eolian instability. Relevant date is ANU-1530 (5650 ± 95 ^{14}C yr BP*). 3) First phase of progradation occurred between 5000 and 4500 ^{14}C yr BP*. Critical dates for this event are ANU-1336 and GaK-1469, -1470 (see Thom *et al*, 1978) from within nearshore shelly facies and ANU-1528 on estuarine shells near contact with coarse beach sands. 4) Along seaward margin of Outer Barrier over last 3000 ^{14}C yr* or so a complex foredune has developed which is now undergoing extensive eolian erosion, esp at N end.

Wonboyn series

Embayment at Wonboyn on far S coast of NSW (37° 16′ S, 149° 57′ E) has extensive beach-ridge plain which is 1.6km wide and contains max of 60 beach ridges.

ANU-1396.   D^{14}C = −362.2 ±10.5‰   **3610 ± 130**
$\delta^{13}C = +1.0‰$

Shell hash. Dilution, 38% sample (1080 min count).

ANU-1584. D^{14}C = −315.9 ±7.9‰ **3050 ± 90**
$$\delta^{13}C = +1.4‰$$

Shell hash (980 min count).

ANU-1585. D^{14}C = −521.8 ±5.0‰ **5930 ± 90**
$$\delta^{13}C = +1.4‰$$

Shell hash (1000 min count).

General Comment (BT&GB): sample ANU-1585 (5480 ± 95 yr BP*) coll from beneath inner edge of beach-ridge plain 1.4km from shoreline is consistent with ages from other sites of regressive shelly sands loc at rear of Outer Barriers. Wonboyn plain shows younger ages towards present shoreline with ANU-1396 (3160 ± 135 yr BP*) at 600m inland and ANU-1584 (2600 ± 100 yr BP*) at 500m.

Stationary Bay Barriers

Merimbula

On S coast New South Wales (36° 54′ S, 149° 54′ E). Although barrier possesses a few beach ridges, its narrow width (< 300m), wide back-barrier flat, and arrangement of facies, are typical of stationary bay barriers (Thom *et al*, 1978). In comparison with extensive beach-ridge plains, Merimbula barrier is relatively high, averaging 8 to 10m above MSL. Barrier consists of a thin wedge of near-shore shelly sand overlain by leached, well-sorted quartzose sands. However, shelly sands are not as clearly graded coarse to fine downward as in case of prograded barriers. A ^{14}C date of 5530 ± 85 ^{14}C yr BP* (ANU-1404) has been obtained from seaward side of barrier at depth of 7m below MSL.

ANU-1404. D^{14}C = −525.0 ±4.5‰ **5980 ± 80**
$$\delta^{13}C = +1.4‰$$

Shell hash (1380 min count). *Comment* (BT): stratigraphic pattern at Merimbula and other localities where stationary bay barriers have been drilled suggests 2 main phases of deposition. First commenced as transgressing Holocene sea entered embayments. Between ca 8000 and 7000 ^{14}C yr* ago transgressive barrier beach facies started to accumulate vertically as well as recede slowly inland. Behind beach washover processes initiated deposition of a relatively thick backbarrier sand facies (up to 20m). Second phase of barrier development occurred after sea level reached its present position (ca 6000 ^{14}C yr BP*). During this phase backbarrier deposition became a less active process as foredune ridges grew in height. Progradation, if it took place at all, occurred ca 5500 ^{14}C yr* ago. Thus, present shoreline position of stationary bay barriers dates from ca 5000 ^{14}C yr BP*.

Episodic Dune Barries

Eurunderee

At Eurunderee, near Myall Lakes (32° 29′ S, 152° 22′ E), Holocene Outer Barrier is composed of active sand blowouts and stabilized parabolic dunes. Elongate blowouts up to 1km in length penetrate N along troughs and up terminal walls of stabilized parabolic dunes (Thom, 1965,

pl 1), most landward side of Outer Barrier overlies peats of interbarrier depression which date 3620 ± 130 ^{14}C yr BP (ANU-1673).

ANU-1673.   D^{14}C = −362.8 ±6.3‰   **3620 ± 130**

$Est\ \delta^{13}C = −24.0\ ±2.0‰$

Organic soil, treated with hot HCl (980 min count). *Comment* (BT): episodic dune bay barriers contain either a predominantly eolian sequence both above and below sea level, or a transgressive-regressive marine sand sequence below sea level covered by mid- to late-Holocene dunes (eg, Bherwerre; Thom *et al*, 1978). In both cases, buried peats and soils, plus morphologic "nesting", attest to episodes of transgressive dunes (parabolic or long-walled types) followed by phases of vegetation stabilization of free-moving sand surfaces.

Composite Bay Barriers

Newcastle Bight series

Newcastle Bight, N coast of New South Wales (32° 48′ S, 151° 55′ E) is best studied example of a composite barrier. Morphologically barrier consists of a small area of beach-ridge plain exposed at E end and 3 long-walled transgressive ridges (2 stabilized plus seaward ridge, still mobile) which have overrun rest of barrier. 5 cross-sections have established gen stratigraphy (Ly, 1976) and show characteristic arrangement of sedimentary facies beneath barrier. Thom *et al* (1978, figs 8, 9) give morphologic map of area.

