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Palaeoenvironments and prehistory of Australia's tropical Top End

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Introduction

The remote 'Top End' of Australia, far distant from the main urban centres, has been largely neglected in the search for evidence of the long-term interaction between humans and their environment. However, for those few areas that have been studied in detail, there is significant evidence for human modification of the environment, and a variety of human responses to environmental change. Given the preliminary nature of Quaternary research within the region, the success to date suggests a great potential for answering questions about prehistoric landscape change and human ecology. Some of the human-environment interactions to be discussed, such as the alteration of fire regimes which accompanied the appearance of humans and their firesticks, are indicated in other parts of the continent, while others such as the entry of people into Australia and their utilisation of broad floodplains that formed during the Holocene, are best addressed in tropical northern Australia.

Environmental setting

The tropical region of Australia is characterised by a highly seasonal summer rainfall pattern. The dominant rainfall component over much of the area is derived from north-westerly monsoons but this is outweighed along the north-eastern coastal margin by rain from the south-easterly trade winds. Cyclones provide an additional, though erratic, source of precipitation in all coastal areas. Orographically-induced rainfall results in highest totals at higher altitudes including the plateaux of the Kimberlies and Arnhem Land and particularly the north-eastern coastal ranges and tablelands. The persistence of the south-east trades effectively maintains moist conditions on and around the highest mountains of the Cairns/Innisfail area for much of the year. There is a general decrease of rainfall inland to about 600 mm annually in the driest parts of the region.

Much of the landscape is extremely old and this factor, combined with the strongly seasonal precipitation pattern, has resulted in deep lateritic soil profiles of low nutrient status (Jones and Bowler 1980). Exceptions include the more fertile, heavy alluvial soils of the Artesian Basin and major river valleys and more recent soils of the eastern highlands, particularly those derived from basalt outpourings.

In general terms, major vegetation types reflect the variation in physical environments. Sclerophyll open forests and woodlands dominated by the genus *Eucalyptus*, but also with *Melaleuca*, *Casuarina*, *Acacia* and *Callitris* as important canopy genera, give way to tussock grasslands on heavy clay soils within the Artesian Basin and to rainforest in

the moister parts of the eastern highlands. This broad picture, however, masks a great deal of local variation, particularly in sclerophyll/rainforest distributions. Rainforest, as defined for Australia, covers a whole range of floristically related, closed canopied communities (Webb and Tracey 1981). These include not only the floristically diverse and structurally complex types requiring high rainfall, but also semi-evergreen and deciduous monsoon forests and thickets that form a continuum from the coast inland under a gradient of decreasing rainfall. These have very restricted distributions but extend through much of the region. Generally they are found in locally moist and fire-shadow patches but can occur in environments apparently identical with surrounding sclerophyll vegetation. Conversely, patches of sclerophyll vegetation occur within the more extensive east coast rainforest massifs, generally, but not exclusively, where rainforest development is inhibited by poor or excessive drainage and regular disturbances.

Fire is of major importance in the determination of the distribution of the variety of communities. Regular fires are a particular feature of the fire-promoting eucalypt communities and influence the survival of less fire-tolerant sclerophyll and rainforest communities. There is evidence that in the recent past, and present within some areas, Aboriginal burning regimes have had a significant influence on the maintenance of vegetation patterns (Jones 1975, Haynes 1986).

Hunters and gatherers

Many of the late Holocene interactions between Aboriginals and the environment were observed during the early period of European settlement and recorded in historical journals. Although many such observations were haphazard, they provide valuable information about variations in economy and demography which reflect environmental conditions. These historical sources are particularly relevant for short-term events with a duration of less than one generation (say twenty-five years), because phenomena on this timescale usually cannot be distinguished in the archaeological record. Thus, while the human–environmental interactions, such as the human response to annual climatic cycles, take place over periods of weeks, significant mechanisms for shaping cultural or environmental change may be below the threshold of archaeological visibility. For this reason, an overview of historic information indicates the kinds of events which, in concert, may have led to the long-term events which are archaeologically visible.

It is known from the records of European explorers and early settlers that Aboriginal people were living throughout northern Australia. These records, together with more recent observations of Aboriginal communities, indicate that the population density varied markedly in response to environmental parameters (Tindale 1974). Along the rich, well-watered tropical coastline of Arnhem Land, the average densities usually exceeded 5–6 km² per person, sometimes reaching as high as 1 km² per person (Rose 1987). Further inland, where rainfall is lower, population densities were also lower. Birdsell (1953) has implied that the correlation between water availability and population density reflects demographic limits imposed on the human populations by environmental productivity (cf. Hardesty 1977).

Where population densities were relatively high, such as along the coast and major rivers, the territory size of any group tended to be small whereas in drier, 'less productive' regions, territory size was larger (Tindale 1974). Territory shape also displayed the effects of physiographic or ecological features (Tindale 1974).

The economy of Aboriginals living in northern Australia during the period immediately prior to the arrival of Europeans was based on a broad range of hunting and gathering activities. This subsistence system has been described as 'foraging' because of the characteristic pattern of daily trips to obtain food and other materials, returning to a base camp each night. Economic strategies varied greatly across the top end, often reflecting the environmental context in which groups lived. Meehan (1977, 1982) has documented subsistence practises of the coastal Gidjingali in Arnhem Land. Marine resources such as fish and shellfish contributed a substantial portion of the diet, supplemented by terrestrial food plants and small reptiles. These foods were obtained in a variety of ways, including digging and collecting plants and shellfish, spearing or clubbing animals, and the construction of capture devices such as fish traps made from stone or basketry (for example, Meehan 1977, Campbell 1982, Smith 1983). Away from the coast the economic focus shifted to riverine or terrestrial resources of various kinds. It is clear that plants often played a significant role in Aboriginal diet in the late Holocene. Across northern Australia this use of plant materials was enhanced by the application of processing technologies which removed dangerous chemicals, and enabled normally dangerous species to be eaten. The classic example of this is the leaching of toxins from cycads, which changed an otherwise unusable material into a plentiful food capable of sustaining large gatherings of people (Beaton 1982).

Although the targeted foods and the procurement technology varied regionally across the north, the settlement system and material culture of foragers was everywhere affected by the drastic seasonal changes in climate. The location of people in the landscape, and the degree of population aggregation or dispersion, changes seasonally as hunter-gatherers adjusted to conditions such as the inundation of floodplains or the drying of surface water. Seasonal changes in the level of mobility and the location of occupation within the landscape were usually situated to take advantage of seasonally abundant resources. Even the artefacts that were constructed and employed changed seasonally to reflect the raw materials at hand, the extractive functions, and the distances being travelled (for example, Thomson 1939).

Human activities were not simply a passive response to environmental conditions because there was widespread modification of the environment by humans; indeed these were cultural landscapes in which the investment of labour increased the productivity of the land (Rose 1987). Perhaps the major mechanism for land management was burning, which was used to remove dried plant material and promote green feed that would attract animals. Firing of certain plant species, such as cycads, may have increased and/or regularised the production of edible seeds (for example, Beaton 1982). Vegetation clearance through burning also facilitated movements, and reduced unwanted plant and animal species (for example, Tindale 1976). It is clear that the Aborigines' continuous use of fire in this way created long-term ecological changes.

Another means of modifying the environment was the redistribution of resources through trade. Throughout northern Australia the systematic exchange of goods served as a 'chain of connection' linking together groups which required materials not locally available (Mulvaney 1976). Exchange networks, made up of a chain of groups who passed material to their neighbours, served to distribute both prestige and utilitarian items to areas in which they were not naturally found. In north-west Queensland, for example, coastal peoples living in a landscape of Quaternary sediments had few outcrops of hard rock suitable for the manufacture of stone artefacts. This environmental limitation

was partly overcome by substituting locally abundant materials such as shell, but the acquisition through trade of axes from inland regions containing volcanic rocks was highly significant. While it is clear from the historical records that trade fulfilled a variety of social functions (Mulvaney 1976, McBryde 1986), it is also clear that the exchange systems acted as a cultural solution to environmental inadequacies.

Sites of palaeoenvironmental and archaeological study

The age and stability of the landscape, together with the highly seasonal precipitation pattern, has inhibited the development of sites suitable for the detailed investigation of late Quaternary environments through much of the region. Consequently, attention has been focused on coastal lowlands, where sedimentation has occurred since the postglacial rise in sea level flooded the continental shelves, and on the less seasonal Cairns/Innisfail area of north-east Queensland. Coastal evidence of past environments is derived mainly from extensive clay plains that characterise the coastline of northern Australia (Davies 1986). Much of the sediment is derived from rivers which have high-intensity discharge during the wet summer months. The formation and maintenance of the tidal component of these plains is facilitated by low-to-moderate wave energies and high-to-moderate tidal ranges. In drier areas, the plains are largely unvegetated while in wetter areas, wetlands, dominated by sedges, grasses and swamp forest, are prevalent. Mangroves are also frequently present, generally confined to the seaward edge of the plains or along tidal channels, but may be more extensive along the humid north-east coast. Here, rainforest may also form a significant vegetation component beyond the influence of sea water. Particular palaeoenvironmental events are also recorded in coastal chernier and sand dune sequences, the former often associated with coastal plain sedimentation. In north-eastern Queensland, volcanic lakes and swamps on the Atherton Tableland have provided some of the best sites for palaeoenvironmental reconstruction on the continent. This is due to the sensitivity of the sites to vegetation changes in this region of high climatic, topographic and consequently vegetation diversity. In addition, sedimentary evidence is preserved as spring deposits and in some tectonically-controlled inland drainage basins. Of these drainage basins, some research has been undertaken on Lake Woods, close to the southern limit of the region, and in the Gulf of Carpentaria to the north, which contained a lake during the last glacial, low sea level phase.

The combination of landscape stability and generally poor conditions for organic preservation created by the seasonal contrasts in rainfall have also shaped the archaeological record. Throughout northern Australia there are large tracts of land which consist either of erosional or stable land surfaces. In these areas, organic materials have disappeared, leaving scatters of stone artefacts which are difficult to date. For this reason archaeologists seeking information on chronological change have concentrated on environmental zones in which the sediments from different time periods are physically separated.

One landscape in which this occurs comprises the areas of progradation around the present coast. Here, piles of discarded shells on dunes and chernier ridges generate an alkaline micro-environment that has sometimes preserved even highly perishable organic materials such as wood, seeds and small bones. This kind of coastal evidence for past human activities has been obtained from a number of regions, especially north Queensland and the Alligator Rivers region in the Northern Territory (see Figure 4.1).

While the preservation in these coastal middens is generally good, sites in such landscapes usually date only from the middle Holocene and most are late Holocene in age. This has meant that research issues involving older time periods, or non-coastal regions, have been addressed using rock shelters or caves. In the comparatively sheltered conditions of caves, sediment accumulation has buried the debris from sequential occupation events, producing stratified and datable deposits suitable for examining issues of cultural and environmental change.

Archaeological investigations of these caves and rock-shelter sites are constrained by a range of environmental factors. One factor is the presence of such sites. Caves and rock-shelters are common mainly along escarpments and within gorges cut into sandstone or limestone plateaus. Sometimes these escarpments are near the coast, as in Kakadu where the Arnhem Land escarpment abuts the coastal wetlands, and the associated cave deposits can therefore yield information about coastal occupation. Elsewhere, such as at the base of the Gulf of Carpentaria, the escarpment is separated from the coast by hundreds of kilometres of flat plains. In these instances the cave deposits reveal human occupation of inland environments. Thus, the geology of a region determines the availability of suitable rock-shelter sites.

A second environmental phenomenon important to the study of archaeological deposits in north Australian rock-shelters is the origin and nature of sedimentation. Where sedimentation is extremely slow and/or the matrix is fluid in behaviour, chronological resolution is reduced because occupational events are superimposed or artefacts move vertically within the deposit. The result is greater uncertainty about the precise timing of events, which has led archaeologists to discuss changes in terms of broad periods.

Late Pleistocene environmental history and human occupation

Palaeoenvironmental background

Evidence for the Late Pleistocene is derived mainly from four sedimentary sites: Lynch's Crater and Strenekoff's Crater on the Atherton Tableland (Kershaw 1973, 1986, Kershaw et al. 1991a), glacial Lake Carpentaria (Torgersen et al. 1988, McCulloch et al. 1989) and Lake Woods (Jones and Bowler 1980, Bowler 1986). Microfossil and sedimentological records from the former three sites suggest that the late Pleistocene was characterised by moisture levels as low as half those of today. Similar low precipitation is indicated at Lake Woods by the extension of desert dunes over the dry lake surface at this time. These data provide strong support for the climatic model of Nix and Kalma (1972) that proposes that dry conditions prevailed throughout the whole of northern Australia.

Open savannah was the dominant vegetation around both the Atherton Tableland sites and Lake Carpentaria, and rainforest vegetation must have had very restricted distribution. The abundance of charcoal in the sediment cores suggests that fire was a constant and important feature of these environments. Lake Carpentaria itself was fresh-to-brackish and surrounded by extensive herbaceous wetlands similar to those of the black soil plains currently occupying the southern margins of the Gulf of Carpentaria. The exclusion of woody vegetation from these low-lying areas suggests seasonal inundation and it is likely that the rainfall pattern was similar to today's.

