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# Shell mound formation in coastal northern Australia

Tim Stone

*Department of Geography, Australian National University, Box 4, Canberra, A.C.T. 2601, Australia*

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**Abstract**

Shell mounds are late Holocene deposits typically dominated by a single shell species. In northern Australia these mounds are associated with prograding coastal plains. The largest and most numerous are at Weipa on Cape York Peninsula. Archaeologists claim that these mounds were formed by generations of shellfishing Aborigines. This hypothesis is false because most of the shells from the type-site are of a similar radiocarbon age. Mapping and augering of two contrasting shell mound environments along the Mission River at Weipa demonstrates that mound formation is a natural consequence of local chenier plain development. This is supported by shell ages from across the Weipa landscape. The shell mounds at Prumanung originated as a coarse shell berm. The large mounds on the Uningan plain originated as small shell cheniers. The only reasonable explanation for the transformation of these natural shell deposits into tall, steep-sided mounds is the mound-building behaviour of the Orange-footed Scrubfowl *Megapodius reinwardt*. Similar mounds composed predominantly of sand and gravel are also present at these localities. The strong likelihood that the shell mounds are natural shell deposits raises serious questions about basic principles of shell midden archaeology. New methods for distinguishing between cultural and natural shell deposits are needed.

## 1. Introduction

Tall, steep-sided mounds composed of a variety of sediment types are a conspicuous feature of the northern Australian coastal landscape. Some of these mounds are dominated by shells of a single bivalve species while others comprise earth, sand or a mixture of sediments. The largest shell mounds in the region are at Weipa on the west coast of Cape York Peninsula. These mounds are thought by archaeologists to be among the world's largest prehistoric middens (Wright, 1971; Mulvaney, 1975; Bailey, 1977, 1983). Elsewhere in northern Australia shell mounds of significance to archaeologists are present at Princess Charlotte Bay (Beaton, 1985), Aurukun (Cribb, 1986; Cribb et al., 1988), Milingimbi Island (McCarthy and Setzler, 1960; Mulvaney, 1981), and near the mouths of the Glyde and Blyth Rivers (Peterson, 1973; Meehan, 1982). Fig. 1 shows the distribution of these sites across northern Australia.

Many earth mounds in northern Australia are also thought by archaeologists to be human in origin (Peterson, 1973; Meehan et al., 1985; Meehan, 1988). However, very similar features have been described by ornithologists and palaeoecologists as the nest mounds of the Orange-footed Scrubfowl *Megapodius reinwardt* (e.g. Stocker, 1971; Crome and Brown, 1979; Bowman et al., 1994). Birds of this species construct large mounds in which to incubate their eggs by raking surface sediments up into heaps with their powerful feet.


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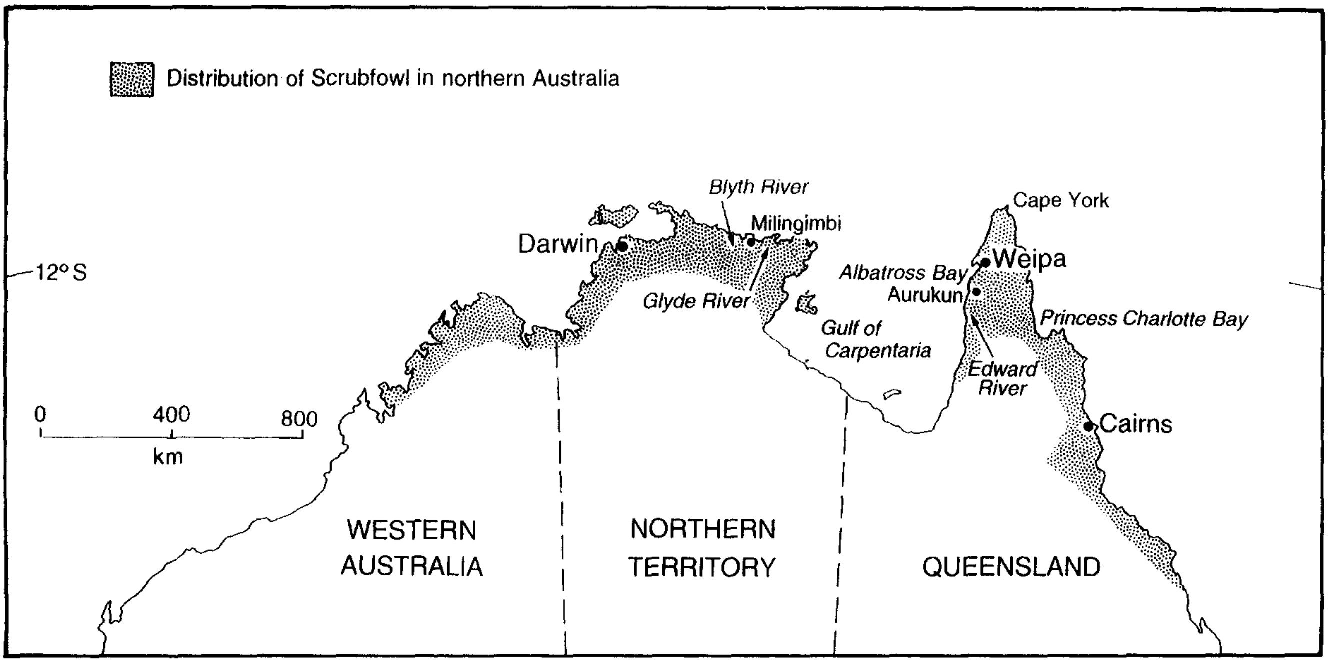


Fig. 1. Major shell mound localities in northern Australia. Scrubfowl distribution after Blakers et al. (1984, p. 112).

The distribution of these mound-building birds closely coincides with the distribution of shell mounds (Fig. 1).

Stone (1989, 1991a) drew attention to the many similarities between the large shell and earth mounds recorded by archaeologists and Scrubfowl mounds arguing that archaeologists had mistaken Scrubfowl mounds for humanly formed middens or constructions. This claim attracted strong protest from archaeologists (Bailey, 1991; Cribb, 1991) and Stone (1991b) replied. From this debate it emerged that little is actually known about the environments of "archaeological" mound sites or how these landscapes might have formed. This paper presents the results of research designed to test the hypothesis of human origin and establish a geomorphological context in which to interpret the origins of the Weipa shell mounds (Stone, 1992).

## 2. Environmental setting

Weipa is a bauxite mining township located near Albatross Bay in the Gulf of Carpentaria (Fig. 2). It has a tropical savannah climate characterised by a short wet season between December and March and a long dry season between April and November. Mean minimum and maximum daily temperatures range between 18 and 35 degrees Celsius throughout the year. During the dry season easterly and southeasterly trade winds prevail and humidity is relatively low. During the wet season Weipa receives most of its average annual rainfall of around 1700 mm. Northwesterly winds are dominant at this time and tropical cyclones may develop.

Albatross Bay is a fully marine coastal embayment with a depth of water generally less than 10 m and a maximum tidal range of 2.6 m (Blaber et al., 1990). The Pine, Mission, Embley and Hey Rivers empty into the bay forming estuaries which extend for more than 30 km inland. These estuaries are bordered by extensive mangrove forests and mudflats and at slightly higher elevations salt pans and floodplains have developed. During the wet season when river discharge is high these estuaries experience dramatic changes in salinity and turbidity (Blaber et al., 1989).

Geologically the area comprises a lateritised plateau underlain by Cretaceous sedimentary rock (Smart, 1977). The plateau is subdued and supports mostly *Eucalyptus tetradonta* open-forest (Specht et al., 1977). Patches of monsoon vine forest (MVF) grow around the low-lying edges of

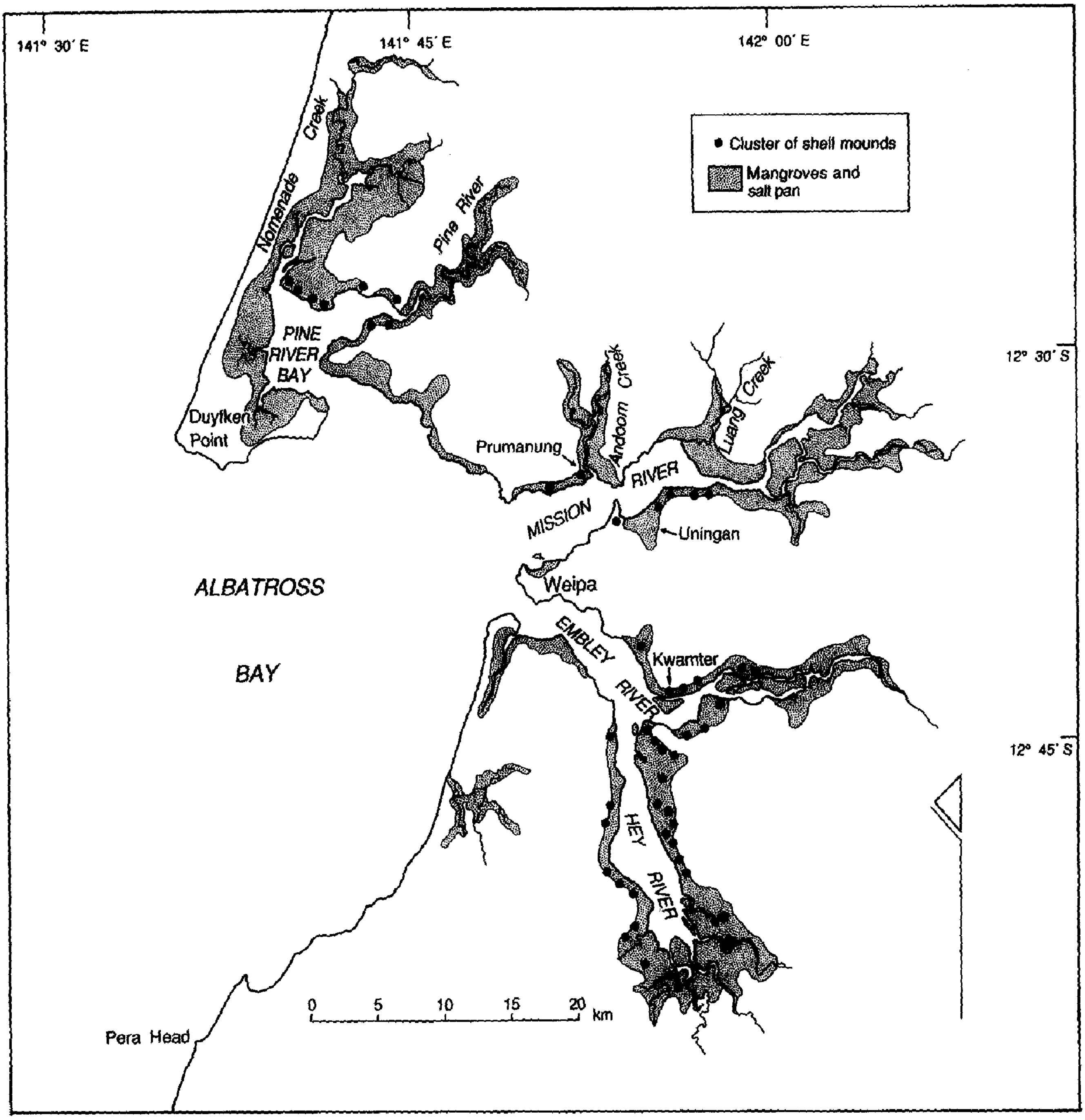


Fig. 2. Map of the Weipa area showing the general distribution of shell mounds and the field sites investigated. Shell mound distribution after Bailey (1983, fig. 1).

the plateau and on adjacent beach ridges and dunes. Specht et al. (1977) believed that MVF was more continuous in the past when there had been more rainfall and attributed the contraction of MVF boundaries to climatic change rather than to fire or cyclone damage.

## 3. The Weipa shell mounds

Bailey (1975, 1977, 1983) has estimated that there are about 500 shell mounds around Weipa with most located along the banks of the four tidal rivers which flow into Albatross Bay (Fig. 2).

These deposits range in size from shell scatters 3 m in diameter to steep-sided mounds up to 13 m high. Some appear as truncated cones and others as long, linear ridges. Many are irregular in shape or have a composite structure. Excavation of some of the shell mounds along the Embley and Hey Rivers has revealed that they are composed almost entirely of shells of the bivalve *Anadara granosa* (Stanner, 1961; Wright, 1963, 1971; Bailey, 1975, 1977).

The more prominent shell mounds are located in floodplain environments and on low-lying sandy ridges at the edge of the lateritised plateau. The largest are in the southeastern part of the Hey River. Four of these reach heights of over 10 m. However, the vast majority (94%) of the Weipa shell mounds are less than 5 m high (Bailey, 1975). Less than one third of these are on laterite surfaces. These mounds are much smaller than those on the floodplain with most only a metre or less in height. In some instances these low shell mounds or scatters may be located up to 250 m inland of the floodplain/laterite boundary.