Inner Barrier surface lies buried by shelly transgressive sand sheet from which 4 dates have been obtained: 9520 + 1590 − 1330 ^{14}C yr BP* (ANU-1330), 8500 ± 145 ^{14}C yr BP* (ANU-1676), 8260 ± 295 ^{14}C BP* (ANU-1526) and 8100 ± 165 ^{14}C yr BP* (ANU-1677). Above this sheet is a wedge-shaped unit composed of near-shore shelly sand. Early mid-Holocene phase of progradation suggested by 6070 ± 125 ^{14}C yr BP* (ANU-1525). ANU-1675 (6770 ± 225 ^{14}C yr BP*) is also from this unit, but shell sample was probably reworked from older deposit. From within mobile dunes, an *in situ* tree stump was exhumed on deflated windward side and yielded age of 300 ± 70 ^{14}C yr BP (ANU-1331). There is no evidence of beach ridges amongst long-walled ridges, but landward stabilized long-walled ridge (Ridge I) has clearly overrun beach ridges to N and E. Ridge I also directly overlies either estuarine muds, containing a rich molluskan fauna (ANU-1332, 4310 ± 105 ^{14}C yr BP*), or backbarrier flat sands, on its landward side. Second vegetated long-walled ridge (Ridge II) more or less parallels shoreline and rests upon beach and nearshore sand facies. Seaward, active ridge front of mobile dune sheet (Ridge III) is burying old beach ridges at E end of barrier, transgressing swampy deflation surface of Ridge II. Figs 8 and 9, Thom *et al* (1978) show these features.

+1580

ANU-1330.   D^{14}C = −710.9 ±51.5‰   **9970**

−1320

$Est\ \delta^{13}C = +1.0\ ±1.0‰$

Shell hash. Dilution, 6% sample (900 min count).

ANU-1526. $D^{14}C = -661.9 \pm 11.9\%_o$ **8710 ± 290**

$\delta^{13}C = +1.8\%_o$

Shell hash. Dilution, 28% sample (1220 min count).

ANU-1525. $D^{14}C = -556.0 \pm 6.8\%_o$ **6520 ± 120**

$\delta^{13}C = +1.4\%_o$

Shell hash (1020 min count).

ANU-1332. $D^{14}C = -447.2 \pm 6.7\%_o$ **4760 ± 100**

$\delta^{13}C = +1.9\%_o$

Shell hash (1280 min count).

ANU-1675. $D^{14}C = -592.8 \pm 10.8\%_o$ **7220 ± 220**

$\delta^{13}C = +1.5\%_o$

Shell hash. Dilution, 34% sample (1020 min count).

ANU-1676. $D^{14}C = -671.8 \pm 5.6\%_o$ **8950 ± 140**

$\delta^{13}C = +1.1\%_o$

Shell hash (1040 min count).

ANU-1677. $D^{14}C = -655.1 \pm 6.7\%_o$ **8550 ± 160**

$\delta^{13}C = +1.1\%_o$

Shell hash (1040 min count).

ANU-1678. $D^{14}C = -702.1 \pm 4.3\%_o$ **9730 ± 120**

$\delta^{13}C = +0.5\%_o$

Shell hash (1020 min count).

ANU-1679. $D^{14}C = -970.1 \pm 6.8\%_o$ **28,180 ± 2100**

$\delta^{13}C = 0.0\%_o$

Shell hash. Dilution, 40% sample (1440 min count).

ANU-1331. $D^{14}C = -36.0 \pm 7.8\%_o$ **300 ± 70**

Est $\delta^{13}C = -24.0 \pm 2.0\%_o$

Wood (1020 min count).

General Comment (BT&GB): 1) Basal transgressive shelly sand facies at −40m overlies oxidised pre-Inner Barrier clay. Shells date 27,730 ± 2100 ¹⁴C yr BP* (ANU-1679), which, if assumed to reflect true age of deposition, supports est of −41 ± 1m for the 28,000 yr BP* low sea level determined from Reef complex II on the Huon Peninsula (Bloom *et al*, 1974). 2) Non-calcareous sand 4m thick, here interpreted as a nearshore-beach sand leached during Last Glacial sea level min. 3) Slightly muddy sand, rich in estuarine or open bay mollusks, at −25 to −30m, could reflect backbarrier sedimentation 9000 to 10,000 ¹⁴C yr* ago (ANU-1678). 4) Shelly sand facies, quite coarse and containing granules, assoc with last phase of marine transgression. Shells which date 8100 ± 165 ¹⁴C yr BP* (ANU-1677) and 8500 ± 145 ¹⁴C yr BP* (ANU-1676) could have been reworked upward from more seaward barrier as argued for Moruya. 5) Thick backbarrier sand wedge interfingering with 4). 6) Nearshore shelly sand facies which overlies 4) and coarsens upward into tabular beach sand unit. Nearshore shelly sand is associated with sedimentary regression which formed "core"

of Outer Barrier at present sea level. 7) Barrier is surmounted by 3 massive, cross-bedded sand bodies up to 30m thick. Two vegetated dune ridges, I and II, possess different degrees of soil development indicating discrete phases of deposition, followed by currently active phase III which is at least 300 ^{14}C yr old (ANU-1331).

SUMMARY

Episodic history of Holocene barriers in NSW is suggestive of synchronous processes initiating phases of marine regression or beach-ridge progradation, vertical foredune accretion, foredune erosion and destruction, transgressive dune mobilization, and vegetative colonization. Termination of postglacial marine transgression ca 6000 ^{14}C yr BP* on this coast and subsequent attainment of beach-nearshore equilibrium may explain rapid transfer of sand from offshore to onshore. In comparison with other coastal barriers, which have been documented by ^{14}C dating (eg, Bernard *et al*, 1962, Galveston I.), bay barriers of SE Australia exhibit more diverse age structures in that they commenced and generally ceased progradation earlier than N Hemisphere counterparts, although rates of progradation were similar at times of max accretion (3 to 6m/yr; Thom *et al*, 1978). Subsequent episodes may be best explained by secular variations in storminess and wave climate in Tasman Sea. Extent to which these variations correlate with mid to late Holocene global changes in climate (and/or slight undocumented changes in sea level) remains unknown.

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