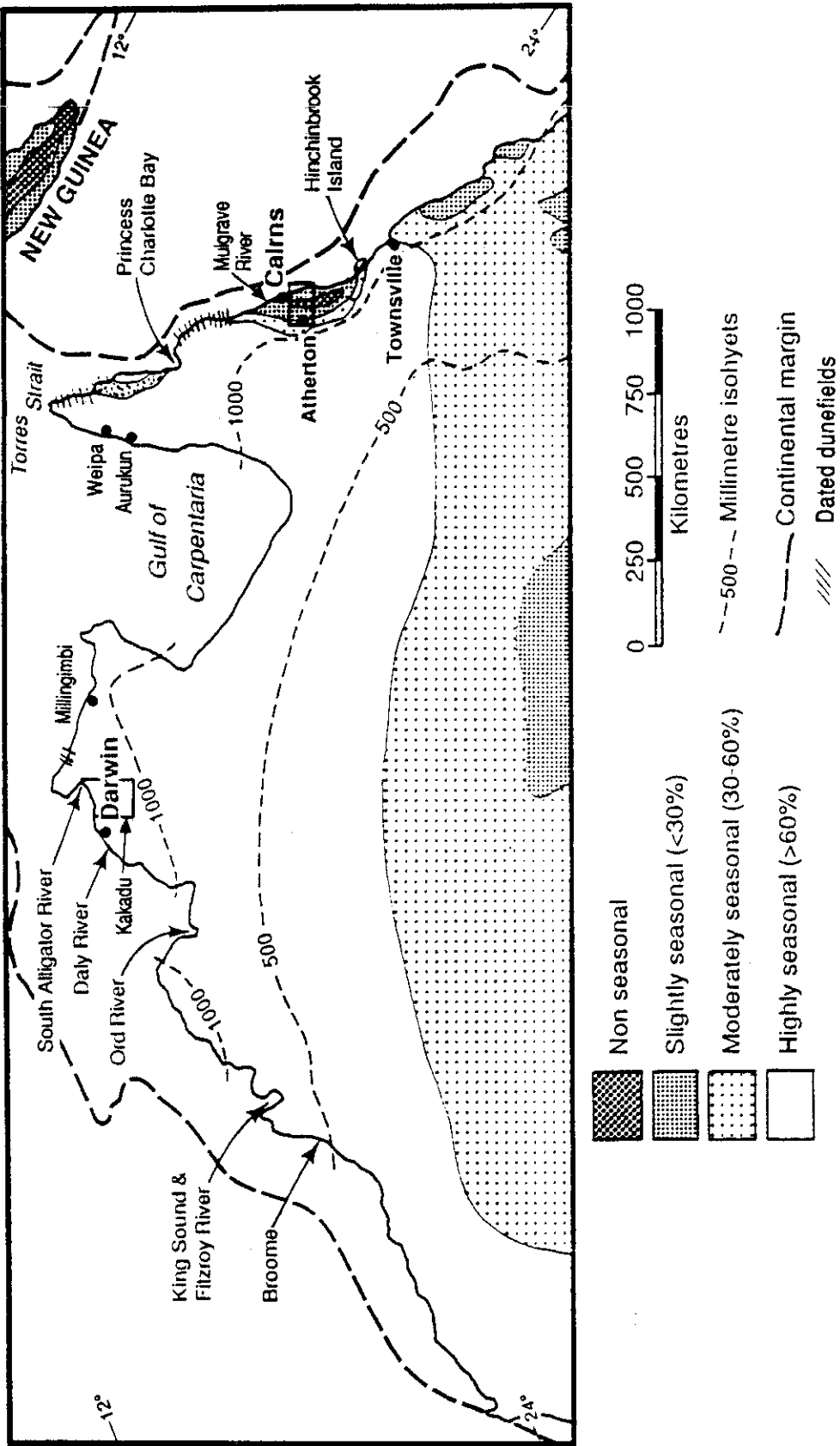


Figure 4.1 The present environment of northern Australia showing the location of key regions discussed in the text.

All records indicate that lowest effective precipitation was achieved around 25 000 years ago but there is little consensus about conditions before this time. Limited data from Lake Woods suggests that pre-existing lake levels were substantially higher than those of today. However, relatively low precipitation, indicated by both lake levels and dry land vegetation, appears to have been maintained from about 80 000 years ago on the Atherton Tableland. Relatively low lake levels existed in Lake Carpentaria back to at least 35 000 years ago. Before this time, environmental interpretations are complicated by marine influences during a high sea level stand. The close proximity of the sea would most likely have resulted in higher precipitation. Some reduction in precipitation may have occurred around 38 000 years ago around Lynch's Crater, as indicated by a fall in lake level and a change in the regional vegetation from araucarian vine forest to savannah. However, as these changes coincide with a massive increase in charcoal particle concentrations, it is considered that an increase in burning was the major cause of the destruction of the drier rainforest. This would have resulted in local hydrological changes affecting the lake basin. However, a minor reduction in precipitation would have facilitated the replacement process. The importance of this environmental change for the Tableland is indicated by complementary evidence from Strenckoff's Crater. In this condensed sequence, the changes are dated at some time prior to 23 000 years ago.

Between about 13 000 and 14 000 B.P., prior to the direct influence of rising sea level on Lake Carpentaria, there is evidence for increased precipitation in this area. This is considered by McCulloch et al. (1989) probably to have been due to a southward migration of monsoon rainfall. This increase is not reflected in sites on the Atherton Tableland where effective precipitation may have been lowest for the late Pleistocene between about 15 000 and 11 000 years ago. Either the monsoon system had not penetrated this far south or its effects were nullified by rising temperatures. Apparently rainfall from the predominant south-east trades within this area had not increased by the end of the Pleistocene.

Colonisation

All of the colonisation models put forward by Australian archaeologists hypothesise that hominids first enter Sahul from the north, either via the New Guinea land mass or directly into north-western Australia. The cause and nature of colonisation is currently ill-defined, although it is becoming clear that the movement of people from Sunda into new lands may have been widespread, and directed eastwards into Melanesia as well as southward into Australia (Allen 1989). What is currently debated is the timing of this colonisation; whether there was an early occupation (60–120 000 B.P.) or a relatively late one (c. 40 000 B.P.), and the implications for the type of hominids involved (archaic or modern *Homo sapiens*).

The debate about the antiquity of colonisation has become polarised in recent years. Archaeologists such as Allen (1989) have argued for a 40 000-year-old date, pointing out that it is consistent with all known radiocarbon dates in Australia, New Guinea and Melanesia. Opposing this view are those of Thorne (1977) and Jones (1979), for example, who argue for a much older colonisation, pointing out that it is consistent with certain interpretations of the robust features on Pleistocene Australian skeletons—the 'mark of ancient Java' in Weidenrich's (1946) terms.

This debate is now being waged over Kakadu National Park in northern Australia. Roberts et al. (1990) have recently announced that thermoluminescence dates on artefact-bearing sandy sediments from Malakunanja II, a rock-shelter in the Arnhem Land escarpment, reveal human occupation between 50 000 and 60 000 years ago (see Figure 5.17, Chapter 5). They have also suggested that these dates mark the time of initial human arrival in the Sahul. Responses to this interpretation from Bowdler (1990), Frankel (1990) and Hiscock (1990), have highlighted the weakness of the claim. It is suggested that, for the period beyond 10 000 B.P., thermoluminescence dates overestimate actual age (Hiscock 1990). Furthermore, the statistical uncertainties (standard deviations) connected with these thermoluminescence dates are so great that they are difficult to interpret. For example, the dates from Malakunanja II merely indicate that artefacts are between 19 000 and 85 000 years old, which is of little help in evaluating the two views of colonisation (Hiscock 1990). However, the observation that there appears to be a hiatus in sedimentation between about 20 000 and 40 000 B.P. has been used to suggest that occupation at Malakunanja is probably late, and that stone artefacts have moved downwards into pre-human levels of the deposit as a result of prolonged disturbance to the stable shelter floor (Hiscock 1990). If this is the case, then the Kakadu evidence supports information from elsewhere in Australia and Melanesia in suggesting that modern *Homo sapiens* colonised the region about 40 000 years ago.

Palaeoenvironmental evidence does little to help resolve this debate. Through most of the period 120 000 to 40 000 B.P., sea levels were lower than today and this would have facilitated movement into Australia, particularly from New Guinea where there was almost continuous land connection. The increase in burning, dated at Lynch's Crater to 38 000 years ago, may be of some significance. The most likely cause of this was fires lit by Aboriginal people and it adds some support to the view that colonisation of this part of tropical Australia was relatively late.

It is puzzling that, while colonisation is thought to have taken place initially in the north, sites in the southern portions of the continent are generally older than those in the north. Conventional radiocarbon dates from the well-studied Kakadu National Park have not been older than 25 000 B.P., while sites in the south, such as Lake Mungo, Upper Swan and Devils Lair have given dates of 35–40 000 years. A common explanation of this phenomenon has been that sites in the south are near a stable coastline, and that we are still able to see the early phase of colonisation, whereas in the north, the massive lateral shift in Holocene sea level (moving hundreds of kilometres inland) has drowned early sites. It is interesting to note also that in a palynological study at Lake George near Canberra, similar to that at Lynch's Crater, a much earlier date has been proposed for a substantial increase in burning attributable to the activities of Aboriginal people (Singh and Geissler 1984). Although the original date of about 120 000 B.P. has been brought into question (for example, Wright 1986, Kershaw et al. 1991b), it is still possibly older than 40 000 B.P.

Late Pleistocene environments and human settlement

One of the earliest ecological/economic strategies of humans in Australia might have been the use of fire as an agent in vegetation management. As previously mentioned, this may be indicated by increased charcoal levels in the Lynch's Crater pollen diagram from 38 000 years ago, shortly after the likely time of arrival of people on the continent. There

has been some debate about the significance of this event—whether or not it does represent a change in fire regime and, if it does, whether this was caused by people or climate. Horton (1982) in particular argues that Aboriginal people would have had little impact on the plant landscape, largely because ‘fire-stick farming’ would have affected food resources adversely—particularly the supply of small mammals. However, considering the sustained vegetation changes associated with the increase in charcoal and the lack of a similar change during the previous dry, glacial period, Aboriginal firing must be considered the most likely explanation. The more recent evidence from Strenckoff’s Crater further demonstrates that this was a regional feature. The most likely scenario is that Aboriginal people had a major initial impact, perhaps before the realisation of the dramatic effects of fire and the establishment of management strategies. The resulting, more fire-tolerant or fire-promoting vegetation would then have supported higher burning levels, regardless of whether the fire regimes were natural or anthropogenic.

Some support for widespread vegetation disturbance through human firing regimes may be found in archaeological sites. In several areas across northern Australia the appearance of artefacts in rock-shelter deposits coincides with increased sediment deposition rates, raising suspicions that soil erosion may have been caused by human activities. In north-west Queensland, a large limestone cave on Louie Creek with a basal layer radiocarbon dated to approximately 19 000 B.P. has artefacts extending down to bedrock, and Hiscock (1988) has interpreted this pattern as an increase in the rate at which sediment entered the cave after human activity in the local area becomes archaeologically visible. A similar trend, although on a larger scale, has been documented along the western edge of the Arnhem Land escarpment. At some sites, such as Nauwalabila and Malangangerr (see Figure 5.17, Chapter 5), sand deriving from the nearby sandstone plateau began accumulating at the same time as the initiation of human occupation (Hope et al. 1985). Large quantities of sand from the escarpment face and top filled not only rock-shelters, but also the floor of narrow valleys, again in the same period as human occupation. Hope et al. (1985) argue that human activities, especially firing, were a major factor in the erosion that led to this valley infilling.

Further evidence for human modification of Pleistocene vegetation patterns may come from the tool kit recovered during excavations. Stone axes from the Pleistocene are found across northern Australia and New Guinea (Morwood and Trezise 1989), and these artefacts are usually thought to reflect woodworking and forest clearance activities (Hayden 1977, Groube 1984). The suggestion by Morwood and Trezise (1989) that the Pleistocene edge-ground axes were one solution to problems in scheduling activities, matches Schrire’s (1982) descriptions of Pleistocene axes in Arnhem Land rock-shelters being stored along the shelter wall. A more complete understanding of the role of axes in landscape modification requires further investigation.

All of the Pleistocene archaeological sites known in northern Australia are rock-shelters, with faunal remains generally poorly preserved, and so there are few indicators of subsistence activities. Excavations at the Mandu Mandu Creek rockshelter, near the Exmouth Gulf in Western Australia, have demonstrated that between 25 000 and 19 000 B.P. people were exploiting coastal resources such as fish, turtle, crab, and shellfish (Morse 1988). Bowdler (1977) has hypothesised that this sea food component of the diet is a continuation of the original coastal orientation of the people who colonised Australia. Evidence for regional breaks in the exploitation of marine foods during the Holocene, due to fluctuations in sea levels, now challenges the notion of a continuous pan-continental

coastal adaptation throughout the whole of the Pleistocene period of occupation (Beaton 1985). Nevertheless, it is clear that marine environments were a valuable resource zone for human inhabitants of the Pleistocene coastline.

Although it was once thought that Pleistocene occupation was restricted to coastal regions (Bowdler 1977), it is now known that, prior to the last glacial maximum, humans had occupied many environmental zones across inland Australia (for example, Maynard 1980, Hiscock 1984, 1988, Brown 1987, Smith 1989). Human adjustment to rapidly changing environmental conditions was less than complete, however, and there is good reason to conclude that, at the last glacial maximum, large areas of arid and semi-arid northern Australia were abandoned in the face of increasing desertification. The best example of this response to climatic change comes from the edge of the Barkly Tableland in north-west Queensland, where several limestone caves reveal evidence of the contraction of group territory to oasis areas, excluding the poorly watered plains to the north (Hiscock 1988).

A similar claim has been made for the Pleistocene levels of rock-shelters along the Arnhem Land escarpment. In forming her coastal colonisation model, Bowdler (1977) noted that in the Arnhem Land sites then excavated, there were no radiocarbon dates from the period of the glacial maximum at 18 000 B.P. to the Holocene. Bowdler also noted that at Malangangerr there was only 10 cm of deposit between a date of 18 000 B.P. and the base of the midden dated to 5980 B.P. This would be consistent with a stratigraphic and occupational break. Another such break between about 20 000 and 7000 was observed by Schrire (1982) at nearby Nawamoyrn shelter (see Figure 5.17, Chapter 5). Bowdler used these data to conclude that '...the early inhabitants of the plains sites were exploiting a river system which then dried up considerably, and they retreated to the coast'.