The distribution of the shell mounds conforms closely to the pattern of the coastline with many having their long axes running roughly parallel to the shoreline (Valentin, 1959; Stanner, 1961). They also tend to be distributed in clusters with each comprising a range of mounds of variable size (Bailey, 1975). One such cluster on the east bank of the Hey River consists of three linear mounds 2–7 m high aligned along the floodplain/laterite boundary. On the floodplain nearby are three conical mounds 2.5–4 m high and behind these a mostly shore-parallel string of twelve low mounds on the gently sloping laterite (see Bailey, 1977, fig. 4).

### 3.1. The Kwamter mound

The type-site is the Kwamter mound located on the north bank of the Embley River (Fig. 2). This is a shore-parallel mound 110 m × 45 m with a maximum thickness of 3 m and an estimated volume of 2250 cubic metres (Bailey, 1977). Its base rests on sand underlain by marine mud (Wright, 1963). The stratigraphy of the mound is exposed in a bulldozer trench cut perpendicular to the shoreline. This shows that the mound is composed of randomly-oriented *Anadara granosa* valves interspersed with thin bands of charcoal and ash. Its surface supports monsoon vine forest and mangroves grow nearby.

Excavation of the Kwamter mound by Wright (1963, 1971) uncovered stone and bone artefacts, broken wallaby bones, stingray barbs and crocodile teeth. The bone artefacts (points) were recovered in situ from the lowest levels of the bulldozed section. These artefacts were described by Wright (1963) as liberally present throughout the excavated deposits. Stone artefacts, however, were exceedingly rare. Wright (1971) also obtained two radiocarbon dates on charcoal from the top and bottom of the 3 m deep trench. These returned ages of 235 ± 110 (I-1737) yrs B.P. and 810 ± 105 (I-1738) yrs B.P., respectively.

A more detailed investigation of the Kwamter mound by Bailey (1975, 1977) showed that *Anadara granosa* comprises 95% by weight of all shell in the mound. A typical sample contains 54% by weight of intact single valves, 24% of small fragments and 22% of single valves with damaged edges (Bailey, 1977). Shells of 14 other species were also identified in the deposit along with small fragments of mammalian bone, fish vertebrae, crab claws and 25 stone and bone artefacts. Charcoal from the upper and middle levels of the section Bailey excavated returned ages of 710 ± 100 yrs B.P. (SUA-147) and 855 ± 80 yrs B.P. (SUA-148). Charcoal from the base returned an age of 1180 ± 80 yrs B.P. (SUA-149).

## 4. Previous hypotheses of origin

### 4.1. The hypothesis of human origin

The hypothesis of human origin states that the Weipa shell mounds were deposited by generations of shellfishing Aborigines. This was first proposed by Roth (1901) who saw the remains of fires and huts on the tops of some of the mounds. Wright (1963, 1971) and Bailey (1975, 1977) developed this idea further because the deposits clearly met archaeological criteria for the identification of shell middens. The predominance of large shells of a single species was considered evidence of human selectivity and other faunal evidence also interpreted as the remains of Aboriginal meals. The discovery of artefacts and bands of charcoal and ash in some mounds was considered particularly diagnostic of human origin as was the location of the mounds on apparently older and unrelated substrates.

Bailey thought that the Weipa shell mounds were human in origin because of the way they differed from deposits he recognised as natural shell accumulations. He compared the Kwamter mound with a shell bank in the middle of the Embley River and a shelly beach ridge at Edward River some 250 km away. Differences between the range of shellfish species represented in the mound and the shell bank were held to indicate that the shells in the mound had been humanly selected. Furthermore, those in the shell bank were graded, water-worn and bored by marine organisms whereas their counterparts in the mound were apparently not. The shelly beach ridge at Edward River was also very different. Its section revealed horizontal layering, a wide range in shell size and no organic matter. These contrasts convinced Bailey that the shell mounds were not natural shell deposits.

In the belief that shellfishing led to mound growth Peterson (1973) described a scatter of shell on a beach in Arnhem Land as an incipient shell mound. As Aborigines were camped on this scatter he concluded that this represented the essential process of mound formation. That is, families would camp on the shell scatter in various locations and gradually enough shells would accumulate to form a tall, steep-sided mound. Bailey (1977) proposed that the basic unit of shell mound formation was a small Aboriginal family living in a hut. Shells accumulated in a process of upward growth as generations of Aborigines returned to camp on their domestic residue. He wrote that the Kwamter dates indicate that shells began to be collected about 1200 years ago and accumulated more or less continuously until quite recently.

### 4.2. *Stanner's dissent*

Valentin's (1959) claim that the Weipa shell mounds were "kitchen-middens" based on a brief flight over them was challenged by Stanner (1961) who reasoned that the mounds were natural in origin. In Stanner's view the close conformity of the large shell mounds to the pattern of the coastline and their roughly shore-parallel alignment suggested that they were more likely to have been formed by wave-action. He considered the mechanical piling of shells by this process to be a familiar fact of observation and proposed environmental changes associated with fluctuating sea levels, climatic change and tectonics to explain them.

Although Stanner had difficulty in identifying specific mechanisms which led to shell mound growth he was adamant that the large mounds could not have been constructed by Aborigines. He claimed that the shells showed no traces of human interference or calcination by fire and that a significant proportion of them were unopened and filled with silt. Another feature which he thought inconsistent with the theory of human origin is that the shells are not densely compacted but loose like scree. He saw no evidence of a long process of bedding or settling down that would be expected if the mounds were lived on by people. He did concede, however, that some of the much smaller mounds on the laterite might be middens.

### 4.3. *The Scrubfowl hypothesis*

Stone (1989, 1991a) proposed that the large shell and earth mounds recorded by archaeologists in northern Australia were not built by Aborigines but by generations of nesting birds. These were of a species of mound-building megapode known as *Megapodius reinwardt* or the Orange-footed Scrubfowl. Its distribution in northern Australia conforms closely to the distribution of mounds recorded by archaeologists (Fig. 1). Struck by the similarity between Scrubfowl mounds and archaeological mounds Stone believed he had identified the agent of mound formation. Excluded from the Scrubfowl hypothesis were low shell mounds and scatters which Stone thought had a better chance of being undisturbed shell middens.

Scrubfowl mounds and archaeological mounds are similar in size, shape, appearance and distribution which led Stone to suspect a common origin. Typically Scrubfowl mounds are 3–5 m high but

Stone claimed that they can vary from 0.5 m to over 10 m which is close to the range recorded for the Weipa mounds. Both groups of mound also vary widely in shape from tall, conical mounds to long, steep-sided ridges and both are commonly located in clusters along the edges of tidal rivers, beaches, mangrove swamps and freshwater wetlands. The habitat of Scrubfowl is monsoon vine forest and similar closed communities (Stocker, 1971). It has also been observed in mangroves (e.g. Deignan, 1964). These habitat types are a feature of northern Australian mound landscapes.

To account for the presence of cultural material in some mounds Stone proposed a connection between the nesting activities of Scrubfowl and the discard behaviour of Aborigines. That is, artefacts and shell are present in some mounds as the result of either Scrubfowl raking up Aboriginal debris from nearby middens or campsites or Aborigines leaving their artefacts directly on the surface of abandoned Scrubfowl mounds. He contended that the large shell and earth mounds are essentially source-bordering features and that their composition vertically reflects the lateral variation in surface material around the mound site. This material includes shell middens which could be easily reworked by the birds.

## 5. Shell ages

An overview of the age structure of the Weipa shell mounds is possible because of work conducted in 1984 by the archaeologist John Beaton. He submitted a quantity of *Anadara* shells to the ANU Radiocarbon Dating Laboratory for analysis but did not take the work further. The laboratory has since made the results available including $^{13}C$ values for each shell (Table 1). The uncorrected results indicate that the mounds are late Holocene in age comprising shells less than 200 years old to shells more than 2000 years old.

Fig. 3 shows that the shells furthest from the sea tend to be older than the shells nearer to the sea. Six of the seven dates on the landward side of the sandy ridge east of Luang Creek are significantly older than two dates from the seaward side of this ridge. On the south side of the Mission River there are ten dates which also tend to decrease in age in the seaward direction. This pattern is again repeated in the southeastern part of the Hey River. The overall trend of the shell ages around Weipa to become progressively younger in the seaward direction is consistent with a prograding shoreline sequence.

Table 1
Radiocarbon dates obtained on shells collected by J. Beaton from the Weipa shell mounds

| ANU no. | $^{13}C$ | Conventional age (yrs B.P.) |
|---|---|---|
| 4408 | −1.6 | 790±60 |
| 4409 | −2.0 | 760±75 |
| 4410 | −1.5 | 360±100 |
| 4411 | −2.4 | 580±70 |
| 4412 | −2.3 | 710±75 |
| 4413 | −2.9 | 1420±80 |
| 4414 | −2.5 | 1250±80 |
| 4415 | −3.8 | 1210±60 |
| 4416 | −3.4 | 180±50 |
| 4417 | −3.6 | 520±80 |
| 4418 | −2.0 | 770±70 |
| 4419 | −2.8 | 1460±60 |
| 4420 | −3.0 | 710±60 |
| 4421 | −1.1 | 970±60 |
| 4423 | −2.4 | 870±70 |
| 4424 | −4.3 | 630±60 |
| 4425 | −3.5 | 2070±60 |
| 4426 | −2.7 | 720±60 |
| 4427 | −2.3 | 2100±80 |
| 4428 | −4.3 | 1810±80 |
| 4429 | −3.4 | 2010±80 |
| 4430 | −2.3 | 1800±80 |
| 4431 | −2.3 | 1580±70 |
| 4432 | −3.3 | 890±80 |
| 4433 | −3.8 | 1390±80 |
| 4434 | −3.4 | 1790±90 |
| 4435 | −3.5 | 1520±80 |
| 4436 | −2.7 | 1330±80 |
| 4437 | −3.9 | 270±70 |
| 4438 | −3.7 | 960±60 |
| 4439 | −3.8 | 500±70 |
| 4440 | −5.2 | 220±50 |
| 4441 | −3.6 | 800±70 |
| 4790 | −2.8 | 119.8±0.6% |

## 6. Testing the hypothesis of human origin

The fundamental tenet of the hypothesis of human origin is gradual accumulation. Bailey

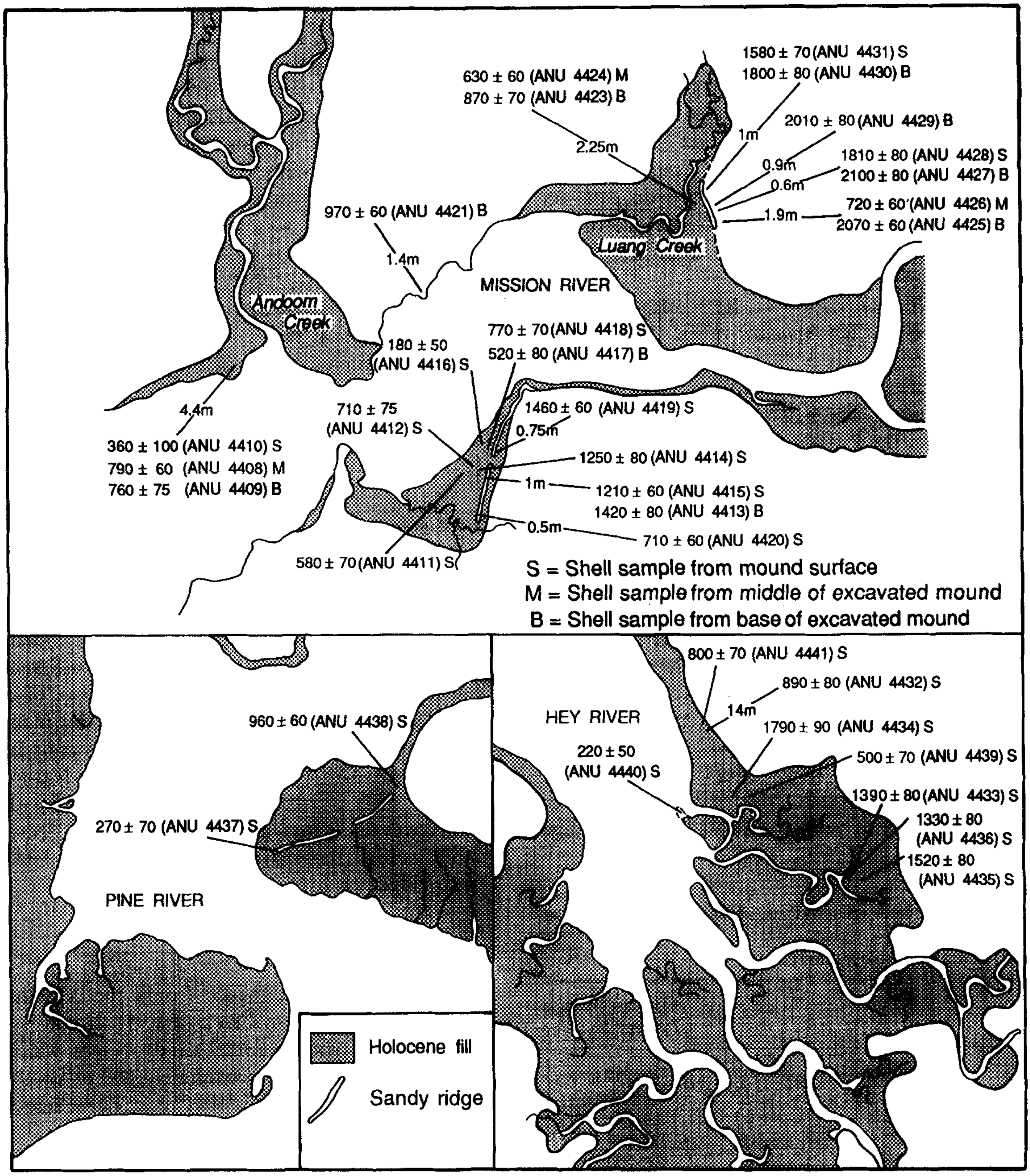


Fig. 3. Locations of shell mounds investigated by J. Beaton in the Weipa area and Conventional Radiocarbon Ages obtained on shells collected from them. Figures in metres (m) represent mound heights recorded by Beaton.