More recent excavations, by Kamminga and Allen (1973) and Jones and Johnson (1985b), have reinforced this picture, albeit with slight modification. Malakunanja II has radiocarbon dates of $18\,040 \pm 300$ and $13\,390 \pm 400$ but no dates between (a gap of about 40 cm). Excavations at Nauwalabila I have dates of $12\,000 \pm 600$ and $13\,195 \pm 175$, and then a date of $19\,975 \pm 365$ separated by 10–40 cm of deposit. So it remains possible to argue that the rock-shelter sites in Kakadu were abandoned during the glacial maximum.

However, it is not clear that the absence of radiocarbon dates in that period necessarily means abandonment. The short depth between Pleistocene and Holocene dates in Schrire's (1982) excavations probably does imply lack of occupation in those sites. But Malakunanja II and Nauwalabila I both have about 40 cm of deposit which is undated. Artefacts are found in this portion of the deposit and there is no stratigraphic indication of abandonment. In these sites it is equally possible that there was occupation during the glacial maximum, but that the excavators have created an apparent gap by dating the lowest cultural levels rather than obtaining a sequence of dates. Furthermore, since the available evidence from swamp and lake sediments elsewhere in northern Australia indicates a much longer period of aridity than the inferred abandonment of archaeological sites in Kakadu, it is possible that factors other than, or additional to, aridity were contributing.

Although preservation of organic archaeological materials is relatively poor for the Pleistocene, added details about economy and technology are available from art surviving from the period. At least during the latter part of the period, rock art was practised across northern Australia; this is evidenced by the fragments of ochre and haematite with ground faces, containing striations which are found well below a radiocarbon date of $19\,000 \pm 365$ in Nauwalabila I, and estimated to be 25–30 000 years old by Jones and Johnson (1985a).

They argue that the ground surfaces on these fragments is strong presumptive evidence of their use as iron ore 'crayons' to prepare paint for rock art. This evidence supports inferences of art in Kakadu at least 25 000 years ago.

Despite the rarity of absolute dates (cf. Loy et al. 1990), several researchers have claimed a Pleistocene age for rock paintings along the Arnhem Land escarpment (Chaloupka 1984, 1985; Lewis 1988). These claims are based on the existence of distinctive painting styles, containing images of extinct animals, which are visibly weathered and overlain by other figures. There have been several intriguing observations of this early art. Boomerangs, which are known from Pleistocene swamp deposits in southern Australia (Luebbers 1975), are depicted in early Arnhem Land art, but are not represented in later rock art and were not historically. Lewis (1988) suggests that the boomerang figures ceased being created in the early Holocene as rainfall significantly increased. While a denser woodland cover may have reduced the effectiveness of the boomerang, Lewis suggests that abandonment of this tool may have resulted from a shift in socio-economic strategies in response to climatic change. By analogy with recent desert communities, Lewis argues that the uniformity and widespread occurrence of the boomerang paintings indicates that, in the aridity of the glacial maximum, the socio-economic organisation involved large territories and an emphasis on social integration achieved by adoption of similar art works. With the climatic amelioration, populations would have increased, leading to group fissioning and, as local identity was stressed, to the loss of region-wide items of material culture or artistic symbols.

The depiction of various animals in the rock art of Arnhem Land has been used to indicate faunal change during the period of human occupation, and to reveal the animals that were significant to artists (Murray and Chaloupka 1984). Although the identification of species from rock art is not without problems (cf. Chaloupka and Murray 1986, Lewis 1986), this approach raises three issues of interest. Firstly, all of the animals represented in the Pleistocene and early Holocene rock art are terrestrial species (Murray and Chaloupka 1984), providing confirmation that at this time humans were extremely familiar with non-coastal landscapes in which they lived. Secondly, the representation of genera such as *Zaglossus*, *Protemnodon*, *Sthenurus*, and *Thylacoleo*, is evidence of the co-existence of humans and the large extinct 'megafauna'. Thirdly, the portrayal of thylacines, and perhaps the dingo, raises the question of the role of humans in the extinction of the thylacines on mainland Australia.

The relationship between humans and megafauna is a contentious subject. It has variously been hypothesised that over-exploitation of megafauna led to extinctions soon after humans arrived in Sahul, that the indirect effects of human activities (especially burning) created environmental conditions unfavourable to megafauna, and that, after a long co-existence with humans, the megafauna were unable to cope with progressively drier conditions and became extinct due to natural causes in the terminal Pleistocene (Horton 1980, Flannery 1990). While the late dates for megafauna in eastern Australia appear to support the proposition that humans may have had little direct role in the extinctions (cf. Horton 1990, Wright 1990) the proposed changes in vegetation due to Aboriginal burning may have altered moisture regimes sufficiently to cause extinction through the creation of a more arid environment at the height the last glacial period than had been experienced during previous dry, glacial periods (Kershaw 1989). However, before it can be determined that the timing and causes of extinction were identical over the whole continent, much more, and dated, information is required.

In northern Australia, archaeological deposits more than 15–20 000 years old typically have modern fauna (Schrire 1982, Campbell 1984, Hiscock 1988) and perhaps the 'exotic' megafauna (excluding *Sarcophilus* and *Thylacinus*) were locally extinct at a relatively early time. However, both the Tasmanian devil and Tasmanian Tiger survived into the middle Holocene and may have been adversely affected by competition with the dingo, which was introduced into Australia by humans sometime before 4000 B.P. (Gollan 1984).

Holocene environmental history and human occupation

Palaeoenvironmental records

The much larger number of records available for the Holocene than for the late Pleistocene allows more detailed reconstruction of palaeoenvironments. However, the evidence is still concentrated in sites from the Atherton Tableland and from coastal areas.

The Atherton Tableland

Palynological records covering substantial parts of the Holocene have been derived from Lake Euramoo (Kershaw 1970), Quincan Crater (Kershaw 1971), Bromfield Swamp (Kershaw 1975), Lynch's Crater (Kershaw 1983a), Lake Eacham (Goodfield 1983) and Lake Barrine (Chen 1988, Walker and Chen 1988). The location of these sites in relation to major environmental variables is shown on Figure 4.2. All occur along the steep rainfall gradient from the coast inland, and on the rainforest side of the main rainforest/savannah woodland boundary that approximates the position of the 1300 mm isohyet. A regional synthesis of these records is attempted here with the aid of summary diagrams incorporating some of the more common features of the records (Figure 4.3).

As indicated from the earlier part of the Lynch's Crater record, conditions were much drier than today within this area in the later part of the Pleistocene, with savannah woodland dominating the vegetation. An increase in effective precipitation is indicated at, or slightly before, 10 000 years ago by the beginning of organic sedimentation in Lake Euramoo and Bromfield Swamp, evidence for more permanent lake conditions at Lake Barrine, and a surge in swamp growth at Lynch's Crater. The later date of about 7000 B.P. for the beginning of organic sedimentation at Quincan Crater may be explained by different hydrological conditions in the crater of this scoria cone from those at the other maar sites. In any case, it demonstrates that the regional precipitation was still increasing until at least 7000 years ago. Support for precipitation levels during the early Holocene being lower than those of today is provided by the ephemeral nature of the swamp vegetation at most sites.

Rainforest re-invaded the Tableland, or expanded from refugia within the present rainforest range, in response to this precipitation increase. The time of arrival of rainforest around each of the sites could have been directly related to the achievement of suitable moisture levels. However, as the time of arrival does not appear to have been related to dates for the beginning of organic sedimentation at each of the sites, the critical factor may have been the time taken for migration of rainforest from refugia (Ash 1983). Fire was an additional factor. From the records of charcoal from Lake Barrine and Lynch's Crater, it appears that as the density of sclerophyll vegetation increased with rising precipitation, fires became more intense, effectively inhibiting the rate of rainforest advance. The closely radiocarbon-dated sediments from Lake Barrine suggest that low-

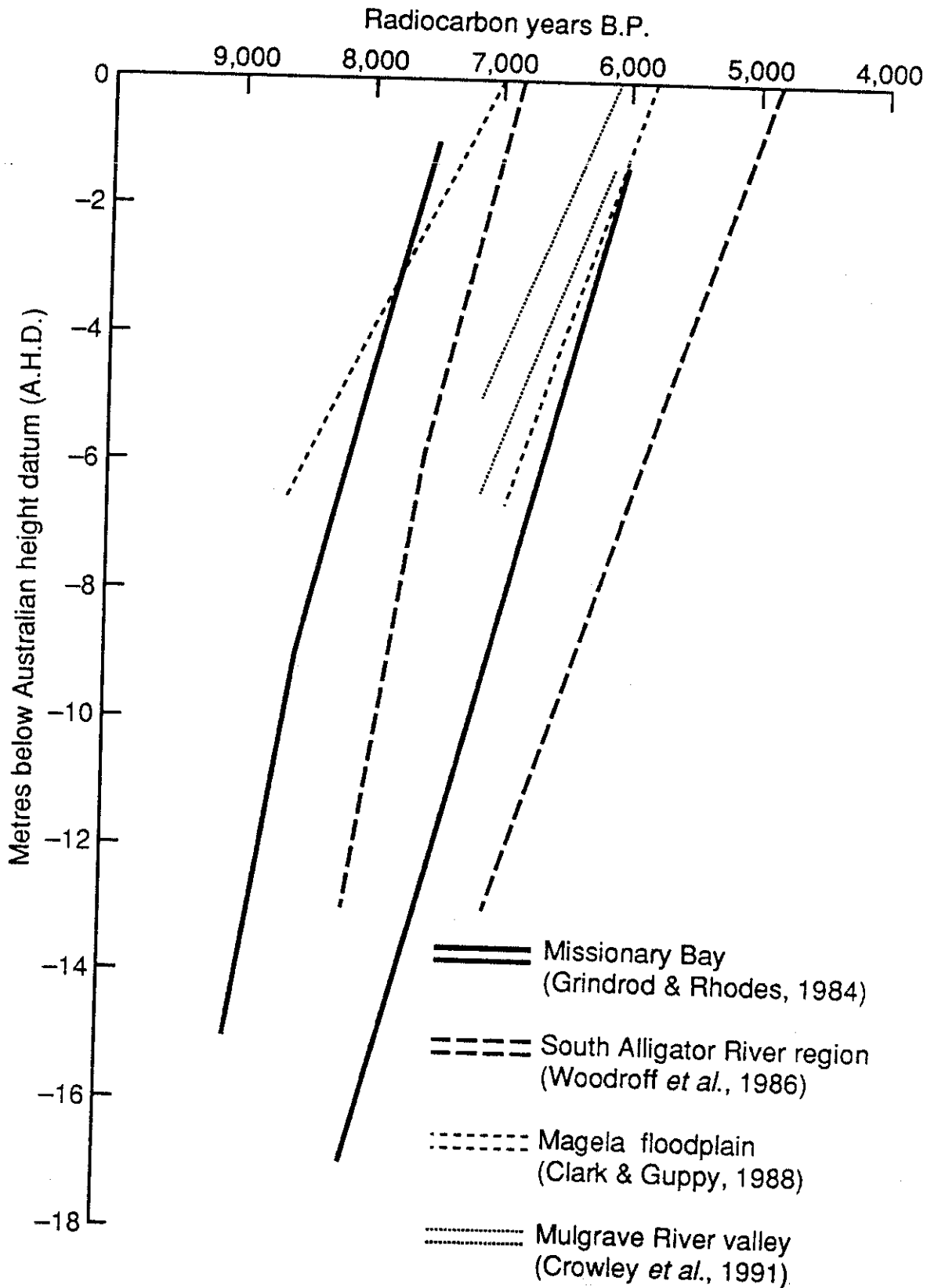


Figure 4.2 The Atherton Tableland and Mulgrave River region of northeastern Queensland, showing palaeoecology sites in relation to major environmental variables.

intensity fires occurred about every fifty years during the early Holocene savannah phase, but increased in intensity with a lower frequency (every 230 years or so) during the period of rainforest colonisation (Chen 1988). There is no firm indication of the location of the sources of the colonising rainforest but these may be revealed by detailed analysis and dating of charcoal preserved in the present rainforest soils (Ash 1988).