(1977) claimed that the shells in the Kwamter mound accumulated gradually from 1200 years ago until recently. This hypothesis can be tested by dating a sequence of shells from the mound. If the shells really had been deposited by generations of shellfishing Aborigines the ages of the shells should get progressively younger from the bottom of the mound to the top. If they do not, the hypothesis of human origin must be questioned. In this event a natural explanation should be sought for the mounds.

The bulldozed section of the Kwamter mound was located and ten *Anadara* valves taken from a face close to the site of Bailey's excavation. These were collected at 30–40 cm intervals to a depth of 3 m and dated. The results indicate that most of the shells in the Kwamter mound are of a similar radiocarbon age (Table 2). They do not show gradual accumulation of the shells and lend no support to the hypothesis of human origin. Three of the oldest shell dates are actually near the top of the sequence. Fig. 4 contrasts these results with Bailey's hypothesis and the ages obtained previously on charcoal from the mound.

Absolute dating of shells in the Kwamter mound is complicated by the fact that they are estuarine in origin. This is indicated by the $^{13}C$ values accompanying each radiocarbon age. If the shells were fully marine it would simply be a matter of applying the Australian Marine Shell Correction Factor of $450 \pm 35$ years to calculate the actual age of each sample. In this case it is uncertain whether a correction factor should be applied or not because the amount of marine water present in the estuary when the shellfish were alive is unknown.

As a consequence of this uncertainty the shell dates are reported as Conventional Radiocarbon Ages only. Absolute dating, however, is not required as actual events in history are not the issue. Only relative ages are needed to understand shell mound formation and clearly these show that the hypothesis of human origin is false. Comparison of shell and charcoal ages suggests that a correction factor is not necessary. ANU 8022 pairs comfortably with SUA 147, ANU 8025 with SUA 148 and ANU 8030 with I-1738. It is likely that the conventional ages are a good reflection of the actual ages of the shells.

Table 2
Radiocarbon dates obtained on shells from the Kwamter mound including $^{13}C$ values for each sample. Depths are from the surface of the mound to the base

| ANU no. | Depth | $^{13}C$ | Conventional age (yrs B.P.) |
|---|---|---|---|
| 8021 | surface | $-2.0 \pm 0.1$ | $630 \pm 40$ |
| 8022 | 40 cm | $-2.3 \pm 0.1$ | $670 \pm 70$ |
| 8023 | 70 cm | $-1.8 \pm 0.1$ | $1030 \pm 40$ |
| 8024 | 100 cm | $-1.6 \pm 0.1$ | $980 \pm 40$ |
| 8025 | 140 cm | $-1.6 \pm 0.1$ | $990 \pm 70$ |
| 8026 | 170 cm | $-1.8 \pm 0.1$ | $930 \pm 80$ |
| 8027 | 200 cm | $-0.8 \pm 0.1$ | $830 \pm 80$ |
| 8028 | 230 cm | $-1.4 \pm 0.1$ | $900 \pm 80$ |
| 8029 | 270 cm | $-1.7 \pm 0.1$ | $910 \pm 90$ |
| 8030 | 300 cm | $-1.1 \pm 0.1$ | $890 \pm 70$ |

## 7. Geomorphology

Two contrasting shell mound environments were mapped and augered. These are located on opposite sides of the Mission River where it widens into a funnel-shaped estuary (Fig. 2). The first is known locally as Prumanung and consists of a sequence of linear ridges partly fringed by mangroves. Mounds are located at opposite ends of these ridges. The second is in the Uningan Nature Reserve. This is a broad coastal plain thick with mangroves on its seaward side. Mounds are distributed across the plain and along an isolated linear ridge.

### 7.1. Prumanung

The Prumanung sequence fronts the Mission River west of Andoom Creek (Fig. 5). It consists of a series of shore-parallel sandy ridges which converge on a point approximately 800 m southwest of the mouth of Andoom Creek. These ridges form a thick composite body with only one ridge clearly diverging from the rest. Three elongate shell mounds are located at the point where the ridges converge. These are strung out along the crest of the most seaward ridge for a distance of nearly 200 m. Exposed sections show that the mounds are composed almost entirely of coarse

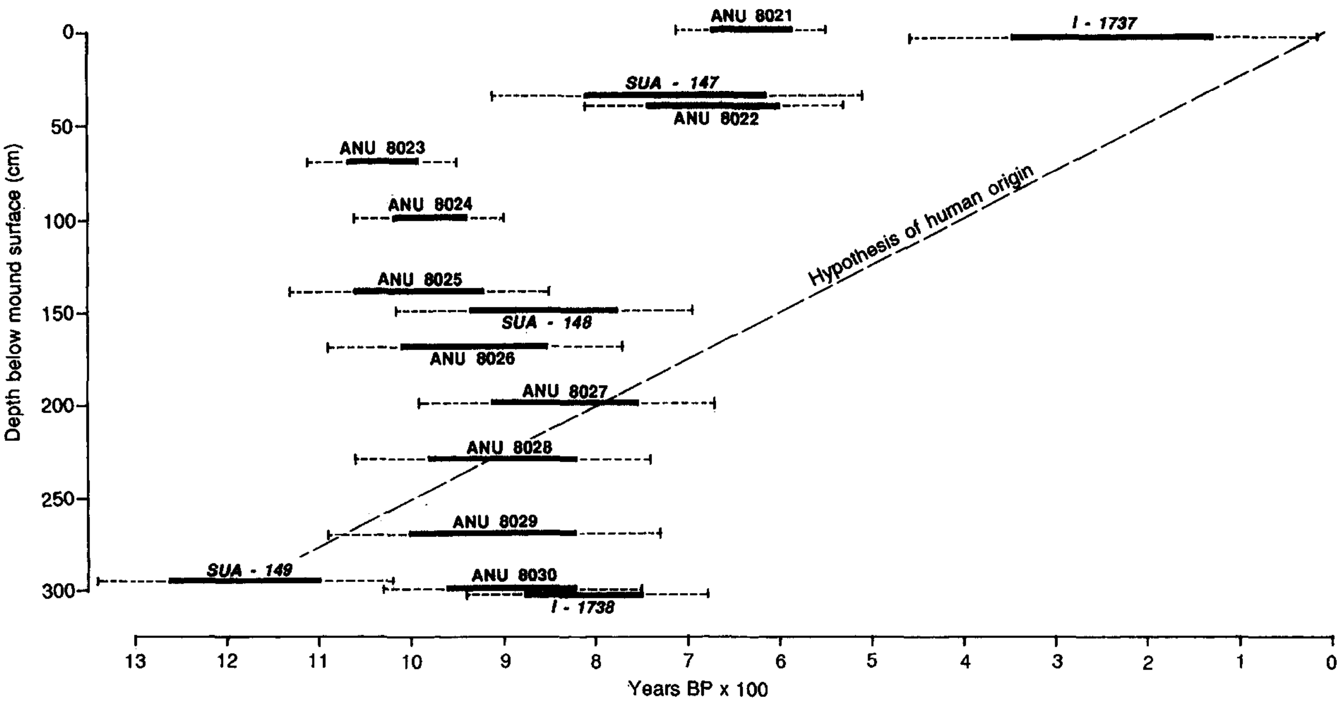


Fig. 4. Shell (ANU dates) and charcoal (SUA and I dates) ages obtained from the Kwamter mound contrasted with Bailey's (1977) hypothesis of human origin.

*Anadara granosa* shell. These shells are also scattered widely over the surface of the adjacent deposits. A feature of the Prumanung shell mounds is their almost complete cover of monsoon vine forest species.

Three transects were surveyed across the Prumanung ridges and their stratigraphy determined by augering. The main Prumanung shell mound is located immediately behind the modern shell-capped beach (Fig. 6a). Its seaward side presents a very steep slope rising 3 m above the crest of the modern beach. Its landward slope is shorter rising only 1.5 m above the adjacent deposits. The sediments beneath the shell mound consist of sand mixed with variable quantities of pisoliths. These are underlain by shelly sand mixed with pisoliths and shell fragments. This part of the depositional complex has been built on a sandy tidal flat.

The Prumanung sequence widens significantly in the direction of Andoom Creek (Fig. 6b). Coarse *Anadara* shell is mixed with the sediments of the seaward ridges but this diminishes away from the sea until sand and pisoliths become the dominant ridge sediments. Closer to Andoom Creek the deposits diverge into four distinct ridges (Fig. 6c). The sandy tidal flat which underlies the deposits elsewhere at Prumanung is replaced by silt and clay. The most seaward ridge is in the mangrove zone. Coarse *Anadara* shell continues to be present in the seaward ridges but scarce in the landward ridges.

Conventional radiocarbon ages were obtained on eight shell samples augered from the four divergent ridges (Table 3). These range from 800 ± 40 yrs B.P. (ANU 8032) at the seaward end

Table 3
Radiocarbon dates obtained on shells from the Prumanung ridge sequence including $^{13}C$ values for each sample

| ANU no. | $^{13}C$ | Conventional age (yrs B.P.) |
|---|---|---|
| 8031 | −2.0 ± 0.1 | 1090 ± 50 |
| 8032 | −1.7 ± 0.1 | 800 ± 40 |
| 8033 | −2.1 ± 0.1 | 790 ± 220 |
| 8034 | −1.7 ± 0.1 | 1490 ± 80 |
| 8035 | −2.0 ± 0.1 | 3820 ± 60 |
| 8036 | −0.4 ± 0.1 | 2790 ± 80 |
| 8037 | −1.4 ± 0.1 | 2850 ± 70 |
| 8038 | −0.7 ± 0.1 | 4530 ± 80 |