The actual replacement of sclerophyll vegetation by rainforest around the sites is estimated to have taken between about 400 and 1000 years (Figure 4.3, phase B) and to have been completed regionally by about 6000 B.P. The rainforest component is characterised, at most sites, by relatively high levels of Cunoniaceae pollen, indicative of 'temperate' or high altitude rainforest. *Rapanea* pollen also has its highest representation here in all but the Lynch's Crater record. Its abundance increases along the present moisture gradient, and it appears to have effectively replaced Cunoniaceae as the major pollen taxon around Lynch's Crater. Comparison of modern and fossil pollen data suggests that mean annual precipitation was similar to present but temperatures may have been 2-3°C lower than today (Kershaw 1973). Results of bioclimatic analysis of taxa from Lake Euramoo support this climatic reconstruction and further indicate that temperatures were

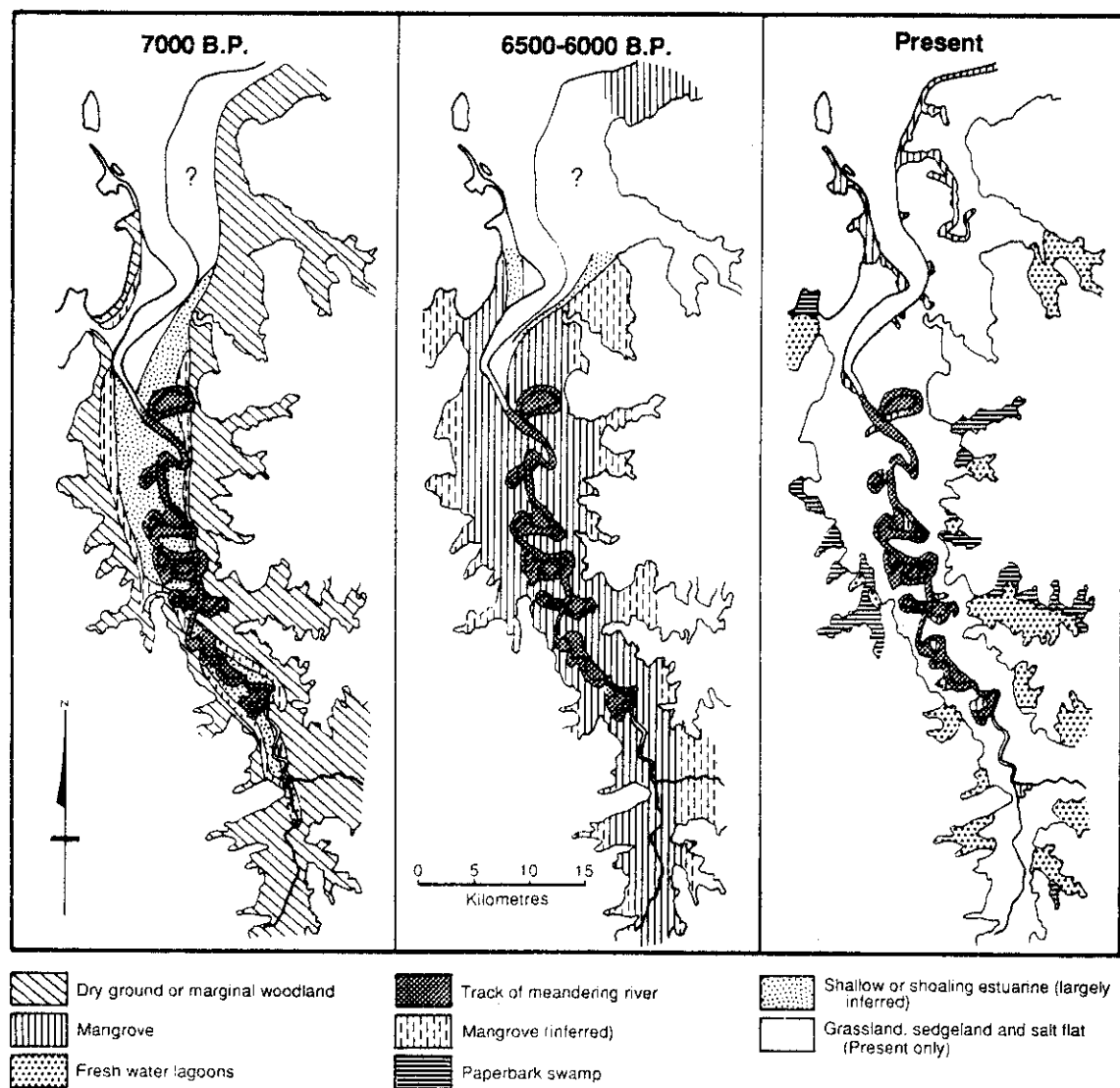


Figure 4.3 A synthesis of pollen analysis records from the Atherton Tableland of northeastern Queensland. For details see text.

lower than today during both summer and winter while rainfall was higher during the winter (Kershaw and Nix 1988). It is possible that the cloud cover was lower and that mist and drizzle were more prevalent during winter.

Around 6500–5900 B.P. rainforest achieved its maximum extent. This coincided with an increase in *Elaeocarpus* relative to Cunoniaceae and *Rapanea* pollen values in all but the Lynch's Crater diagram. From surface sample data, *Elaeocarpus* pollen has its major representation in lower altitude forests and comparisons of surface and fossil pollen spectra indicate that temperatures achieved approximately present day levels while precipitation levels were substantially higher. The bioclimatic analysis of taxa from Lake Euramoo suggests that summer temperatures may have been slightly higher than today while rainfall continued to be high during the winter. The attainment of very high levels of *Rapanea* pollen at Lynch's Crater appears to indicate very different conditions there. However, from plant macrofossils preserved in the peat, it has been demonstrated that most pollen was derived from local swamp forest; this component effectively masked representation from the surrounding dry land vegetation.

Some information on the nature and rates of expansion of individual tree populations during this earlier part of the rainforest phase are provided by Chen (1988) from Lake Barrine. Time of arrival of taxa and development of their populations around the site were influenced by individual taxon characteristics. Population doubling time took between sixty and 165 years for major angiosperms and between 200 and 350 years for the conifers *Agathis* and *Podocarpus*. The majority of taxa expanded in an exponential fashion, apparently free from competition from other species, although competition is used to explain the logistic model of increase in some populations. Data of this kind can be used to provide information on distributional patterns of plants within the existing forests.

A number of changes occurred around 5000–4500 years ago. At Lake Euramoo, there was a sustained rise in pollen of the emergent conifer *Agathis*, while at Quincan Crater pollen values of the early successional taxon, Urticaceae/Moraceae, increased substantially. These changes may have been promoted by an opening of the canopy, perhaps due to an effective reduction in precipitation. This proposal is supported by an apparent fall in water level at Bromfield Swamp indicated by a change from open water to swamp and by some slight expansion of sclerophyll vegetation at all sites, but paradoxically, highest Holocene lake levels are suggested at Lake Euramoo and Quincan Crater. Destruction of the swamp forest on Lynch's Crater occurred at about 4500 B.P. and, although this appears to have been caused by fire, as indicated by a sudden appearance and sharp increase in charcoal particles, a change to drier conditions may have facilitated this burning. However, it is unlikely that naturally-occurring fires could have had such a marked impact; and an anthropogenic cause, whatever the reason, is much more likely, especially as complex rainforest was maintained around the site. It is possible that there was a general increase in human activity around this time and that most changes are attributable to greater levels of disturbance rather than climatic change.

There is also some conflict between climatic estimates derived from surface sample data and bioclimatic analysis of Lake Euramoo taxa between about 5000 and 3000 years ago (Figure 4.3, phase E). Pollen analysis of modern surface samples indicate that the fossil pollen show some rainfall and temperature variability until about 4000 B.P., with values ranging from present day levels to significantly higher than today. After this time, results are in accord with those of the bioclimatic analysis for the whole period which

indicates significantly higher precipitation levels than today, particularly in the summer months, and the highest all-year-round temperatures for the Holocene.

There is less conflict over conditions existing during phase F (Figure 4.3). The beginning of the phase is marked in all diagrams by an increase in sclerophyll pollen values and, in all but the Lynch's Crater diagram, by significant increases in the rainforest margin taxon, *Macaranga/Mallotus*. Reductions in water levels within the sites are also indicated by an expansion of marginal swamp over open water at Lake Euramoo, and by the fixation of floating swamp mats at Quincan Crater and Bromfield Swamp. There is also a sharp change in composition of the swamp vegetation at Lynch's Crater. This regional change is tightly dated to about 3000 B.P. in all diagrams except for Bromfield Swamp. Here, low pollen concentrations inhibited counting of sufficient pollen to produce statistically meaningful results. Climate was the most likely cause of all recorded changes, with both surface sample comparisons and the bioclimatic analysis indicating a general decrease in precipitation and slight decrease in temperatures to present levels. However, charcoal counts from Lynch's Crater indicate that burning continued through this period and may have aided the expansion of sclerophyll vegetation. Problems associated with collection of topmost sediments or disturbances to the most recent sediments have prevented full documentation of the last one or two thousand years. However, there is some indication from Lake Euramoo that the driest conditions may have occurred between about 2600 and 1400 years ago.

More detailed information on the last few thousand years will be provided by the fine-resolution studies being undertaken by Professor Walker of the Australian National University. Here, all components of the Lake Barrine catchment are being monitored to understand processes involved in pollen representation within the lake basin. This in turn will provide the basis for determination of the dynamics of rainforest vegetation within the catchment.

Coastal plains

A number of stratigraphic studies have been undertaken on coastal plain sediments from northern Australia, the most recent of which have incorporated palynology to allow better definition of sedimentary facies and their relationship to existing sea level (Grindrod 1988). They also provide a broader picture of changing vegetation and environments. The locations of these studies are shown on Figures 4.1, 4.2 and 4.4. They include estuaries of major rivers and sheltered inlets. Earliest information, dating from about 9000 B.P., is provided by basal Holocene core sediments off the Hinchinbrook Island coast (Grindrod and Rhodes 1984). These unconformably overlie Pleistocene sediments and there is no evidence of Holocene sedimentation until the arrival of marine conditions around the coring sites. Brackish water-swamp sediment heralds the initial presence of the sea at two sites but domination by *Rhizophora* pollen at the other sites indicates the rapid invasion of mangrove vegetation at the marine transgression.

A number of continuous sedimentary and pollen records from present-day onshore sites provide details of vegetation and environmental changes through the latter part of the marine transgression and subsequent land progradation through sediment infilling. Selected summary diagrams from investigated areas are shown on Figure 4.5, together with inferred vegetation around the coring sites. Regional environmental reconstructions for critical periods within the intensively-studied South Alligator River plain are portrayed on Figure 4.6.

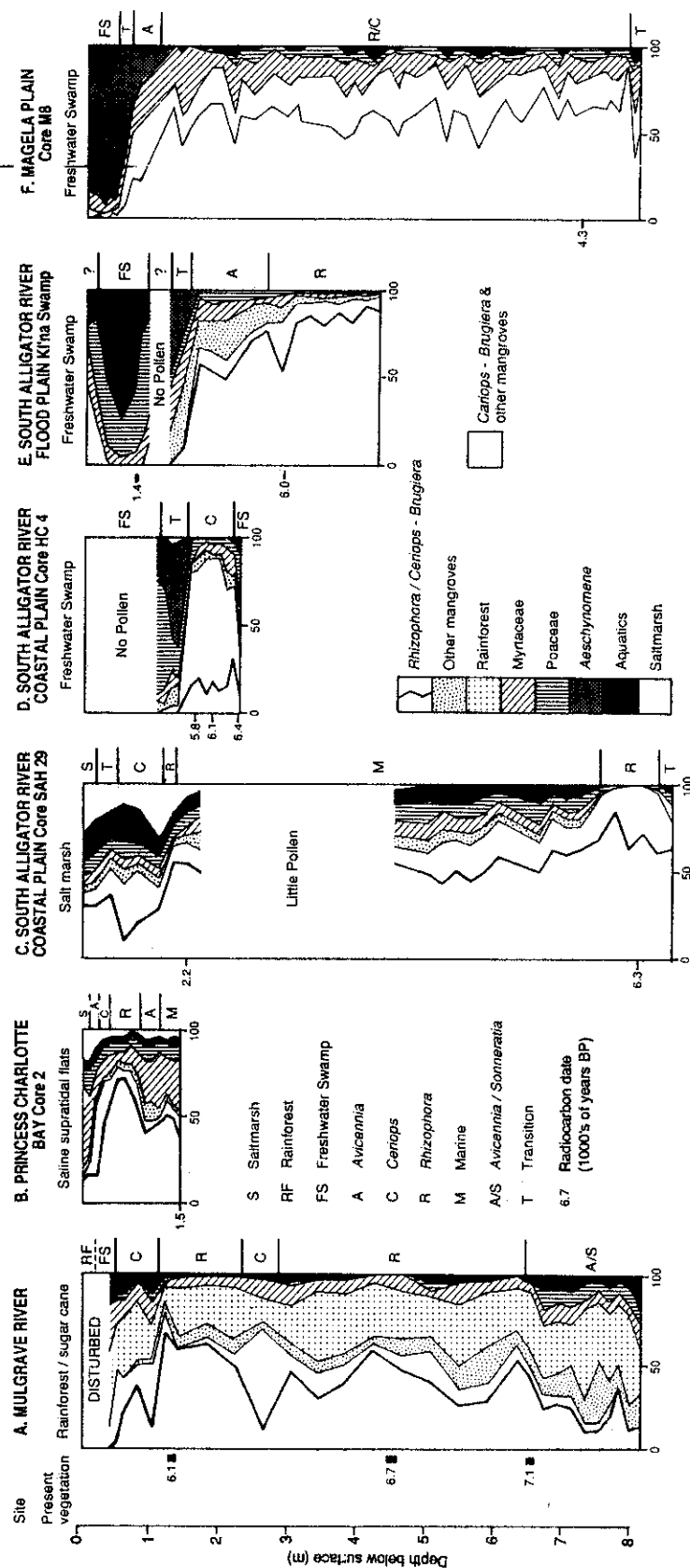


Figure 4.4 The Alligator rivers region of the Northern Territory showing the locations of pollen analysis sites in relation to the coastal, estuarine and alluvial plains.