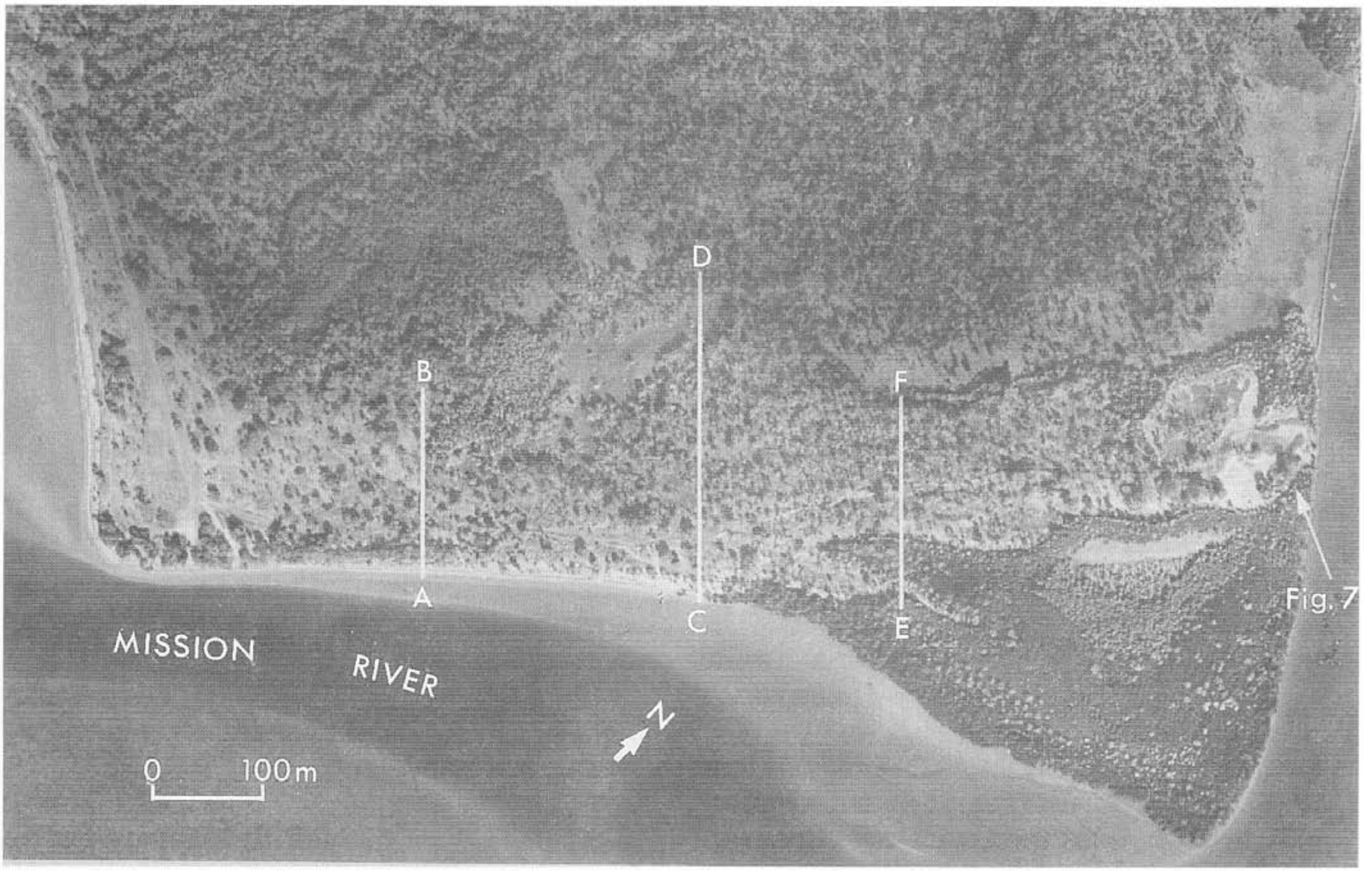


Fig. 5. Aerial view of Prumanung. Cross sections are shown in Fig. 6.

of the sequence to 4530 ± 80 yrs B.P. (ANU 8038) at the landward end (Fig. 6c). The date of 790 ± 220 yrs B.P. (ANU 8033) has a large error band because the sample size was small. These dates compare to the three obtained on *Anadara* samples excavated by Beaton from one of the overlying shell mounds (Fig. 3). Two of these (ANU 4408 and 4409) are similar to dates (ANU 8032 and ANU 8033) obtained from the two seaward ridges.

Mounds composed of shelly sand and pisoliths are also present at Prumanung (Fig. 7). These are located on the second most seaward ridge near the mouth of Andoom Creek. A patch of monsoon vine forest grows on these mounds and mangroves abut the ridge. Part of the smallest mound has been cut away by the creek. The largest is conical to elongate in form with a very steep seaward slope. It rises nearly 2 m above the level of the ridge. The smaller mound nearby rises 80 cm above this level. These mounds are similar to the shell mounds at the opposite end of the sequence. However, these mounds contain only minor amounts of coarse *Anadara* shell.

### 7.2. *Uningan*

The Uningan coastal plain is a broad expanse of silt and clay which fans out into the Mission River from Oxmurra Point (Fig. 8). Along its inner edge there is a discontinuous sandy ridge running parallel to the lateritised plateau. Mounds and monsoon vine forest are found along the length of this ridge. Towards the Mission River the silt and clay plain forms a belt of grassland and salt pan up to 500 m wide. Five conspicuous shell mounds are found in this belt and all support a light cover of monsoon vine forest. At its southern end the plain is cut by the meandering tidal channel of Uningan Creek. Mangroves grow along this channel and along the muddy shore of the Mission River.

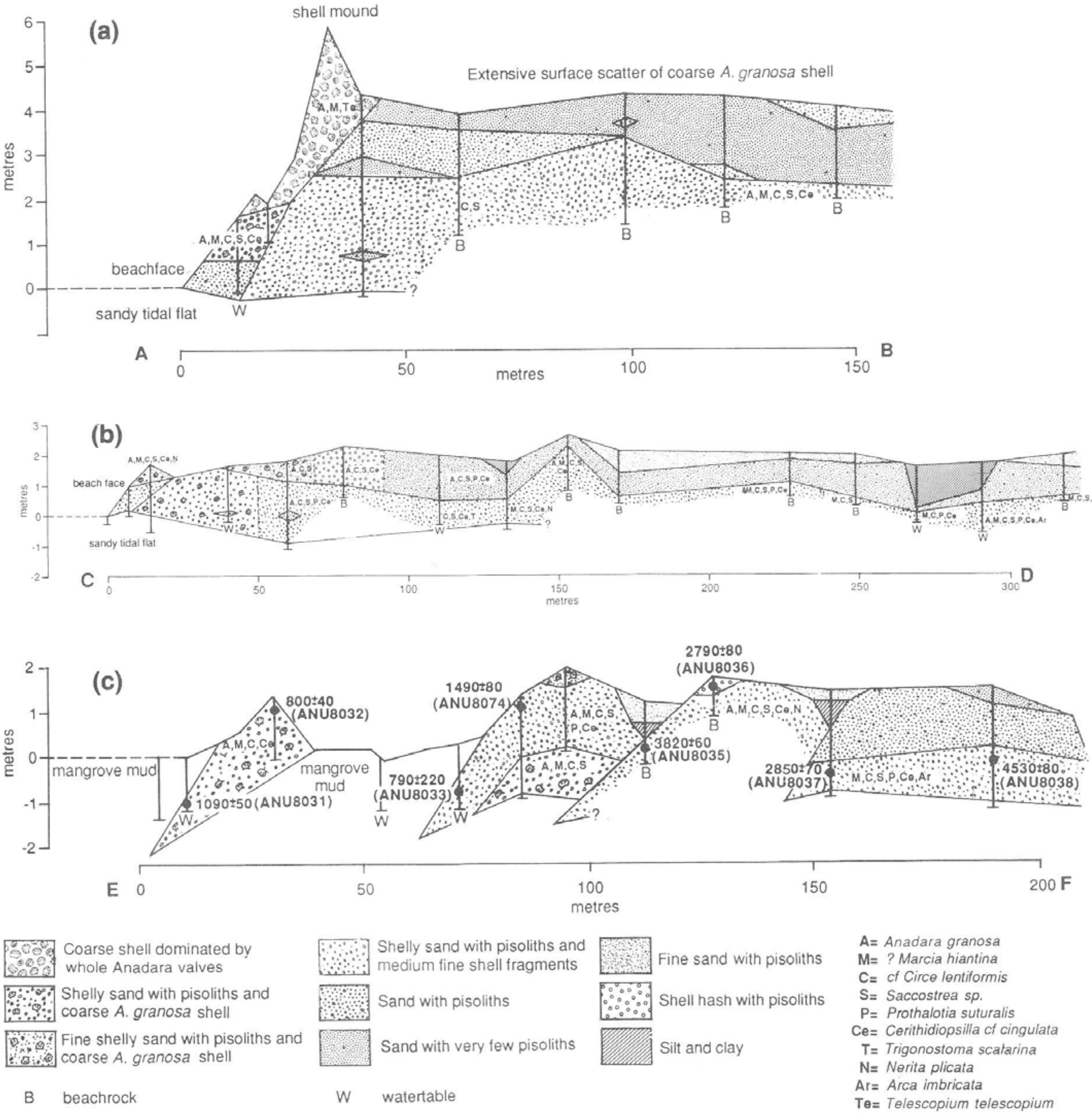


Fig. 6. Cross sections *A–B*, *C–D* and *E–F* across the Prumanung ridge sequence. Shellfish species are those identified from the auger holes.

Conventional radiocarbon ages were obtained on ten *Anadara* samples collected by Beaton from eight of the Uningan shell mounds (Fig. 8; Table 1). The oldest are on shells from the surface of the sandy ridge at the rear of the sequence. These range between $1210 \pm 60$ yrs B.P. (ANU 4415) and $1460 \pm 60$ yrs B.P. (ANU 4419). Towards the shore of the Mission River the shells from the mounds become progressively younger. Most of those from the mounds on the plain are roughly 5–800 years old. The most recent has an age of $180 \pm 50$ yrs B.P. (see also Fig. 3).

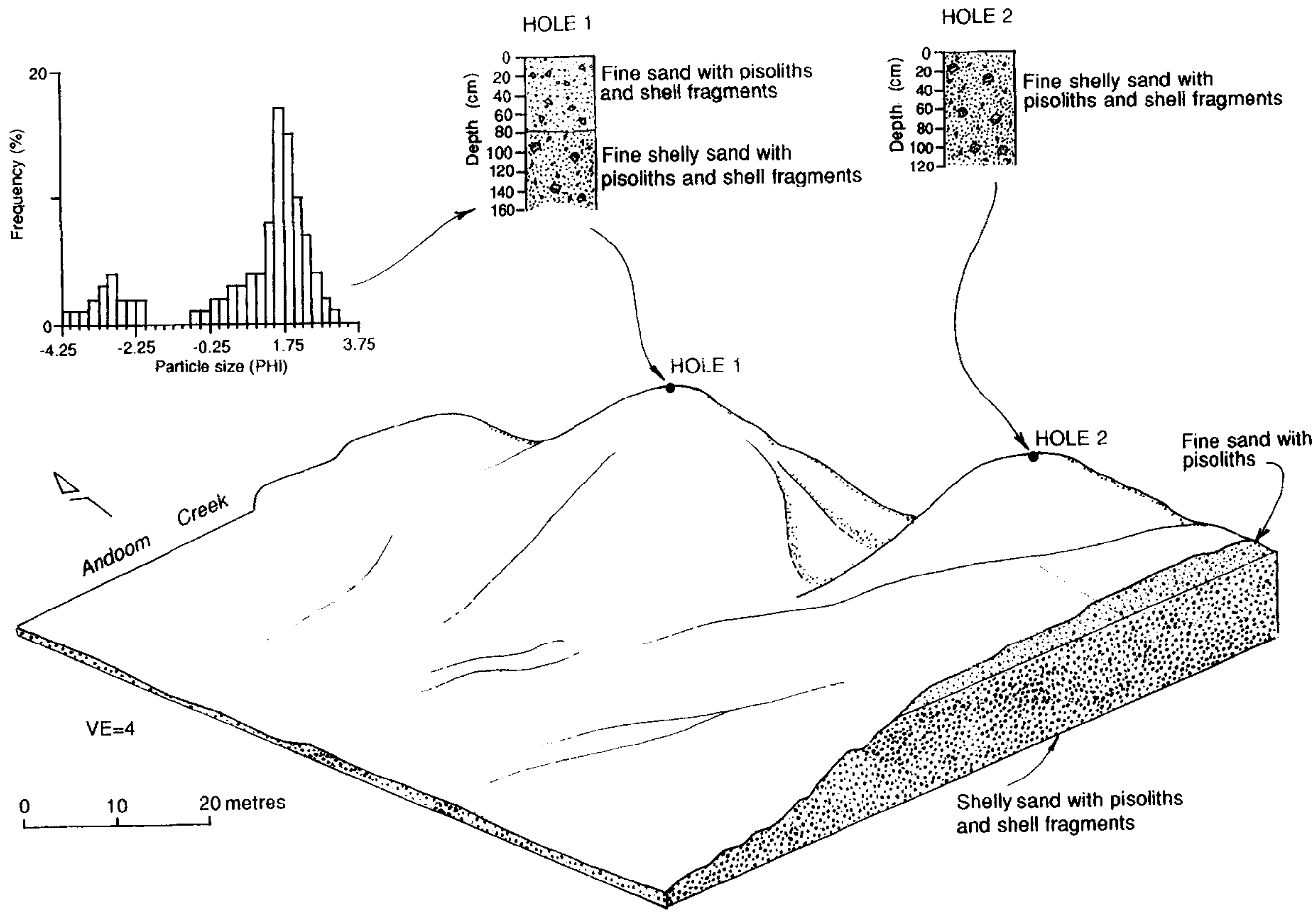


Fig. 7. Block diagram of mounds composed of shelly sand and pisoliths near the mouth of Andoom Creek. See Fig. 6 for location.