The first evidence for the marine transgression is marked in the Mulgrave River Valley and in the Alligator Rivers region by the significant presence of aquatics and Poaceae. Together, these indicate the development of fresh-to-brackish water swamp. Myrtaceae values are also relatively high; one component may have been derived from *Melaleuca*, providing additional evidence for swamp conditions, but it is likely that the majority of pollen is from *Eucalyptus*, indicating the close proximity of open eucalypt woodland to

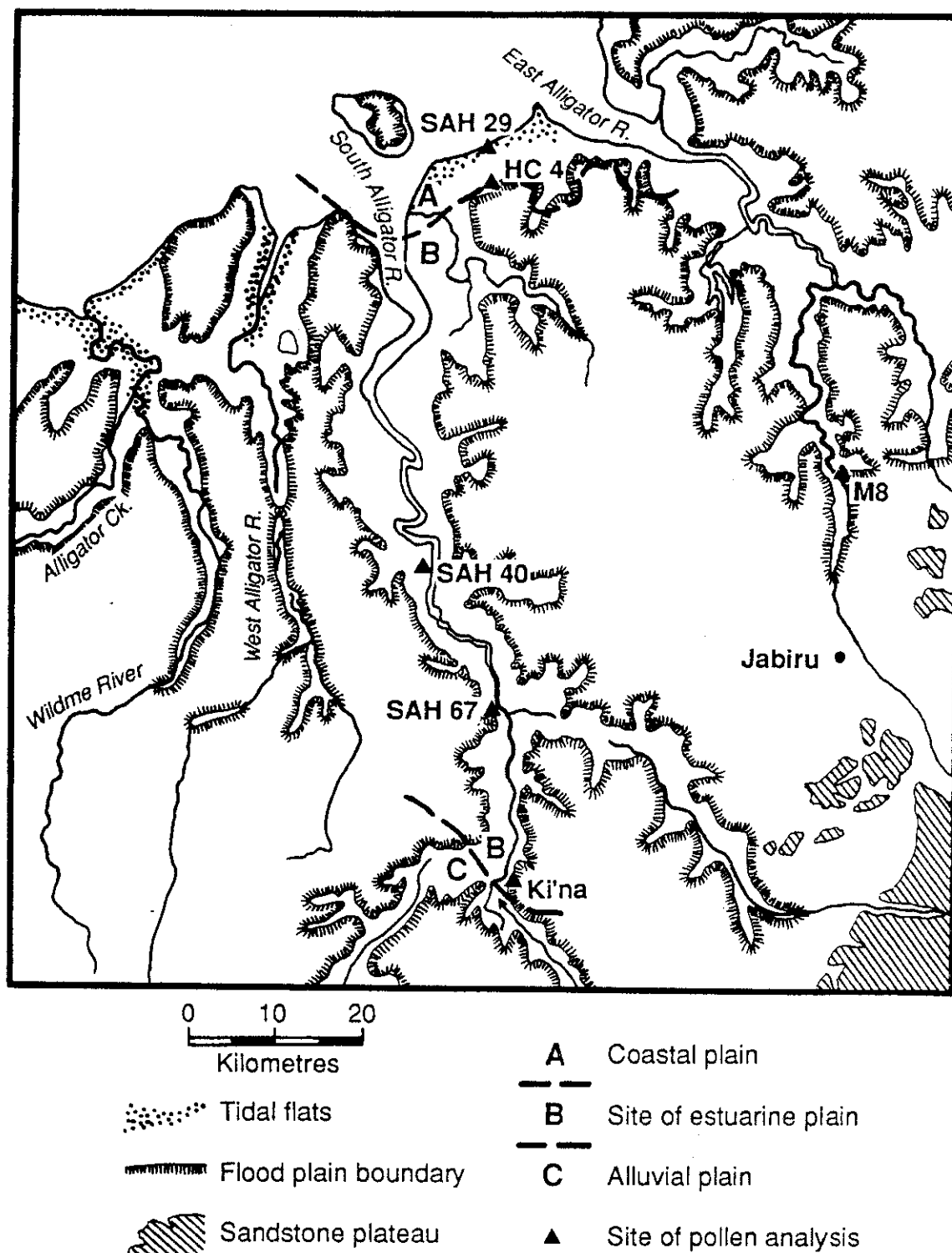


Figure 4.5 A synthesis of pollen analysis records from northeastern Queensland and the Alligator rivers region of Northern Territory. For details see text.

the sites. Mangroves were present in the vicinity, but probably had restricted distribution. The reconstruction from extensive coring over the South Alligator River plain suggests that around this time (c. 7000 B.P.) much of the plain was dry land, perhaps covered with eucalypt woodland. Marine or estuarine conditions were confined to the area immediately around the present meandering river, and the estuary was flanked by a narrow belt of mangroves. In the Mulgrave River Valley, rainforest may have been an important dry land vegetation component, though much of the pollen could have been derived from the extensive highland catchment. The abundance of *Sonneratia lanceolata*, together with significant presence of *Avicennia* and *Aegiceras corniculatum*, suggest a fresh-to-brackish water, riverine, mangrove association over the site at this time (Crowley et al. 1990).

Rapid sedimentation from about 7000–6000 years ago indicates continuing sea-level rise. (The date of 4300 B.P. from the Magela Plain is explained as representing subsequent channel infill sediment (Clark and Guppy 1988). This period is dominated by Rhizophoraceae pollen in all diagrams, indicating the proximity of extensive mangrove forests. Pollen concentrations of Rhizophoraceae, particularly *Ceriops*, are sufficiently high in most diagrams to suggest that mangroves were on site and that sedimentation kept pace with sea-level rise. Exceptions are the cores from Princess Charlotte Bay and

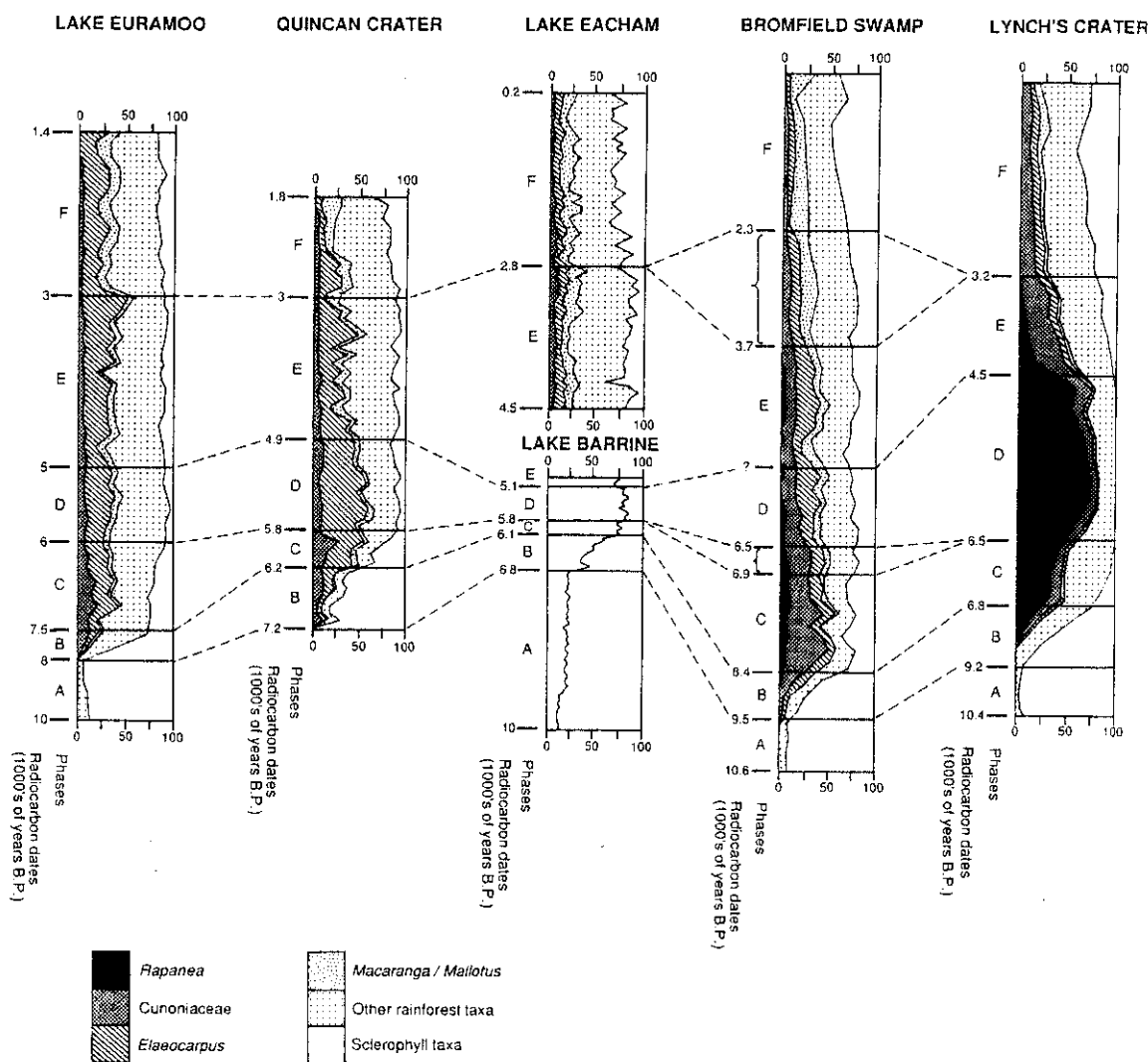


Figure 4.6 Regional environmental reconstructions for 7000 B.P. and 6500 to 6000 B.P., in comparison to the present, for the South Alligator River plain.

the seaward side of the Alligator River plain (Core SAH 29), where open marine conditions would have prevailed. The reconstruction for 6500–6000 B.P. from the South Alligator River system gives some indication of the extent of mangrove development during this 'big swamp phase' (Woodroffe et al. 1985).

After this time, a substantial reduction in the rate of sediment accumulation, accompanied by a transition to dry land or fresh water swamp vegetation, indicates shoreline progradation under stable sea-levels. The successional sequence varied from site to site, but initially involved changes in mangrove representation from what are now more seaward to landward communities. Princess Charlotte Bay Core 2 illustrates the most complete zonal sequence. Here, open marine environments were replaced progressively by a seaward *Avicennia* zone, a *Rhizophora* zone, a *Ceriops/Brugiera* zone and a landward *Avicennia* zone. In other diagrams, the *Ceriops* and landward *Avicennia* zones are missing or difficult to detect. Continued sediment accumulation resulted in the development of fresh water swamps in estuaries and salt flats or saltmarshes adjacent to the coast, while mangroves presumably became restricted to their present habitats. Further succession is indicated in the Mulgrave River Valley where rainforest was present at the site of the core before the area was cleared for sugar cane. This must have replaced the freshwater swamp forest recorded at the top of the pollen analytical sequence. A recent increase in mangrove pollen in the Ki'na Swamp core could suggest a re-invasion of mangroves. However, as there is no *Rhizophora* community close to the site today, the presence of this pollen is attributed either to occasional salt water incursions or to reworked material from older mangrove sediments (Hope et al. 1985).

Some indication of the diversity of environments represented during this progradation phase is provided by the study of the South Alligator River Estuary. Drilling here has identified spatial variation in rates and timing of succession after the 'big swamp phase' of c. 6800–5300 B.P. The replacement of mangroves occurred progressively from 5300–4000 years ago. Diversity was largely created by the development and subsequent changes to the river system. Initially, there was a sinuous, meandering tidal river, evident today in the landscape as palaeochannels. The youngest known of these were active until about 1300 years ago. There was then a transition to the present cusped river, with channel-widening evident within the last 1000 years (Woodroffe et al. 1986).

Data on sea-level changes derived from the major study areas are shown on Figure 4.7. Despite the variables involved in sea level reconstruction which include regional differences in hydro-isostatic adjustment (Chappell et al. 1982), mangrove sediment compaction (Chappell and Grindrod 1984), differences associated with tidal ranges (Woodroffe et al. 1986) and channel effects (Clark and Guppy 1988) and errors associated with radiocarbon dating, there is fair agreement between the sites on the rate and timing of sea level rise. It appears that sea level rose sharply from about 13–6 m below present levels about 8–7000 years ago, and then rose slightly more gradually after this time, reaching today's level around or slightly before 6000 B.P. There is no evidence for significant change since this time; however, studies from other northern coastal environments indicate that sea level has fallen by as much as 2 m (Chappell and Thom 1986). In the most detailed study, based on intertidal coral micro-atolls preserved within reef flats of the Great Barrier Reef, a steady fall of sea level from about 1 m above present level is indicated over the last 6000 years (Chappell et al. 1982). It is considered that there was regional variation in sea-level change as a result of differential crustal

movement across northern Australia due to hydro-isostatic adjustment to post-glacial sea level rise (Chappell et al. 1982).

In contrast with the predominantly fine-grained deposits of the northern coasts are the siliceous and calcareous dunes and ridges. Although there is debate over the conditions responsible for the formation of these features, some authors consider that they can provide some evidence of past climates. A major phase of dune building between about 24 000 and 17 000 years ago is attributed primarily to a large sand supply for aeolian transport during the low-sea-level phase of the last glacial period. However, a sparse vegetation cover under low effective precipitation would have facilitated dune formation (Lees et al. 1990). A cluster of dates on siliceous dunes around 8500–7500 B.P. is considered to represent stabilisation of coastal dunes during the marine transgression as a result of an increase in precipitation (Lees et al. 1990). Finally, a regional concentration of dates for both siliceous dunes and chernier ridges 2700–1800 years ago is taken as an indication of reduced wet-season precipitation (Lees and Clements 1987, Lees et al. 1990).