The subsurface stratigraphy of four of the mounds on the plain was investigated by augering. Two are shown in a fence diagram constructed from holes augered alongside them (Fig. 9). Both appear to be composed mainly of coarse *Anadara* shell. The mound closest to the sea rises 3.7 m above the level of the plain. The basement rock beneath this mound is no more than 90 cm below the surface of the plain. On the seaward side of the mound fragments of *Anadara* shell extend beneath the plain to the rock below. On the landward side the mound is underlain by silt and clay.

Fig. 10 depicts this mound in more detail. The mound is 38 m long and 20 m wide with its long axis running roughly parallel to the shoreline. The landward face of the mound is distinctly lobed along the base. About half way up there is a break in slope which separates the more subdued lower half of the mound from the much steeper upper half. This gives the deposit the appearance of being a steep-sided conical mound supplanted on an elongate ridge.

The other shell mound shown in the fence diagram rises 1.8 m above the level of the plain. On its seaward side fragments of *Anadara* shell extend for 30 cm into the underlying deposits. Near the surface these deposits consist of silt and clay. Beneath these sediments the shell passes into sand mixed with silt and clay. The sandy deposits rest on basement rock on the seaward side of the mound. These run roughly parallel to the shoreline for 70 m and reach a maximum thickness of 1 m directly under the mound. Towards the landward side of the mound the sandy deposits taper out into silt and clay. The sandy ridge at the rear of the sequence consists of coarse sand and gravel overlain by gravelly medium sand.

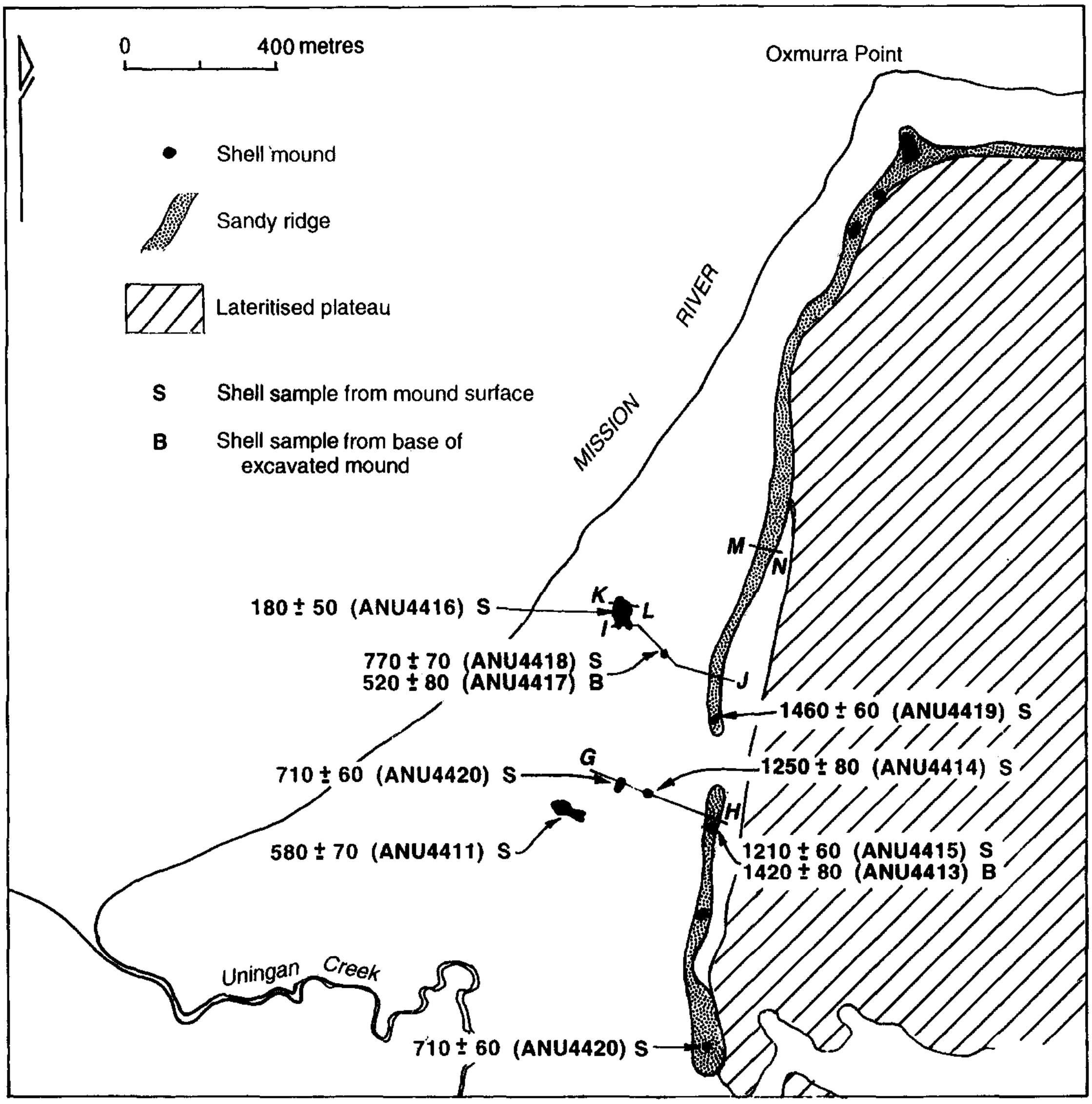


Fig. 8. The Uningan coastal plain. Cross section *G–H* is shown in Fig. 9, *I–J* and *K–L* in Fig. 11, and *M–N* in Fig. 13.

Two more of the Uningan shell mounds are shown in Fig. 11. The largest of these is actually a composite feature consisting of three steep-sided conical mounds superimposed on two linear shell ridges. The mounds stand between 3 and 4.5 m above the level of the plain. The most landward face is shown in Fig. 12. All appear to be composed of coarse *Anadara* shell. The two linear ridges are also composed of this shell. In both this extends beneath the underlying silt and clay for 60 cm. The ridge on the seaward side forms an arc around the foot of the three mounds. The seaward face of this ridge is relatively gentle and lines of mangrove debris are found along it. However, its landward face dips steeply where it protrudes from under the mounds. The slopes of the ridge behind it are more subdued and rise steadily to merge with the tallest mound. Mangroves encircle the feature.

The shell mound behind the composite feature is much smaller. It measures only 20 m × 10 m in area and rises only 1 m above the level of the plain. The long axis of this mound runs roughly parallel to the shoreline. Coarse *Anadara* shell appears to be the main component. However, this shell does not rise to a conical peak as it does in all the other mounds. Nor does it extend beneath the surface. The sediments underlying this mound are entirely silt and clay.

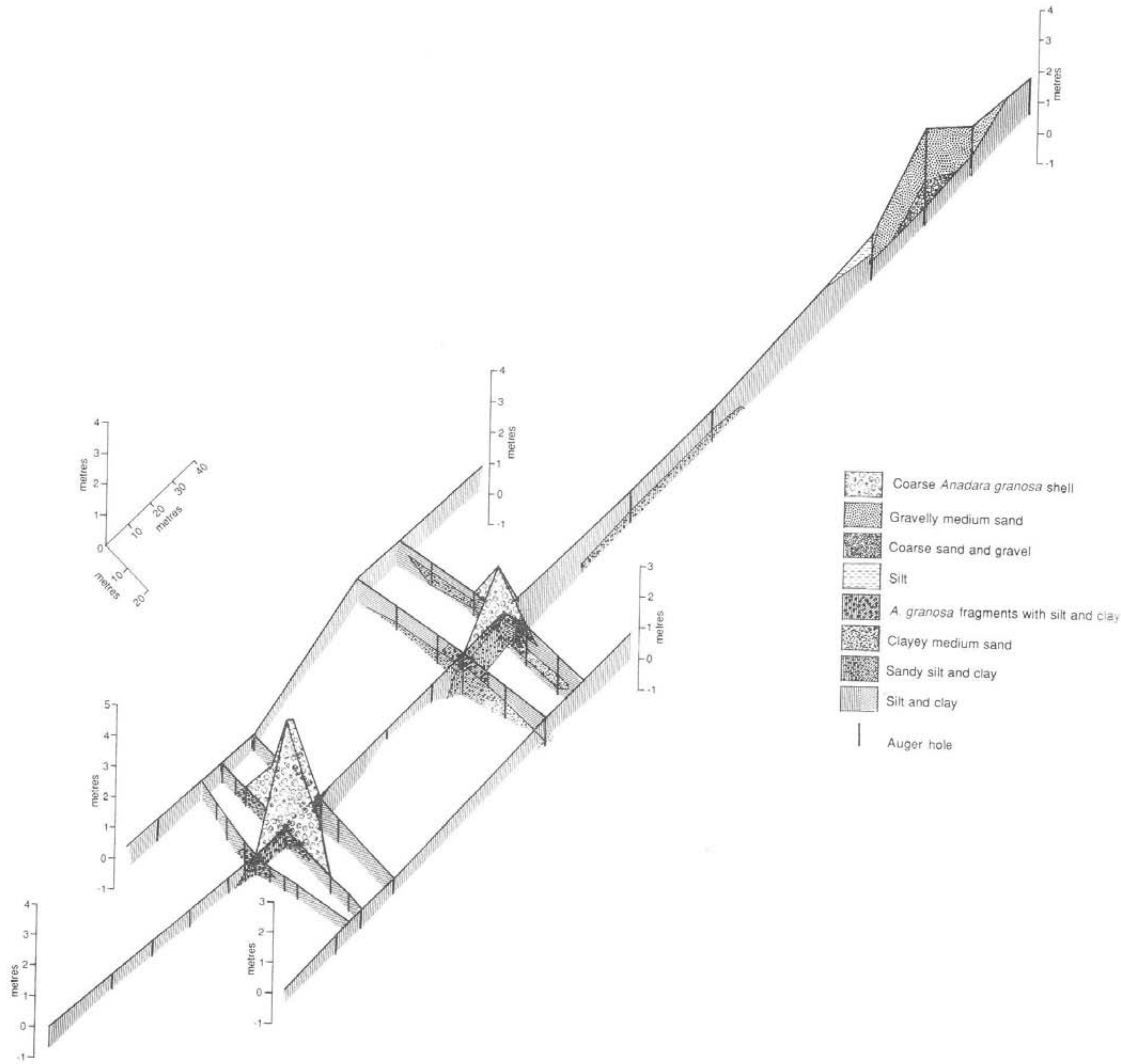


Fig. 9. Fence diagram showing shell mounds and sandy ridge along Transect G–H at Uningan. Note the extension of coarse sediments beneath the shell mounds to the rock below.

Fig. 13 is a section of a mound built on the sandy ridge at the rear of the sequence. This mound is a conical feature which rises 1.2 m above the surface of the ridge. Its composition is similar to that of the ridge beneath it. Similarly-sized mounds which appear to be composed mainly of coarse *Anadara* shell also occur along the top of the ridge. Surface scatters of coarse *Anadara* shell are usually seen within 30 m of the shell mounds.

## 8. The natural origins of the shell mounds

Mapping and augering of coastal deposits at Prumanung and Uningan provides evidence of a natural origin for the Weipa shell mounds. In a geomorphological context the shell mounds are not anomalous and human agencies need not be invoked to explain them. Both Prumanung and Uningan are chenier plains and in these dynamic

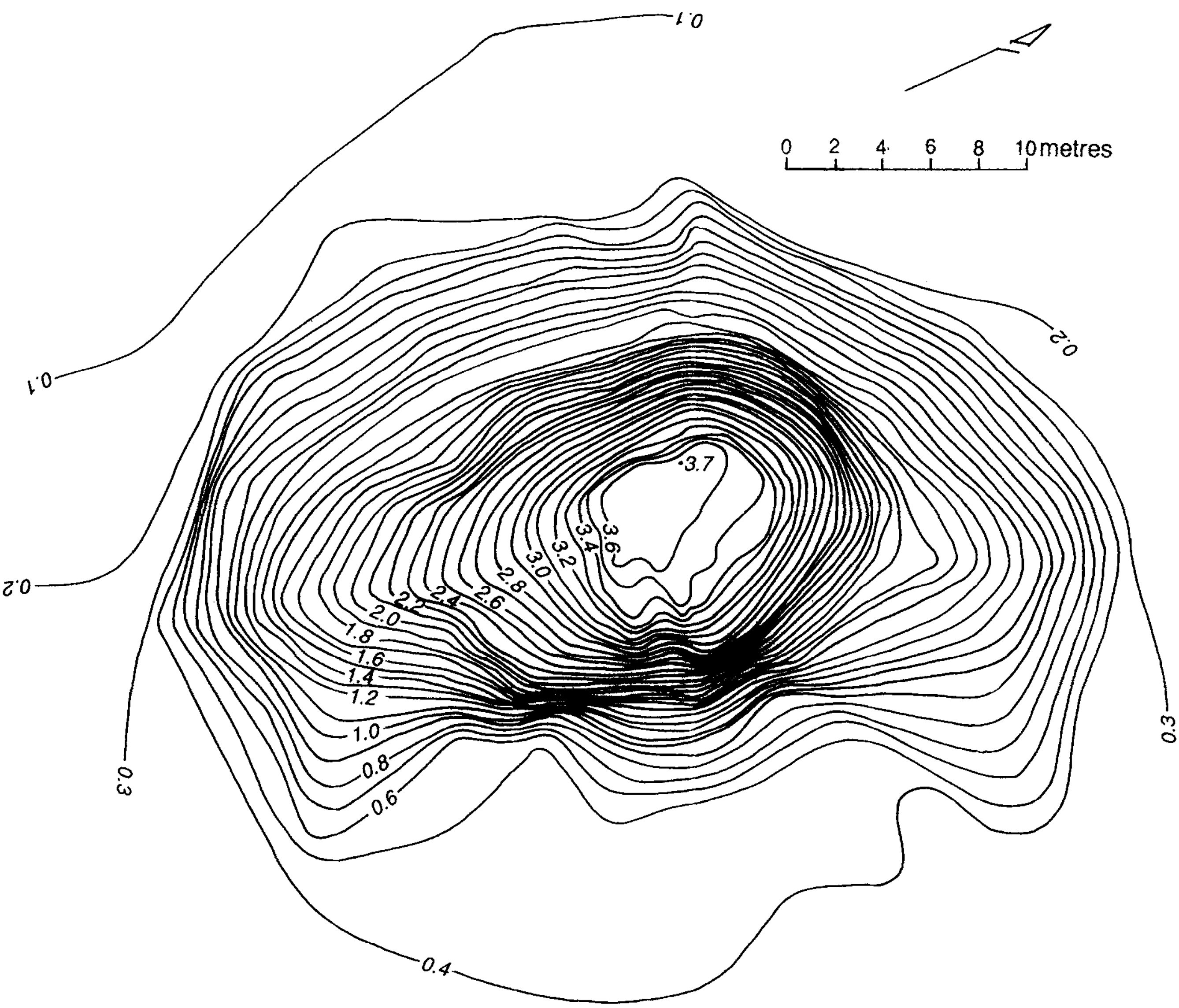


Fig. 10. Contour map of most seaward shell mound along Transect G–H at Uningan.

environments mounds composed of a variety of sediment types have formed. Tall, steep-sided shell mounds are closely associated with wave-built deposits of coarse *Anadara* shell while mounds composed of shelly sand and gravel are present where these sediments predominate. The most likely agent of mound formation is the Orange-footed Scrubfowl *Megapodius reinwardt*.

### 8.1. *Prumanung*

The Prumanung shell mound environment is the result of Holocene coastline progradation at the mouth of Andoom Creek (Fig. 5). A chenier plain comprising a sequence of ridges interspersed with fine-grained muddy deposits has developed. Subsurface investigation shows that where the ridges converge away from Andoom Creek they rest on a sandy shoreface (Fig. 6a and b). Towards the mouth of Andoom Creek the ridges fan out onto much finer shoreface sediments where they become recognisable as cheniers (Fig. 6c). An understanding of the depositional history of these cheniers is necessary to interpret the origins of the mounds located on them.

The model proposed by Rhodes (1980, 1982) to

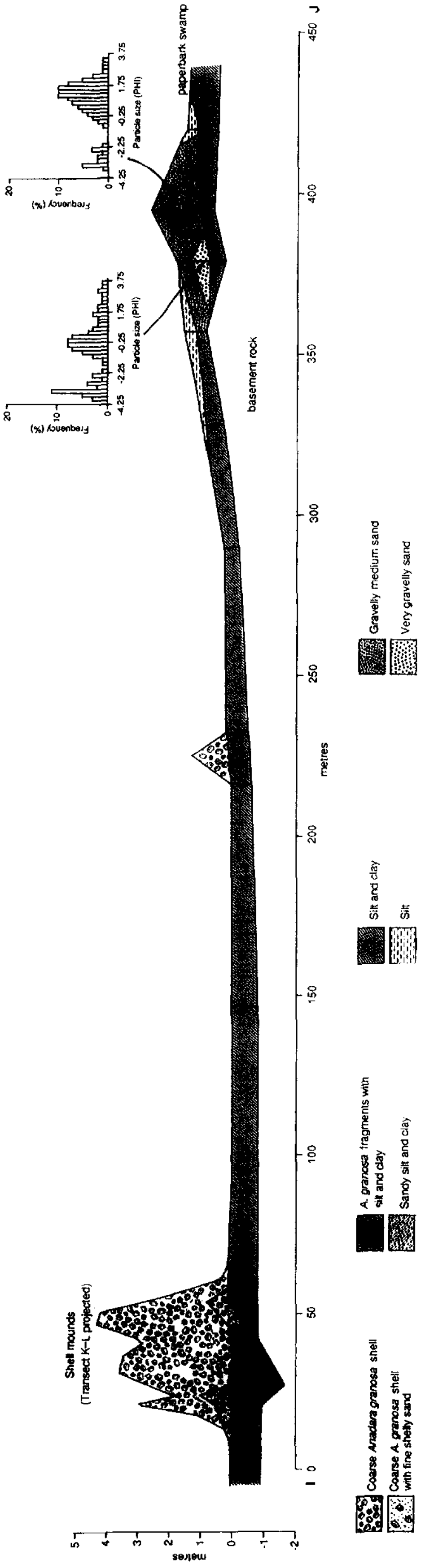


Fig. 11. Cross sections I–J and K–L across the Uningan coastal plain.

explain chenier plain formation in the Gulf of Carpentaria is applicable to Prumanung. Silt and clay transported in suspension by Andoom Creek during periods of high fluvial discharge entered the Mission River where it was deposited in the nearshore zone as low-tide and subtidal mud. As mangroves became established intertidal organic mud was added. Sand and pisoliths contained in the overlying cheniers probably derived from ebb-tidal delta deposits formed at the mouth of Andoom Creek. These coarse sediments were mixed with the shells and redistributed in the shallow subtidal and intertidal zones away from the creek mouth. During periods of reduced mud input the coarse sediments were concentrated due to winnowing and transported onshore to form the Prumanung cheniers.

Ages obtained on shells from the Prumanung cheniers indicate when each ridge formed (Fig. 6c). These results must be interpreted with caution because the accompanying $^{13}C$ values show that the shells are mostly estuarine (Table 3). As a consequence it is uncertain whether the marine shell correction factor should be applied. Further uncertainty arises with the possibility that the shells have been reworked from older deposits and do not date the actual period of chenier formation. It is usual to assume that the youngest date from each chenier is closest to the time of its emplacement (Lees, 1992a).

Despite these uncertainties it is clear that the two landward cheniers are significantly older than the two closest to the sea. Shells from the landward cheniers range in age from 2790±80 yrs B.P. (ANU 8036) to 4530±80 yrs B.P. (ANU 8038). These cheniers are more subdued than the seaward cheniers and the oldest is devoid of shell in its upper layers. This may reflect prolonged leaching. Shells from the seaward cheniers range in age from 790±220 yrs B.P. (ANU 8033) to 1490±80 yrs B.P. (ANU 8034). These cheniers are distinguished by an intervening mudflat and the presence of large quantities of coarse *Anadara* shell.

The two seaward cheniers are probably less than 800 years old. The date of 790±220 yrs B.P. (ANU 8033) provides a maximum age for them. The appearance of large quantities of *Anadara* shell in these cheniers is probably due to environ-

Fig. 12. Landward face of tallest shell mound along Transect K–L.

mental change. Unfortunately little is known about environmental conditions which favour the proliferation of *Anadara granosa* in Australia but the species has received attention in Malaysia where it is a commercial crop (e.g. Pathansali, 1966; Broom, 1982). On the west coast of the Malayan Peninsula the natural habitat of *Anadara granosa* is intertidal estuarine mudflat. The densest populations are found in fine, soft brackish mud seaward of mangroves. Similar conditions are present near the mouth of Andoom Creek where formation of the locally extensive mangrove mudflat probably triggered an increase in the *Anadara* population.

The highest concentration of coarse *Anadara* shell on the Prumanung chenier plain is at the point where the cheniers converge. Most of this shell is contained in the three mounds located immediately behind the modern beach (Fig. 6a). Closer to the mouth of Andoom Creek coarse *Anadara* shell is much less concentrated and the cheniers are sandier. Present are mounds of shelly sand and pisoliths in place of coarse shell mounds (Fig. 7). This kind of change in predominant sediment type over the length of a chenier is common in northern Australia. For example, Rhodes (1980, p. 88) mentions sandy cheniers which grade laterally into shell away from tidal inlets and Lees (1992b) notes a similar gradation for the Princess Charlotte Bay cheniers.

The coarsest sediments on the Prumanung chenier plain are whole *Anadara* valves. These are concentrated at the point where the cheniers converge because the terrigenous sediment normally mixed with them diminishes with increasing distance from its source at the mouth of Andoom Creek. Another reason for the concentration of whole *Anadara* valves at this end is the steeper offshore profile. Todd (1968) explains that without

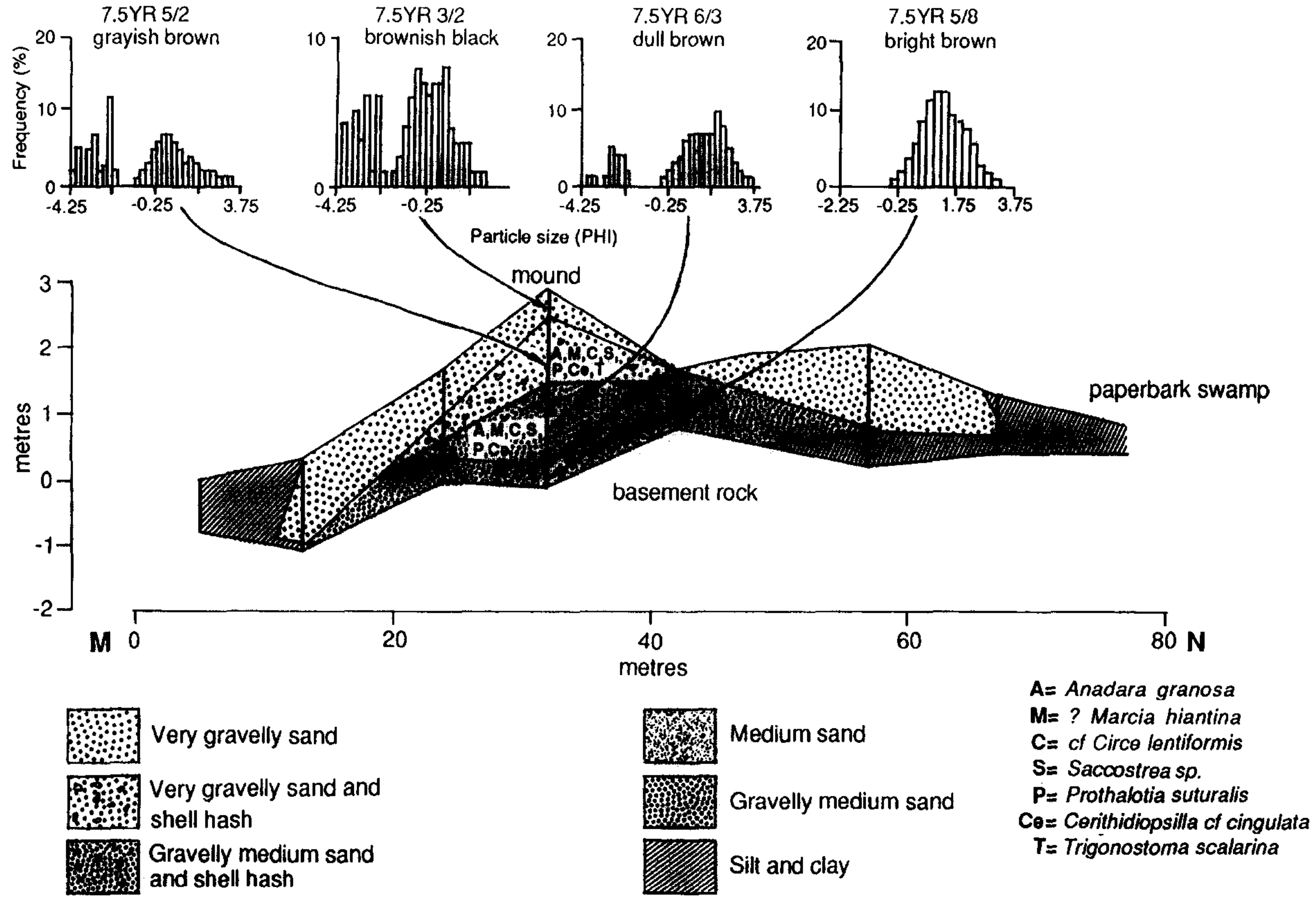


Fig. 13. Cross section *M–N* across shelly sand and gravel mound on sandy ridge at rear of Uningan sequence. Shellfish species are those identified from the auger holes.

the impediment of mud in the local nearshore zone wave energy is higher. This enhances winnowing and coarse sediment is concentrated. More effective wave-action also results in better sorting. The crest of the beach adjoining the shell mounds has been capped by numerous whole *Anadara* valves (Fig. 6a). This well-sorted deposit is a coarse shell berm (see Thompson, 1968).