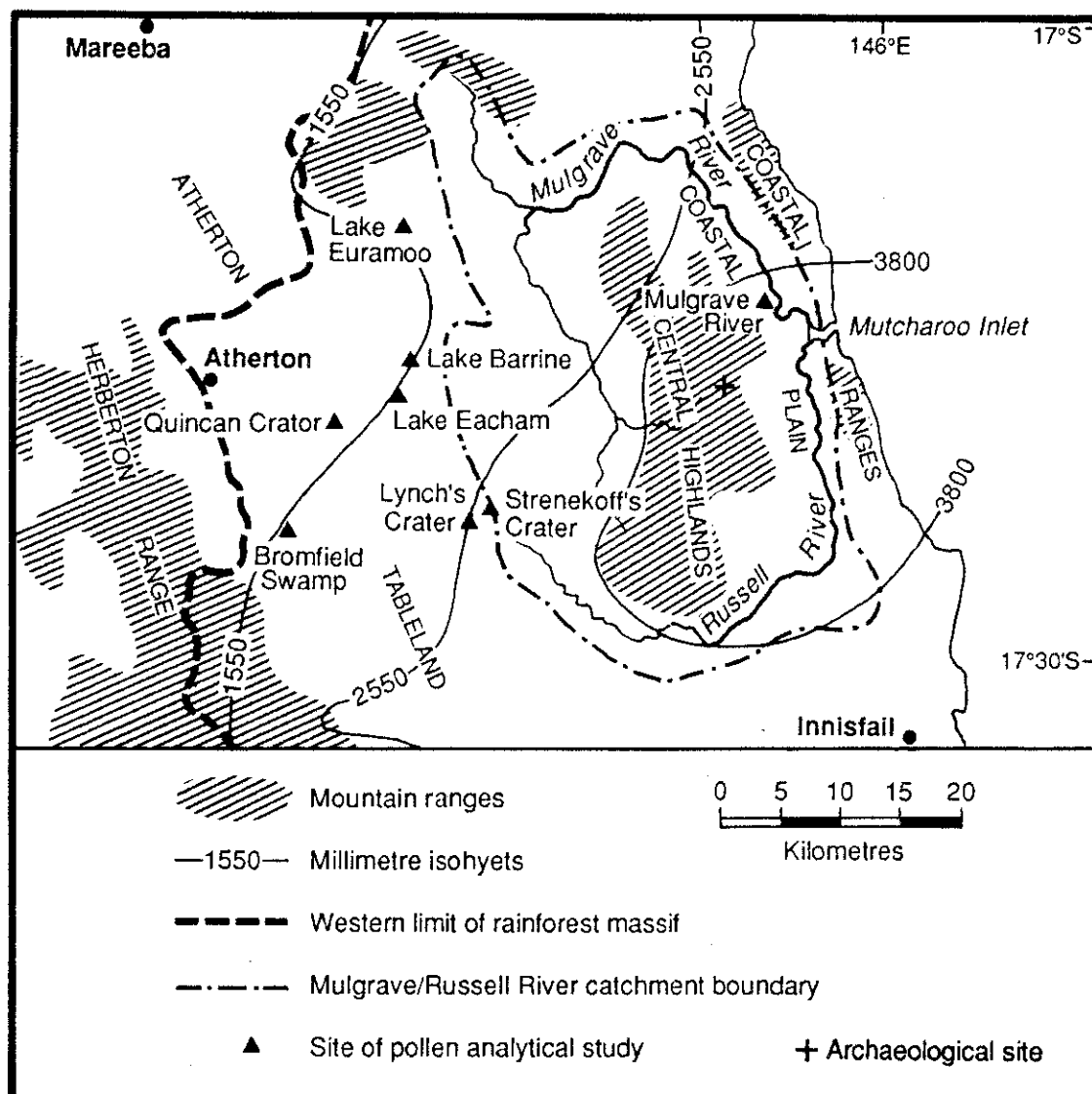


Figure 4.7 Published age/depth envelopes for sea-level change in the Holocene of northern Australia.

Spring deposits

Organic sediments associated with springs provide limited information on Holocene conditions in low rainfall, inland areas. Swamps in the Great Sandy Desert of northern Western Australia show the initiation of organic sedimentation as a result of a regional increase in precipitation about 7000 years ago (Wyrwoll et al. 1986). Unchanging regional vegetation and local site characteristics since this time are considered to indicate relatively stable climatic conditions. Similar unchanging regional vegetation is indicated through the last 1000 years at Louisa Creek in central Queensland, although evidence of peat erosion and deposition of sand layers within the peat sequence could indicate periodic extreme climatic events (Bell et al. 1989).

Environmental history and human settlement

Introduction

As with palaeoenvironmental records, documentation and understanding of prehistoric human economy and ecology is relatively refined for the Holocene in comparison with the Pleistocene. It is also the case that, while intensive research projects have revealed plentiful data for several areas, these remain islands of information within largely unexplored territory. Under these circumstances it would be unrealistic to attempt a general reconstruction of human/environment interactions applicable to the whole of northern Australia. Instead we have decided to focus on areas where both significant archaeological and environmental information is available. Three case studies have been selected. Moving from east to west these are: the Mulgrave River region on the east coast, the Princess Charlotte Bay region on Cape York Peninsula and the Alligator Rivers region in western Arnhem Land (see Figure 4.1).

Case study: Mulgrave River region

There have been few archaeological investigations of tropical rainforests in Australia, although the development of specialised rainforest groups has intrigued Australian prehistorians for some time (for example, Tindale 1940, Tindale and Birdsell 1941, Harris 1978, Bowdler 1983). Perhaps the most significant site is in the Mulgrave River region which lies between the palynological sites of the Atherton Tableland and that of the Mulgrave Estuary. The chronology of human occupation rests primarily on information from Jiyer Cave, a large concavity in volcanic rock overlooking the Russell River. Horsfall's (1983) excavations at Jiyer Cave demonstrated that human occupation of the cave began in the mid-Holocene (c. 5000 B.P.), but remained at a very low level until the recent past.

There is an intriguing correlation between the timing of occupation of this cave and indications of rainforest disturbance within the vegetation of the Atherton Tableland. Increased representation of pollen from successional plants may be an indication of increased burning at rainforest margins and in patches of open sclerophyll vegetation within the rainforest massif, perhaps to maintain and extend route-ways through the forest. The destruction of swamp forest at Lynch's Crater demands a different explanation. Original visits to the swamp may have been for plant foods such as the roots of *Cyclosorus gongylodes* and *Blechnum indicum*, both known to have been used by Aborigines of this region (Golson 1971) and identified as present on the swamp from their spores (Kershaw 1983). Burning may have facilitated access or encouraged the growth of these and other

desirable swamp species. At present, the swamp supports a number of additional food plant species such as *Lepironia articulata*, *Melastoma malabathricum* and *Typha angustifolia* (Golson 1971) and these may have been promoted by the activities of people.

The original swamp forest could have provided an ideal habitat for taro (*Colocasia esculenta*), a root crop extensively cultivated in the south-east Asian region (Spriggs 1982) and exploited in north-eastern Australia (Golson 1971). Local residents have indicated that Aborigines made annual visits from the coast to Lynch's Crater to collect taro, so this may have been the reason for initially visiting the swamp and subsequent manipulation of the vegetation. The lack of taro pollen in the sediments is not significant, considering that its pollen has not been identified from many sites outside Australia where taro is known to have been cultivated (Spriggs 1982).

The expansion of rainforest in association with increased precipitation in the early Holocene would have favoured its occupation. However, it appears from sites on the Atherton Tableland and in the Mulgrave River Estuary that rainforest had achieved at least its present extent some 2000 years before the evidence for occupation. One suggestion for the timing of occupation is the acquisition of toxic-plant processing techniques which would have enlarged available rainforest resources (cf. Beaton 1982). Another possibility is that the availability of taro encouraged occupation. The question of whether or not taro is native to Australia has not been resolved (Golson personal communication) and it is possible that it was introduced from New Guinea or further afield at this particular time. These ideas on the timing of occupation are very speculative and remain to be tested, as does the validity of generalising from so few data from one rainforested area.

In contrast to the low level of archaeological visibility in the basal layers of Jiyer Cave, the top 30 cm of deposit is rich in food debris and stone artefacts. Estimated sediment deposition rates from available radiocarbon dates indicate that within the last 280 years there was greatly increased sedimentation, and far greater discard rates of artefacts and bone than previously. Horsfall (1983) has argued that this increase in material reflects greater occupation of the site in the Nineteenth Century as a response to European encroachment on the more accessible portions of the rainforest. This conclusion may imply that, prior to European settlement, rainforest margins were the major location of human rainforest use.

Case study: Princess Charlotte Bay

Archaeological work at Princess Charlotte Bay has demonstrated that coastal occupation in this region began only about 4700 years ago, at least 1000 years after the sea reached its present level (Beaton 1985). The inability of hunter-gatherers to utilise the coastline during the period immediately after the sea-level rise may reflect the rapidly changing and unpredictable nature of the marine ecosystem. If this is the case, environmental instability here must have been far greater than along other parts of the tropical coast, where there is evidence for minimal disruption of coastal lifestyles during the latter stages of the marine transgression (cf. Barker 1989). Beaton (1985, 1990) prefers the suggestion that sites proliferated in the late Holocene because of continental-wide population growth.

Even after human occupation in the region became archaeologically visible in the mid-Holocene, the human use of the area continued to be influenced by landscape evolution. For example, economic evidence in the form of shell middens and mounds suggests that between 2000 and 1000 B.P. the prehistoric coastal foraging economy relied

on the procurement of large quantities of *Anadara granosa*, a mudflat-dwelling shellfish species. These shellfish were apparently carried onto nearby chernier ridges where they were eaten and dumped (Beaton 1985). As the coastline prograded, the focus of occupation moved gradually seaward to maintain the same relative position in the landscape (Beaton 1985). The local extinction of *A. granosa* by about 600 B.P., probably a result of dramatic climatic events (for example, heavy wet season or cyclone), led to the cessation of mound-building and the switch to alternative foraging patterns, perhaps including greater emphasis on reef shellfish available on nearby islands and hunting of dugong (Minnegal 1984, Beaton 1985).

The chronological framework for prehistoric occupation of Princess Charlotte Bay is based on the excavation of thirteen shell mounds, and is reinforced by archaeological examinations of rockshelters and palaeoenvironmental studies of coastal progradation. Similar mounds have been recorded across northern Australia. For example, McCarthy and Setzler (1960) have described the Macassar Well mound on Millingimbi; Bailey (1977) and Cribb (1986) describe a large number of tall, conical shell mounds on Cape York near Weipa and Aurukun; Meehan et al. (1985) describe the Ki'na earth mound in the Kakadu flood plain. Archaeologists have argued that humans created these mounds, either through repeated occupation or deliberate construction. In support of this position some archaeologists refer to the contents of the mound. For example, Meehan et al. (1985) cite an interpretation of the matrix of the Ki'na mound as termite nest, which was presumably carried to the site.

The purpose of these mounds is not self-evident. It seems feasible that earth mounds may have been purposely constructed to serve as platforms for houses (cf. Williams 1984). However, it is also possible that some mounds accumulated gradually as sediments were heaped around fires so that food could be cooked in a dirt oven (cf. Williams 1984). But when the mound consists of shells, it must also be possible that it has accumulated as a result of food discard, just like shell middens in southern Australia. The curious aspect of such middens would be the determined mounding behaviour of occupants. Another possibility that has been raised is that artificial mounds provide an expanded habitat for some plant species, and that mound building therefore enhances available plant food resources and is a means of environmental control (Cribb 1986). This phenomenon might have been either a stimulus for mound production, or, more likely, a beneficial outcome of mounding behaviour.

Recently, the notion of a human origin for mounds has been challenged. Stone (1989) has proposed that shell and earth mounds recorded in tropical Australia are built by generations of nesting scrub-fowl (*Megapodius reinwardt*). In favour of this theory, Stone gives several lines of evidence, including the coincidence in distribution of mound sites and scrub fowl, the conformity of mound content and known scrub-fowl activities, and the similarity in size and shape of prehistoric mounds to those currently being built by scrub-fowl. In terms of the Princess Charlotte Bay mounds, Stone emphasises the reversal of radiocarbon dates as supporting the idea that mounds have been churned over by megapodes, although the well-defined stratigraphy evident in the South Mound may be taken as evidence for an anthropogenic origin, with minimal disturbance.

If this suggestion of a non-human origin of mound formation can be sustained, it has significant implications for the interpretation of north Australian prehistory. It implies that any archaeological material within a mound is in a secondary, disturbed context and its current location can provide little useful information. Furthermore, this hypothesis

removes from archaeological discussion the mounds themselves. We shall return to this issue in the next section. It is clear that the interpretation of these sites, and the distinction between anthropogenic and megapode mounds is, in fact, quite complex.

Case study: Alligator Rivers region

A key theme in all the Holocene archaeological research in the Alligator Rivers region has been the way in which human groups exploited a variable environment. The initial investigation (White 1967, Schrire 1982) focused on the human response to the marked seasonal and topographic contrasts which exist at the junction of the sandstone plateau and the flood plains of the Alligator Rivers. This quest was stimulated by the pronounced differences in the mid-Holocene assemblages of stone artefacts between the plateau and the plain. Excavated sites on the plateau contained relatively large numbers of flakes, both unretouched and retouched (particularly points); whereas on the plain excavated sites contained few flakes. After considering the possibility of two separate groups, occupying different parts of the landscape, White interpreted these patterns in terms of the seasonal use of the region. The idea was that people manufactured stone tools during their wet season occupation of the uplands, and then carried a small number of finished tools onto the flood plains where they spent the dry season. This explanation highlights the short-term environmental variations to which prehistoric hunter-gatherers along the tropical coastline had to respond. Ethnographic information demonstrates that the likely response to seasonal inundation and seasonal variation in the abundance of plant and animal foods typically took the form of changing settlement localities and changes in resource procurement, although not necessarily of the precise form suggested by White.

Superimposed on these seasonal changes in the environment, are longer-term alterations to the landscape. Jones (1985) argues that the population size in Kakadu probably increased in the last 800–1000 years as a result of environmental changes. There are two pieces of archaeological evidence used to support this statement.

Firstly, excavations at Anbangbang I, a shelter in the Nouralangie Outlier, revealed a large amount of material in the upper levels: wooden spear points, spear shafts, firesticks, wood shavings, twine, pieces of woven bag, gum, shell tools, bone tools, bone from animals (such as fish, turtle, goanna, wallabies, bats, freshwater mussel), and fragments of plant foods. Jones and Johnson (1985a) took this to indicate greater use of the shelter in the recent past, perhaps reflecting population increase. This interpretation, however, disregards dating ambiguities and the apparent rapid decay of organic materials. The vertical changes in numbers of stone artefacts, which are relatively resistant to decay, perhaps support the interpretation of Jones and Johnson, although this is unclear.