Localisation of so much coarse *Anadara* shell at one end of the Prumanung chenier plain is a geomorphological phenomenon. There is no evidence to suggest that any of this shell was collected by Aborigines for food. The emergence of distinctive mounds from these sediments and from wave-deposited sediments elsewhere on the chenier plain is also a natural phenomenon. Below is a discussion of the process most likely to have given rise to these mounds.

### *8.2. Uningan*

The Uningan shell mound environment is a broad progradational plain (Fig. 8). It formed along a sheltered part of the Mission River which usually experiences low wave energy. Consequently development of the Uningan plain has been dominated by silt and clay deposition. Seaward accretion of mangrove mud has added to its size. Across this broad plain coarse sediments are relatively sparse. Sand and pisoliths are concentrated in the one linear ridge at the rear of the sequence (Figs. 9 and 11). This wave-built deposit is a chenier. Towards the sea there is a change in predominant coarse sediment type with the appearance of five isolated mounds of coarse *Anadara* shell. The origins of these mounds are revealed by their morphostratigraphy and geochronology.

Surface morphology strongly suggests that the Uningan shell mounds originated as cheniers. All are elongate and run roughly parallel to the modern shoreline. At their base each has a gently curving seaward margin with at least one having an irregular landward margin probably lobed by washover (Fig. 10). The two linear ridges which protrude from under the composite shell mound are even more obvious as cheniers (Fig. 11). These have been recurved by wave refraction around the main body of the shell mound. The most seaward is still active and has moved over mangrove roots on its steep landward side.

Subsurface investigation shows that contrary to archaeological belief the shell mounds do not sit on the surface of older landforms. The two mounds shown in the fence diagram are composed of coarse *Anadara* shell which extends beneath the chenier plain surface (Fig. 9). This shell continues to basement rock on the seaward side of the taller mound and on the seaward side of the other it grades into sand. The two ridges at the foot of the composite shell mound are also composed of shell which extends beneath the chenier plain surface (Fig. 11). This kind of subsurface expression is further evidence that the mounds originated as cheniers. Each marks the position of a former shoreline rather than the location of a human habitation site.

The ten radiocarbon dates on *Anadara* shell from the Uningan mounds are also consistent with a chenier sequence (Fig. 8). The shells from the surface of the sandy chenier at the rear of the sequence are the oldest. It is likely that these were transported to the chenier crest by wave-action before the shoreline had prograded far. The only anomalously young shell age from the sandy chenier is the date of $710 \pm 60$ yrs B.P. (ANU 4420). It is conceivable that this shell came from an Aboriginal midden but it may also have been transported to the chenier crest by strong wave-action from deposits of this age further seaward.

Some time after 1400 yrs B.P. sand and pisoliths ceased to become available for chenier construction. Either the Mission River no longer supplied terrigenous material or the sea had lost its capacity to transport relict bay sediments shoreward. This environmental change was followed by significant mudflat accretion. Conditions for the proliferation of *Anadara* were enhanced and its shell valves became the predominant coarse sediment type. The first shells winnowed from the mud and redeposited to form an isolated shell mound have an age of $1250 \pm 80$ yrs B.P. (ANU 4414). Subsequent shoreline progradation produced shell mounds between 5–800 years ago and about 200 years ago.

Geomorphological investigation shows that the Uningan shell mound environment has changed considerably over the past 1000 years. This is contrary to the claim made by Bailey (1983) that the coastal environment of Weipa has not changed during this period. The most obvious indicators of environmental change are the shell mounds out on the silt and clay plain. These deposits originated as cheniers and were constructed largely from the remains of one species of shellfish. They are not evidence of a static environment camped on frequently by Aborigines. Each shell mound marks the changing position of the shoreline and implicates mass mortality of *Anadara* as a cause of shell accumulation. The most likely reason why so many of these mounds are unusually shaped and tall is discussed below.

## 9. Ornithogenesis

Ornithogenesis describes the formation of deposits by birds (Reineck and Singh, 1973, p. 135). An impressive example of this process is mound-building by the Orange-footed Scrubfowl *Megapodius reinwardt* (Fig. 14). Although its nest mounds are usually less than 5 m high some grow much taller (e.g. Forshaw and Muller, 1978). Sediments are raked into mounds from a radius of 25 m and possibly from as far away as 150 m (Marchant and Higgins, 1993, p. 327). Decaying organic material is usually mixed with the sediments to generate heat for egg incubation. Eggs are deposited in holes dug into the mounds and buried. The birds breed between July and March but work on the mound may occur all year round (Crome and Brown, 1979).

On Channel Island near Darwin the optimum locality for mound construction is the boundary between shoreline deposits and bedrock. At this interface mangroves meet with monsoon vine forest and beach sediments are abundant. These two vegetation types are ideal habitat for

Fig. 14. The Orange-footed Scrubfowl *Megapodius reinwardt*. The bird is about the size of a chicken. (Photo supplied by Ian Morris.)

Scrubfowl and both supply organic material for generating heat in the mounds. When wave energy is high mangrove trash is delivered to the beach face and in shoreline settings this may be more important as a source of rotting vegetation than litter from monsoon vine forest.

Scrubfowl mounds can grow rapidly. Frith (1956) observed one at Iron Range east of Weipa increase in diameter from 2.4 m to 3.7 m and in height from 0.9 m to 1.5 m over a nine month period. Lincoln (1974) observed a Scrubfowl on Komodo Island (Indonesia) shift 2 $m^3$ of soil into a hole in a mound in less than three hours. Crome and Brown (1979) recorded mound profile changes and observed one Scrubfowl shifting a rock weighing 6.92 kg. Single mounds may be worked for generations and old mounds re-used (Marchant and Higgins, 1993, p. 327).

### 9.1. The Weipa bird mounds

The mound-building behaviour of Scrubfowl is the only process capable of explaining the transformation of shoreline deposits at Weipa into tall, steep-sided mounds. Habitats favourable to Scrubfowl are associated with each mound location. The strength of the Scrubfowl hypothesis is that it can explain the growth of shell mounds and mounds composed predominantly of sand and gravel. The composition of each clearly reflects the lithology of the adjacent or underlying deposits. It is unnecessary to think that shell mounds might be a separate category of mound more likely to have been built by people.

The Prumanung shell mound has all the attributes of a Scrubfowl mound (Fig. 6a). It appears to have grown lengthwise by Scrubfowl heaping shell from the adjoining berm composed of whole *Anadara* valves. The close fit between the shell ages from the excavated mound (ANU 4408 and 4409) and the maximum age for the two seaward cheniers (ANU 8033) is consistent with Scrubfowl having reworked the shells from the most seaward deposits. At the opposite end of the Prumanung chenier plain the mounds are composed of shelly sand and pisoliths (Fig. 7). Mound composition changes in accordance with changes in chenier composition and reworking by Scrubfowl is the only possible explanation.

Most of the shell cheniers at Uningan also appear to have been reworked by Scrubfowl into tall mounds. The best example of this is the composite shell mound located near the inner edge of the mangrove fringe (Figs. 11 and 12). This incorporates three steep-sided conical mounds up to 4.5 m in height. These near radial features have all the morphological attributes of Scrubfowl mounds. The two linear cheniers beneath these mounds are an obvious source of shell for mound construction. Scrubfowl are likely to have utilised the mangrove habitat and monsoon vine forest species once these had colonised the mound.

The seaward chenier shown in the fence diagram is also likely to have been reworked by Scrubfowl (Fig. 9). This is indicated by the contour map which shows a steep-sided conical mound supplanted on an elongate ridge (Fig. 10). The feature may have been encircled by mangroves when it was first occupied by Scrubfowl and colonised by monsoon vine forest species after the shoreward migration of the mangrove fringe. Of the remaining shell mounds on the silt and clay plain the role of Scrubfowl is less evident. In fact the isolated mound shown in Fig. 11 is simply a small shell chenier with no suggestion of Scrubfowl reworking.

The composition of the mounds along the sandy chenier at the rear of the Uningan sequence reflects the diverse lithology of the ridge. Present are relatively small, conical shell mounds as well as shelly sand and gravel mounds with very similar dimensions. At Oxmurra Point where wave energy is higher coarse *Anadara* shell is more concentrated and consequently the shell mounds are more clustered (Fig. 8). Active Scrubfowl mounds are present at Oxmurra Point indicating that mound-building processes are ongoing.

The shell mounds on the east bank of the Hey River mapped by Bailey (1977, fig. 4) also present likely examples of ornithogenesis. The three mounds on the floodplain/laterite boundary are in an optimum locality for Scrubfowl mound construction and almost certainly were built by Scrubfowl from shells deposited by wave-action. The three mounds on the floodplain also have the dimensions and locational characteristics of Scrubfowl mounds built from natural shell deposits. The low mounds on the laterite are too small to have been obviously mounded by Scrubfowl but deposition by wave-action is suggested by their roughly shore-parallel alignment. Their location on the laterite up to 250 m inland could be explained by hydro-isostatic emergence (see Rhodes, 1980). These mounds are likely to be significantly older than those further seaward.

### *9.2. Kwamter reinterpreted*

The Kwamter mound is a thanatocoenoses or transported death assemblage (Boucot, 1953). The prevalent species is *Anadara granosa* but other estuarine and terrestrial species are present. These need not be assumed to be the remains of Aboriginal meals. The damaged edges of some of the *Anadara* valves suggest offshore predation by gastropods or crabs (e.g. Carter, 1968). The charcoal and ash bands in the mound are likely to be natural because fires happen frequently in northern Australia and the remains of burning are common soil features. The presence of artefacts at depth in shell deposits can also be explained by natural processes (e.g. Salemme et al., 1989). The most likely in this case is bioturbation.

The Kwamter mound differs in composition from the natural shell deposits identified by Bailey (1977) because it is in a different depositional environment. The shells in the mound are separated from the much finer sediments beneath it simply because of sorting by wave-action (see Thompson, 1968). The mound originated as a shore-parallel shell ridge and formed in a habitat highly favourable to Scrubfowl. These birds appear to have built up the mound some 900 years ago as shells were being delivered to the beach face or soon after. New material appears to have been added by the birds some 300 years later.

### *9.3. Princess Charlotte Bay*

Shell mounds composed of coarse *Anadara granosa* shell and shell cheniers coincide at Princess Charlotte Bay (Chappell and Grindrod, 1984). A total of 38 shell mounds were recorded by Beaton (1985) on the surfaces of the shell cheniers and 13 were excavated or sectioned. One of the largest, the South Mound, was excavated to a depth of 2.4 m. It revealed layers of *Anadara* shell rich and poor in dark silty sediment and a few small lenses of burnt wood. The remains of turtle and a few fish were recorded but no artefacts. Beaton obtained 27 shell ages from the mound. These show that the shells forming the bulk of the deposit are roughly 1400–2000 years old. Shells from the top 75 cm are around 1100 years old.

Beaton (1985) believed that the shell mounds were Aboriginal shell middens. Broad sheets of coarse *Anadara* shell 15–40 cm thick on the crests of the underlying cheniers were described by Chappell and Grindrod (1984) as human occupation deposits. A more likely explanation is that the broad sheets of shell are coarse shell berms. Shells from these deposits were raked up by Scrubfowl into distinct conical mounds. Of relevance is that the shell cheniers fan out into cheniers composed of coarse sand and gravel (Lees, 1992b). On the sand and gravel cheniers are mounds composed of these sediments almost identical to the shell mounds. Scrubfowl are the only possible explanation for both sets of mounds.

The dating of the shell cheniers at Princess Charlotte Bay also supports reinterpretation of the South Mound as a Scrubfowl mound constructed from natural shell deposits. Ages obtained on shells by Chappell and Grindrod (1984) from the chenier underlying the South Mound suggest that it formed less than 2500 years ago. A shell age from the chenier further seaward suggests that it formed less than 1300 years ago. During the intervening period the beach face of the chenier beneath the South Mound would have been exposed to wave-action. Shell ages from the mound are consistent with transport of shells to the chenier crest by washover during this period.