The second piece of archaeological data employed by Jones in his demographic argument came from examinations of open sites located in the wetlands. Meehan et al. (1985) observed that, at most sites in the wetlands, artefacts were restricted to the top 10–20 cm of alluvium and, where artefacts were found lower down, they argued that these had derived from the near surface levels. Consequently, Meehan et al. concluded that the use of wetlands was relatively recent; perhaps within the last 1000 years.

This claim has been tested by only one excavation in the wetlands. Meehan et al. (1985) excavated the open site of Ki'na, which is located on a peninsula that juts into a freshwater billabong. The site consists of a scatter of stone artefacts over an area 250 by 120 m, in which there are several discrete mounds of earth and shell. One of these mounds was dug to a depth of 80 cm, where the underlying lateritic bedrock was revealed.

Freshwater mussel shell and stone artefacts were found throughout the deposit. Unfortunately the excavation was carried out using only 5 units, limiting the chronological resolution. Two radiocarbon dates from unit 4 both gave determinations of 280 ± 140 B.P. Meehan et al. (1985) were unconvinced by this result, concluding, 'We suspect that our carbon date is too young, resulting from the goanna burrows..'. They considered that the site formed over the past 500–1000 years, and that other sites on the freshwater wetlands have the same antiquity.

The interpretation of the Ki'na mound is problematic. We have already discussed the difficulty of differentiating between human and megapode origins for such mounds. While Meehan et al. (1985) argued that the mound is anthropogenic because it was constructed mainly from fragments of transported termite nest, no analysis of the sediments was presented to substantiate this claim. This issue is complicated by Russell-Smith's (1985) interpretation of mounds on the Ki'na site as the product of scrub-fowl activity. Stone (1989) argues that the cluster of dates for the commencement of mound building around 1600 B.P. is consistent with a spread of monsoon vine forest—the habitat of scrub-fowl. It is consistent with Russell-Smith's (1985) suggestion that scrub-fowl populations expanded during the Holocene. Given these apparently conflicting statements concerning the Ki'na mounds, it is not certain that increases in human population numbers is necessary to explain mound building. Nevertheless, the observation by Meehan et al., that most sites on the flood plains consist of surficial material on a recent alluvial surface, is support for the inference of a late Holocene increase in site numbers.

Geomorphic data indicate that backswamps were largely formed in the cusate river phase, during the last 2500–1000 years (Jones 1985; Woodroffe et al. 1986). Hope et al. (1985) place the timing of the last saline flooding, and the conversion of lagoons to freshwater, at or before about 1400 B.P. along the southern South Alligator River flood plain where the Ki'na site is situated (see Figure 4.6). As described previously, Meehan et al. (1985) assert that the majority of archaeological sites are more recent than the time of formation of freshwater lagoons. On this basis, Jones (1985) concluded:

... it was only about 1000 years ago, with the transformation of the wetland landscape and the appearance of the freshwater swamps, that the population density increased dramatically and the Aboriginal economy was reorganised to take advantage of the new food resources which abounded in the swamps.

This model implies not only that the environmental changes precede the increase in site numbers (and by implication human numbers), but also that the greater productive capacity of this new landscape was a causal agent in the cultural change. Jones (1985) posits that this case study is generally applicable throughout Australia, and that a fixed relationship existed between population density and the productive capacity of the landscape, irrespective of the technology and organisation of production employed.

While this scenario is interesting, it is not unconditionally supported by the available dating. One concern must be the chronological similarity of environmental change and human response. Although it is possible to argue for landscape change in the Ki'na area at about 1400 B.P., changes elsewhere in the flood plains are not likely to have been contemporary. More importantly, while the perceived increase in site numbers may have taken place about 1000 years ago, this age estimate is not based on hard data. It is equally possible to use the radiocarbon chronology at Ki'na and Anbangbang to infer that there was no change in the human economy or demography

until only 200–300 years ago. If this were the case, then possible causes for the cultural changes might include the effects of European or Macassan contact, rather than, or in addition to, alterations in environmental productivity. Although such a claim would be difficult to demonstrate on available evidence, the existence of a viable alternative reflects the preliminary nature of our understanding of long-term human-environment interactions in northern Australia.

Conclusion

Since Thomson's (1939) seminal work on the economic and social effects of seasonal climatic change on Cape York Aborigines, prehistorians have been motivated to investigate the environmental context of archaeological materials. Over the last few decades, the interests of Quaternary environmental researchers have converged on the questions being asked by archaeologists, as geomorphologists and palynologists have become aware of the impact of humans upon the Australian landscape. The result has been the creation of research projects with a distinct geoarchaeological flavour (Hughes and Sullivan 1982), in which a major goal has been to describe and explain the human-environmental interaction which took place in northern Australia during prehistory. This interdisciplinary co-operation, although still at a preliminary stage, has been productive in highlighting the patterns described in this paper.

It appears that since humans first entered the continent, they have modified their environment, most dramatically through the use of fire. In the short term, systematic anthropogenic fires may have reduced vegetation cover and promoted particular plant and animal species, while in the long term burning may have permanently altered the composition of floral communities and initiated or increased erosion and valley-fill through the removal of vegetation. Further work is required to determine chronological changes in anthropogenic burning and to assess the role of fire in the creation of landscapes within each region and in Pleistocene megafaunal extinction.

Although Pleistocene people utilised all environmental zones in northern Australia, their use of some areas may have been constrained by environmental phenomena. On the available archaeological evidence, it is possible that Pleistocene use of rain forests was at a low intensity, and perhaps concentrated around rainforest margins. It is most likely that burning levels during the early occupation period caused extensive destruction of drier rainforest types that had the potential to provide a variety of food resources. This apparent destruction is in marked contrast to the conservation measures employed to maintain isolated, remnant patches of vine thicket within parts of the region in recent times (Jones 1975) and reinforces the archaeological evidence for a late utilisation of this resource. While other environmental zones may have been more intensively exploited, the climatic changes associated with the glacial maximum appear to have required adjustments to settlement and subsistence patterns, and in some regions there may have been dramatic depopulation. Problems of survival during the dry glacial maximum and very late Pleistocene may have been exacerbated by landscape alterations due to anthropogenic burning. The verification and elaboration of these ideas requires much more detailed examination of archaeological deposits and far more sophisticated palaeoenvironmental information than has hitherto been reported. In particular, there is a need for the identification of archaeological deposits with relatively good floral and faunal preservation for the Pleistocene period—a rarity in northern Australia.

While it has been argued that the rising seas at the end of the Pleistocene and during the early Holocene must have created massive ecological instabilities which would have significant impact on human use of coastal areas, this has not been demonstrated. Certainly some regions, such as Princess Charlotte Bay, show a lack of occupation during that periods of sea-level adjustment, but this may be a local rather than general phenomenon. Since the mid-Holocene, humans have lived in coastal landscapes that have been constantly altered as a result of coastline progradation and valley infilling, and yet economic and social adjustments were apparently made. An issue that must be addressed in future work concerns the contrast between human adaptation to a changing coastal environment during the middle and late Holocene, and the human response to sea-level change that took place prior to 6000 B.P.

Finally, the scenarios posed by Jones (1985) for the Kakadu wetlands are sufficiently important to deserve extensive testing, both in Kakadu and elsewhere in the north. The creation of flood plains is now beginning to be understood, following recent geomorphic work (for example, Woodroffe et al. 1986), but more extensive archaeological surveys are required before demographic and settlement patterns can be established. It is certainly realistic to believe that the formation of a diverse array of coastal environments within the last 2000 years led to an intensification of occupation in these environments, but any hypothesis needs also to explain similar intensification in other areas, such as rainforest, where significant and relevant environmental change has not been demonstrated. There are also problems in relating earlier evidence (c. 5000 B.P.) for intensification, both in some coastal localities as well as inland, to environmental change. The link between environmental productivity and human resource use and population size is undoubtedly complex, and underlies many of the questions in the investigation of prehistory in northern Australia.

References

- Allen, J. 1989, 'When did humans first colonise Australia?', *Search* 20, 149-54.
- Ash, J. 1983, *Rainfall patterns in north-eastern Queensland, 4 000-9 000 B.P.*, CLIMANZ Conference, Department of Biogeography and Geomorphology, Australian National University, Canberra.
- 1988, 'The location and stability of rainforest boundaries in north-eastern Queensland, Australia', *Journal of Biogeography* 15, 619-630.
- Bailey, G.N. 1977, 'Shell mounds, shell middens and raised beaches in the Cape York Peninsula', *Mankind* 11, 132-43.
- Barker, B. 1989, 'Nara Inlet 1: a Holocene sequence from the Whitsunday Islands, central Queensland coast', *Queensland Archaeological Research* 6, 53-76.
- Beaton, J.M. 1982, 'Fire and water: aspects of Australian Aboriginal management of cycads', *Archaeology in Oceania* 17, 51-8.
- 1985, 'Evidence for a coastal occupation time-lag at Princess Charlotte Bay north Queensland and the implications for coastal colonisation and population growth theories for Aboriginal Australia', *Archaeology in Oceania* 20, 1-20.
- 1990, 'The importance of past population for prehistory', in Meehan, B. and White, N. (eds) *Hunter Gatherer Demography*, Oceania Monograph, Canberra.
- Bell, C.J.E., Finlayson, B.L. and Kershaw, A.P. 1989, 'Pollen analysis and dynamics of a peat deposit in Carnarvon National Park, central Queensland', *Australian Journal of Ecology* 14, 449-56.
- Birdsell, J.B. 1953, 'Some environmental and cultural factors influencing the structuring of Australian Aboriginal populations', *American Naturalist* 87, 171-207.

- Bowdler, S. 1977, 'The coastal colonisation of Australia', in Allen, J., Golson, J. and Jones, R. (eds) *Sunda and Sahul: prehistoric studies in south-east Asia, Melanesia and Australia*, Academic Press, London.
- 1983, 'Rainforest: colonised or coloniser?', *Australian Archaeology* 17, 59-66.
- 1990, '50 000 year-old site in Australia—is it really that old?' *Australian Archaeology* 31, 93.
- Bowler, J.M. 1986, 'Quaternary landform evolution', in Jeans, D.N. (ed.) *The Natural Environment*, Sydney University Press, Sydney.
- Brown, S. 1987, *Towards a prehistory of the Hamersley Plateau, north-west Australia*, Occasional Papers in Prehistory No. 6, Department of Prehistory, Australian National University, Canberra.
- Campbell, J.B. 1982, 'Automatic seafood retrieval systems: the evidence from Hinchinbrook Island and its implications', in Bowdler, S. (ed.), *Coastal Archaeology in Eastern Australia*, Australian National University Press, Canberra.
- 1984, 'Extending the archaeological frontier: a review of work on the prehistory of north Queensland', *Queensland Archaeological Research* 1, 173-84.
- Chaloupka, G. 1984, *From palaeoart to casual paintings*, Monograph Series No. 1, Northern Territory Museum of Arts and Sciences, Darwin.
- 1985, 'Chronological sequence of Arnhem Land Plateau rock art', in Jones, R. (ed.), *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- Chaloupka, G. and Murray, P. 1986, 'Dreamtime or reality?', *Archaeology in Oceania* 21, 145-47.
- Chappell, J. and Grindrod, J. 1984, 'Chernier plain formation in northern Australia', in Thom, B.G. (ed.), *Coastal Geomorphology in Australia*, Academic Press, Sydney.
- Chappell, J., Rhodes, E.G., Thom, B.G. and Wallensky, E.P. 1982, 'Hydro-isostasy and the sea level isobase of 5 500 B.P. in north Queensland, Australia', *Marine Geology* 49, 81-90.
- Chappell, J. and Thom, B.G. 1986, 'Coastal morphodynamics in north Australia', *Australian Geographic Studies* 24, 110-27.
- Chen, Y. 1988, 'Early Holocene population expansion of some rainforest trees at Lake Barrine basin, Queensland', *Australian Journal of Ecology* 13, 225-33.
- Clark, R.L. and Guppy, J.C. 1988, 'A transition from mangrove forest to freshwater wetland in the monsoon tropics of Australia', *Journal of Biogeography* 15, 665-84.
- Cribb, R. 1986, 'A preliminary report on archaeological findings in Aurukun Shire, western Cape York', *Queensland Archaeological Research* 3, 133-58.
- Crowley, G.M., Anderson, P., Kershaw, A.P. and Grindrod, J. 1990, 'Palynology of a coastal Holocene sequence from the Mulgrave River, humid tropical north-east Queensland', *Australian Journal of Ecology* 15, 231-40.
- Davies, J.L. 1986, 'The coast', in Jeans, D.N. (ed.) *The Natural Environment*, Sydney University Press, Sydney.
- Flannery, T.F. 1990, 'Pleistocene faunal loss; implications of the aftershock for Australia's past and future', *Archaeology in Oceania* 25, 45-67.
- Frankel, D. 1990, 'Time inflation', *New Scientist* 7 July, 52-53.
- Gollan, K. 1984, 'The Australian dingo: in the shadow of man', in Archer, M. and Clayton, G. (eds) *Vertebrate Zoogeography and Evolution in Australia*, Hesperian Press, Perth.
- Golson, J. 1971, 'Australian Aboriginal food plants: some ecological and culture-historical implications', in Mulvaney, D.J. and Golson, J. (eds), *Aboriginal Man and Environment in Australia*, Australian National University Press, Canberra.
- Goodfield, M.L. 1983, *A Holocene pollen analytical study of Lake Eacham, Atherton Tableland, north-east Queensland*, unpublished B.Sc. Hons. thesis, Monash University, Melbourne.
- Grindrod, J. 1988, 'The palynology of Holocene mangrove and saltmarsh sediments, particularly in northern Australia', *Review of Palaeobotany and Palynology* 55, 229-45.
- Grindrod, J. and Rhodes, E.G. 1984, 'Holocene sea-level history of a tropical estuary: Missionary Bay, north Queensland', in Thom, B.G. (ed.), *Coastal Geomorphology in Australia*, Academic Press, Sydney.
- Groube, L. 1984, 'Waisted axes of Asia, Melanesia and Australia', in Ward, G., (ed) *Archaeology at ANZAAS*, Canberra Archaeological Society, Canberra.
- Hardesty, D.L. 1977, *Ecological Anthropology*, John Wiley and Sons, New York.

- Harris, D.R. 1978, 'Adaptation to a tropical rainforest environment: Aboriginal subsistence in north-eastern Queensland', in Blurton-Jones, N.G. and Reynolds, V. (eds) *Human Behaviour and Adaptation*, Taylor and Francis, London.
- Hayden, B. 1977, 'Sticks and stones and ground edge axes; the upper palaeolithic in south-east Asia?', in Allen, J., Golson, J. and Jones, R. (eds) *Sunda and Sahul: prehistoric studies in south-east Asia, Melanesia and Australia*, Academic Press, London.
- Haynes, C.D. 1986, 'The pattern and ecology of munwag: traditional Aboriginal fire regimes in north-central Arnhemland', *Proceedings of the Ecological Society of Australia* 13, 203-14.
- Hiscock, P. 1984, 'Preliminary report on the stone artifacts from Colless Creek Cave', *Queensland Archaeological Research* 1, 120-51.
- 1988, *Prehistoric settlement patterns and artifact manufacture at Lawn Hill, north-west Queensland*, unpublished PhD thesis, University of Queensland, Brisbane.
- 1990, 'How old are the artifacts in Malakunanja II?', *Archaeology in Oceania* 25, 122-24.
- Hope, G.S., Hughes, P.J. and Russell-Smith, J. 1985, 'Geomorphological fieldwork and the evolution of the landscape of Kakadu National Park', in Jones, R. (ed.) *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- Horsfall, N. 1983, 'Excavations at Jiye Cave, north-east Queensland: some results', in Smith, M. (ed.) *Archaeology at ANZAAS 1983*, Western Australian Museum, Perth.
- Horton, D.R. 1980, 'A review of the extinction question: man, climate and megafauna', *Archaeology and Physical Anthropology in Oceania* 15, 86-97.
- 1982, 'The burning question: Aborigines, fire and Australian ecosystems', *Mankind* 13, 237-51.
- 1990, 'Comments', *Archaeology in Oceania* 25, 59-60.
- Hughes, P.J. and Sullivan, M.E. 1982, 'Geoarchaeology in Australia: a review', in Ambrose, W. and Duerden, P. (eds), *Archaeometry: an Australian Perspective*, Department of Prehistory, Australian National University, Canberra.
- Jones, R. 1975, 'The neolithic, palaeolithic and the hunting gardeners: man and land in the Antipodes', *Bulletin of the Royal Society of New Zealand* 13, 22-34.
- 1979, 'The fifth continent: problems concerning the human colonisation of Australia', *Annual Review of Anthropology* 8, 445-66.
- 1985, 'Archaeological conclusions', in Jones R. (ed.), *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- Jones, R. and Bowler, J.M. 1980, 'Struggle for the savannah: northern Australia in ecological and prehistoric perspective', in Jones, R. (ed.) *Northern Australia: Options and Implications*, Research School of Pacific Studies, Australian National University, Canberra.
- Jones, R. and Johnson, I. 1985a, 'Rockshelter excavations: Nourlangie and Mt. Brockman massifs', in Jones, R. (ed.), *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- 1985b, 'Deaf Adder Gorge: Lindner Site, Nauwalabila 1, in Jones, R. (ed.), *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- Kamminga, J. and Allen, H. 1973, *Alligator Rivers environmental fact-finding study: report of the archaeological survey*, Department of Northern Territory, Darwin.
- Kershaw, A.P. 1970, 'A pollen diagram from Lake Euramoo, north-east Queensland, Australia', *New Phytologist* 69, 785-805.
- 1971, 'A pollen diagram from Quincan Crater, north-east Queensland, Australia', *New Phytologist* 70, 669-81.
- 1973, *Late Quaternary vegetation of the Atherton Tableland, north-east Queensland, Australia*, unpublished PhD thesis, Australian National University, Canberra.
- 1975, 'Stratigraphy and pollen analysis of Bromfield Swamp, north-eastern Queensland, Australia', *New Phytologist* 75, 173-91.
- 1983, 'A Holocene pollen diagram from Lynch's Crater, north-eastern Queensland, Australia', *New Phytologist* 94, 669-82.
- 1986, 'The last two glacial-interglacial cycles from north-eastern Australia: implications for climatic change and Aboriginal burning', *Nature* 322, 47-9.

- 1989, 'Was there a 'Great Australian Arid Period'?', *Search* 20, 89-92.
- Kershaw, A.P., Baird, J.G., D'Costa, D.M., Edney, P.A., Peterson, J.A. and Strickland, K.M. 1991a, 'A comparison of long Quaternary records from the Atherton Tableland and Western Plains volcanic provinces', in Williams, M.A.J. and De Deckker, P. (eds), *The Cainozoic of the Australian Region: a re-evaluation of the evidence*, Geological Society of Australia, Sydney (in press).
- Kershaw, A.P., D'Costa, D.M., McEwen Mason, J. and Strickland, K.M. 1991b, 'Palynological evidence for Quaternary vegetation on mainland south-eastern Australia', *Quaternary Science Reviews* (in press).
- Kershaw, A.P. and Nix, H.A. 1988, 'Quantitative palaeoclimatic estimates from pollen taxa using bioclimatic profiles of extant taxa', *Journal of Biogeography* 15, 589-602.
- Lees, B.G. and Clements, A.M. 1987, 'Climatic implications of chernier dates in northern Australia', *Radiocarbon* 29, 311-317.
- Lees, B.G., Yanchou, L. and Head, J. 1990, 'Reconnaissance thermoluminescence dating of northern Australian coastal dune systems', *Quaternary Research* 34, 169-85.
- Lewis, D. 1988, *The rock paintings of Arnhem Land, Australia*, British Archaeological Reports international Series 415, Oxford.
- Loy, T.H., Jones, R., Nelson, D.E., Meehan, B., Vogel, J., Southern, J. and Cosgrove, R. 1990, 'Accelerator radiocarbon dating of human blood proteins in pigments from Late Pleistocene art sites in Australia', *Antiquity* 64, 110-16.
- Luebbers, R.A. 1975, 'Ancient boomerangs discovered in South Australia', *Nature* 253, 39.
- McBryde, I. 1986, 'Artefacts, language and social interaction: a case study from south-eastern Australia', in Bailey, G.N. and Callow, P. (eds), *Stone Age Prehistory, Studies in memory of Charles McBurney*, Cambridge University Press, Cambridge.
- McCarthy, F.D. and Setzler, F.M. 1960, 'The archaeology of Arnhem Land', in Mountford, C.P. (ed.) *Records of the American-Australian Scientific Expedition to Arnhem Land*, Vol. 2. Melbourne University Press, Melbourne.
- McCulloch, M.T., De Deckker, P. and Chivas, A.R. 1989, 'Strontium isotope variations in single ostracod valves from the Gulf of Carpentaria Australia: a palaeoenvironmental indicator', *Geochimica et Cosmochimica Acta* 53, 1703-10.
- Maynard, L. 1980, 'A Pleistocene date from an occupation deposit in the Pilbara region, Western Australia', *Australian Archaeology* 10, 3-8.
- Meehan, B. 1977, 'Man does not live by calories alone: the role of shellfish in a coastal cuisine', in Allen, J., Golson, J. and Jones, R. (eds), *Sunda and Sahul: prehistoric studies in south-east Asia, Melanesia and Australia*, Academic Press, London.
- 1982, *Shell Bed to Shell Midden*, Humanities Press, New Jersey.
- Meehan, B., Brockwell, S., Allen, J. and Jones, R. 1985, 'The wetland sites', in Jones, R. (ed.) *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- Minnegal, M. 1984, 'Dugong bones from Princess Charlotte Bay', *Australian Archaeology* 18, 63-71.
- Morse, K. 1988, 'Mandu Mandu Creek rockshelter: Pleistocene human coastal occupation of North West Cape, Western Australia', *Archaeology in Oceania* 23, 81-8.
- Morwood, M.J. and Trezise, P.J. 1989, 'Edge-ground axes in Pleistocene greater Australia: new evidence from SE Cape York Peninsula', *Queensland Archaeological Research* 6, 77-90.
- Mulvaney, D.J. 1976, '"The chain of connection": the material evidence', in Peterson, N. (ed.), *Tribes and Boundaries in Australia*, Humanities Press, New Jersey.
- Murray, P. and Chaloupka, G. 1984, 'The Dreamtime animals: extinct megafauna in Arnhem Land rock art', *Archaeology in Oceania* 19, 105-16.
- Nix, H.A. and Kalma, J.D. 1972, 'Climate as a dominant control in the biogeography of northern Australia and New Guinea', in Walker, D. (ed.) *Bridge and Barrier: the Natural and Cultural History of Torres Strait*, Research School of Pacific Studies, Publication BG3, Australian National University, Canberra.
- Roberts, R.G., Jones, R. and Smith, M.A. 1990, 'Thermoluminescence dating of a 50 000-year-old human occupation site in northern Australia', *Nature* 345, 153-56.

- Rose, F.G.G. 1987, *The Traditional Mode of Production of the Australian Aborigines*, Angus and Robertson, Sydney.
- Rosenfield, A., Horton, D. and Winter, J. 1981, 'Early man in North Queensland', *Terra Australis* 6, Department of Prehistory, Australian National University, Canberra.
- Russell-Smith, J. 1985, 'Studies in the Jungle: people, fire and monsoon forest', in Jones, R. (ed.), *Archaeological Research in Kakadu National Park*, Australian National Parks and Wildlife Service Special Publication 13, Canberra.
- Schrire, C. 1982, 'The Alligator Rivers: prehistory and ecology in western Arnhem Land', *Terra Australis* 7, Department of Prehistory, Australian National University, Canberra.
- Singh, G. and Geissler, E.A. 1985, 'Late Cainozoic history of fire, lake levels and climate at Lake George, New South Wales, Australia', *Philosophical Transactions, Royal Society of London* 311, 379-447.
- Smith, M. 1983, 'Joules from pools: social and techno-economic aspects of Bardi stone fish traps', in Smith, M. (ed.), *Archaeology at ANZAAS 1983*, Western Australian Museum, Perth.
- Smith, M.A. 1989, 'The case for a resident human population in the central Australian ranges during full glacial aridity', *Archaeology in Oceania* 24, 81-92.
- Spriggs, M. 1982, 'Taro cropping systems in the south-east Asian-Pacific region: archaeological evidence', *Archaeology in Oceania* 17, 7-15.
- 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', *Archaeology in Oceania* 24, 81-92.
- Thomson, D.F. 1939, 'The seasonal factor in human culture, illustrated from the life of a contemporary nomadic group', *Proceedings of the Prehistoric Society* 5, 209-21.
- Thorne, A. 1977, 'Separation or reconciliation? Biological clues to the development of Australian society', in Allen, J., Golson, J. and Jones, R. (ed.), *Sunda and Sahul: prehistoric studies in south-east Asia, Melanesia and Australia*, Academic Press, London.
- Tindale, N.B. 1940, 'Results of the Harvard-Adelaide Universities Anthropological Expedition 1938-39: distribution of Australian Aboriginal tribes, a field survey', *Transactions of the Royal Society of South Australia* 64, 140-231.
- 1974, *Aboriginal Tribes of Australia*, University of California Press, Los Angeles.
- 1976, 'Some ecological bases for Australian tribal boundaries', in Peterson, N. (ed.), *Tribes and Boundaries in Australia*, Humanities Press, New Jersey.
- Tindale, N.B. and Birdsell, J.B. 1941, 'Tasmanoid tribes in north Queensland', *Records of the South Australian Museum* 7, 1-9.
- Torgersen, T., Luly, J., De Deckker, P., Jones, M.R., Searle, D.E., Chivas, A.R. and Ullman, W.J. 1988, 'Late Quaternary environments of the Carpentaria Basin, Australia', *Palaeogeography, Palaeoclimatology, Palaeoecology* 67, 245-61.
- Walker, D. and Chen, Y. 1987, 'Palynological light on tropical rainforest dynamics', *Quaternary Science Reviews* 6, 77-92.
- Webb, L.J. and Tracey, J.G. 1981, 'Australian rainforests, patterns and change', in Keast, A. (ed.) *Ecological Biogeography in Australia*, Dr Junk, The Hague.
- Weidenreich, F. 1946, *Apes, Giants and Man*, University of Chicago Press, Chicago.
- White, C. 1967, *Plateau and plain prehistoric investigation in Arnhem Land*, unpublished PhD thesis, Australian National University, Canberra.
- Williams, E. 1984, 'Documentation and archaeological investigation of an Aboriginal 'village' site in south-western Victoria', *Aboriginal History* 8, 173-88.
- 1988, 'Complex hunter-gatherers, A late Holocene example from temperate Australia', *British Archaeological Reports international Series* 423, Oxford.
- Woodroffe, C.D., Chappell, J.M.A., Thom, B.G. and Wallensky, E. 1986, *Geomorphological Dynamics and Evolution of the South Alligator Tidal River and Plains, Northern Territory*, Australian National University North Australia Research Unit, Mangrove Monograph No. 3, Darwin.
- Woodroffe, C.D., Thom, B.G. and Chappell, J.M.A. 1985, 'Development of widespread mangrove swamps in mid-Holocene times in northern Australia', *Nature* 317, 711-13.

- Wright, R. 1986, 'How old is Lake George?', *Archaeology in Oceania* 21, 138-9.
— 1990, 'Comments', *Archaeology in Oceania* 25, 56.
Wyrwoll, K.H., McKenzie, N.L., Pederson, B.J. and Tapley, I.J. 1986, 'The Great Sandy Desert of north-western Australia: the last 7000 years', *Search* 7, 208-10.