## 10. Implications

Archaeologists proposed a human origin for the shell mounds of northern Australia on the basis of criteria for distinguishing between cultural and natural shell deposits laid down by the Danish Kitchen Midden Committee of 1851. One of the key criteria asserts that shell middens will contain shells predominantly large in size showing that people had collected them for food whereas natural shell deposits will invariably contain shells of many sizes including species too small to eat (see also Gill, 1954; Bailey, 1977; and Bowdler, 1983). Other criteria include the absence of water-worn shell and clear stratification in shell middens compared to the presence of these features in natural shell deposits. If indeed these criteria were reliable indicators of origin the shell mounds may well have been middens.

The strong likelihood that the shell mounds are natural in origin suggests that these criteria are fundamentally flawed. Geomorphologists have long recognised that size sorting of shell is possible by wave-action with concentrations of whole shell valves often resulting from the winnowing and removal of finer sediments (e.g. Thompson, 1968; Greensmith and Tucker, 1969; Woodroffe et al., 1983). These shells are commonly transported by waves to the crests of beach ridges where they may easily be mistaken for middens. In the geomorphological literature deposits of whole shell valves are variously referred to as shell gravels, coarse shell or calcirudite.

The lack of wear on shells also indicates little about the natural or cultural origins of shell deposits. In northern Australia whole, unabraded shells are common in beach ridge sediments and their fresh condition simply indicates that they have not been transported far (e.g. Rhodes, 1982; Lees, 1992a). Abrasion may also be minimal because of the soft, muddy character of the sediments over which the shells have been transported (Rhodes, 1980, p. 305). Similarly, absence of clear stratification does not necessarily mean that a shell deposit is a midden either. Sections through shell cheniers, for example, frequently show poorly layered shells without any imbricate structure (e.g. Greensmith and Tucker, 1969; Rhodes, 1980, p. 89).

Given that key criteria for the identification of shell middens can be met by natural shell deposits it would appear that coastal archaeologists have been misled. Consequently open shell midden sites from the smallest shell scatters to the largest shell mounds must be regarded with some scepticism. This is especially so if they are located at or near past or present sea level where natural processes of shell deposition are likely to have had far more impact on the landscape than human shell-gatherers. While it cannot be denied that people have lived on shellfish in the past, the challenge which remains for archaeologists is to find new ways of distinguishing between shells collected by people and shells deposited by nature.

## 11. Conclusions

Geochronological and morphostratigraphic evidence supports Stanner's (1961) view that the Weipa shell mounds are natural in origin. Ages from the Kwamter mound show that the shells are unlikely to have been deposited by generations of shellfishing Aborigines. Shell ages from across the Weipa landscape indicate that the mounds are part of a prograding shoreline sequence. Shell mounds at Prumanung and Uningan coincide with wave-built deposits of coarse *Anadara* shell. The large mounds on the Uningan plain originated as small shell cheniers. In both localities mound composition changes in accordance with changes in chenier composition. The most probable explanation for mound growth is the nesting behaviour of the Orange-footed Scrubfowl. Criteria used by archaeologists to distinguish between cultural and natural shell deposits are flawed.

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## References

Bailey, G.N., 1975. The role of shell middens in prehistoric economies. Ph.D. Thesis, Univ. Cambridge.

Bailey, G.N., 1977. Shell mounds, shell middens and raised beaches in the Cape York Peninsula. Mankind, 11: 132–143.

Bailey, G.N., 1983. Problems of site formation and the interpretation of spatial and temporal discontinuities in the distribution of coastal middens. In: P.M. Masters and N.C. Fleming (Editors), Quaternary Coastlines and Marine Archaeology: Towards the Prehistory of Land Bridges and Continental Shelves. Academic Press, London, pp. 559–582.

Bailey, G.N., 1991. Hen's eggs and cockle shells: Weipa shell mounds reconsidered. Archaeol. Oceania, 26: 21–23.

Beaton, J.M., 1985. Evidence for a coastal occupation time-lag at Princess Charlotte Bay and implications for coastal colonisation and population growth theories for Aboriginal Australia. Archaeol. Oceania, 20: 1–20.

Blaber, S.J.M., Brewer, D.T. and Salini, J.P., 1989. Species composition and biomass of fishes in different habitats of a tropical northern Australian estuary: their occurrence in the adjoining sea and estuarine dependence. Estuarine Coastal Shelf Sci., 29: 509–531.

Blaber, S.J.M., Salini, J.P. and Brewer, D.T., 1990. A checklist of the fishes of Albatross Bay and the Embley estuary, north-eastern Gulf of Carpentaria. CSIRO Mar. Labor. Rep., 210, CSIRO, Australia.

Blakers, M., Davies, S.J.J.F. and Reilly, P.N., 1984. The Atlas of Australian Birds. R. Australas. Ornithol. Union, Melbourne Univ. Press.

Boucot, A.J., 1953. Life and death assemblages among fossils. Am. J. Sci., 251: 25–40.

Bowdler, S., 1983. Sieving seashells: midden analysis in Australian archaeology. In: G. Connah (Editor), Australian Field Archaeology: A Guide to Techniques. Aust. Inst. Aboriginal Stud., Canberra, pp. 135–144.

Bowman, D.M.J.S., Woinarski, J.C.Z. and Russell-Smith, J., 1994. Environmental relationships of Orange-footed Scrubfowl (*Megapodius reinwardt*) nests in the Northern Territory. Emu, 94: 181–185.

Broom, M.J., 1982. Structure and seasonality in a Malaysian mudflat community. Estuarine Coastal Shelf Sci., 15: 135–150.

Carter, R.M., 1968. On the biology and palaeontology of some predators of bivalved mollusca. Palaeogeogr., Palaeoclimatol., Palaeoecol., 4: 29–65.

Chappell, J. and Grindrod, J., 1984. Chenier plain formation in northern Australia. In: B.G. Thom (Editor), Coastal Geomorphology in Australia. Academic Press, Sydney, pp. 197–231.

Cribb, R., 1986. A preliminary report on archaeological findings in Aurukun Shire, western Cape York. Queensland Archaeol. Res., 3: 133–158.

Cribb, R., 1991. Getting into a flap about shell mounds in northern Australia: a reply to Stone. Archaeol. Oceania, 26: 23–25.

Cribb, R.L., Walmbeng, R., Wolmby, R. and Taisman, C.,

1988. Landscape as culturalartefact: shell mounds and plants in Aurukun, Cape York Peninsula. Aust. Aboriginal Stud., 2: 60–73.

Crome, F.H.J. and Brown, H.E., 1979. Notes on social organisation and breeding of the Orange-footed Scrubfowl *Megapodius reinwardt*. Emu, 79: 111–119.

Deignan, H.G., 1964. Birds of the Arnhem Land Expedition. In: R.L. Specht (Editor), Records of the American-Australian Scientific Expedition to Arnhem Land. Melbourne Univ. Press, 4.

Forshaw, J.M. and Muller, K.A., 1978. Annotated list of birds observed at Iron Range, Cape York Peninsula, Queensland, during October, 1974. Aust. Bird Watcher, 7: 171–194.

Frith, H.J., 1956. Breeding habits in the family Megapodiidae. Ibis, 98: 620–640.

Gill, E.D., 1954. Aboriginal kitchen middens and marine shell beds. Mankind, 4: 249–254.

Greensmith, J.T. and Tucker, E.V., 1969. The origin of shell deposits in the chenier plain facies of Essex (Great Britain). Mar. Geol., 7: 403–425.

Lees, B.G., 1992a. The development of a chenier plain sequence on the Victoria Delta, Joseph Bonaparte Gulf, northern Australia. Mar. Geol., 103: 215–224.

Lees, B.G., 1992b. Geomorphological evidence for late Holocene climatic change in northern Australia. Aust. Geogr., 23: 1–10.

Lincoln, G.A., 1974. Predation of incubator birds (*Megapodius freycinet*) by Komodo dragons (*Varanus komodoensis*). J. Zool., London, 174: 419–428.

Marchant, S. and Higgins, P.J. (Editors), 1993. Handbook of Australian, New Zealand and Antarctic Birds. 2. Raptors to Lapwings. Oxford Univ. Press, Melbourne.

McCarthy, F. and Setzler, F.M., 1960. The Archaeology of Arnhem Land. In C.P. Mountford (Editor), Records of the American–Australian Expedition to Arnhem Land. Melbourne Univ. Press, 2.

Meehan, B., 1982. Shell Bed to Shell Midden. Aust. Inst. Aboriginal Stud., Canberra.

Meehan, B., 1988. Changes in aboriginal exploitation of wetlands in northern Australia. In: D. Wade-Marshall and P. Loveday (Editors), Northern Australia: Progress and Prospects. Floodplains Research. 2. Aust. Natl. Univ. App., 2.

Meehan, B., Brockwell, S., Allen, J. and Jones, R., 1985. The wetlands sites. In: R. Jones (Editor), Archaeological Research in Kakadu National Park. Aust. Natl. Parks Wildlife Service, Spec. Publ., 13: 103–153.

Mulvaney, D.J., 1975. Prehistory of Australia. Penguin.

Mulvaney, D.J., 1981. Salvaging salvage archaeology. Aust. Archaeol., 12: 61–62.

Pathansali, D., 1966. Notes on the biology of the cockle, *Anadara granosa* L. Proc. Indo-Pacific Fish. Counc., 11: 84–98.

Peterson, N., 1973. Camp site location amongst Australian hunter–gatherers: archaeological and ethnographic evidence for a key determinant. Archaeol. Phys. Anthropol. Oceania, 8: 173–193.

Reineck, H.E. and Singh, I.B., 1973. Depositional Sedimentary Environments. Springer, Berlin.

Rhodes, E.G., 1980. Modes of coastal progradation, Gulf of Carpentaria. Ph.D. Thesis, Aust. Natl. Univ., Canberra, 375 pp.

Rhodes, E.G., 1982. Depositional model for a chenier plain, Gulf of Carpentaria, Australia. Sedimentology, 29: 201–221.

Roth, W.E., 1901. Food, its search, capture and preparation. North Queensland Ethnogr., 3: 7–31.

Salemme, M., Miotti, L. and Aquirre, M., 1989. Holocene settlement in the Rio de La Plata littoral (Argentina): a methodological approach. Geoarchaeology, 4: 69–80.

Smart, J., 1977. Weipa, Queensland—1:250,000 geological series. Bur. Miner. Resour., Geol. Geophys., Aust., Explanatory Notes, SD 54-3.

Specht, R.L., Salt, R.B. and Reynolds, S.T., 1977. Vegetation in the vicinity of Weipa, North Queensland. Proc. R. Soc. Queensland, 88: 17–38.

Stanner, W.E.H., 1961. The Weipa shell-mounds. The Etruscan, 11: 8–12.

Stocker, G.C., 1971. The age of charcoal from old jungle fowl nests and vegetation change on Melville Island. Search, 2: 28–30.

Stone, T., 1989. Origins and environmental significance of shell and earth mounds in northern Australia. Archaeol. Oceania, 24: 59–64.

Stone, T., 1991a. Megapode mounds and archaeology in northern Australia. Emu, 91: 255–256.

Stone, T., 1991b. Two birds with one stone: a reply. Archaeol. Oceania, 26: 26–27.

Stone, T., 1992. Origins of the Weipa shell mounds. M.Sc. Thesis, Aust. Natl. Univ., Canberra, 172 pp.

Thompson, R.W., 1968. Tidal flat sedimentation on the Colorado River delta, northwestern Gulf of California. Geol. Soc. Am. Mem., 107.

Todd, T.W., 1968. Dynamic diversion: influence of longshore current-tidal flow interaction on chenier and barrier island plains. J. Sediment. Petrol., 38: 734–746.

Valentin, H., 1959. Geomorphological reconnaissance of the north-west coast of Cape York Peninsula (northern Australia). In: R.J. Russell (Editor), 2nd Coastal Geography Conf. Coastal Stud. Inst., Louisiana State Univ., pp. 213–231.

Woodroffe, C.D. Curtis, R.J. and McLean, R.F., 1983. Development of a chenier plain, Firth of Thames, New Zealand. Mar. Geol., 53: 1–22.

Wright, R.V.S., 1963. Report on Archaeological Reconnaissance Work in Cape York. Aust. Inst. Aboriginal Stud. Doc., 63/83.

Wright, R.V.S., 1971. Prehistory in the Cape York Peninsula. In: D.J. Mulvaney and J. Golson (Editors), Aboriginal Man and Environment in Australia. Aust. Natl. Univ. Press, pp. 133–140.