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ENVIRONMENTAL CHANGE AND THE HUMAN OCCUPATION OF AUSTRALIA

ABSTRACT: The majority of long Quaternary pollen records from the Australasian and Indonesian regions show clear evidence of precipitation variation which relates closely to global glacial/interglacial oscillations. However, they also indicate sustained changes in vegetation towards more sclerophyllous or disturbed communities which, from associated changes in charcoal representation, can be attributed to increased burning. Close examination of these records indicates preferred times of change which show some relationship to the archaeological record. It is concluded that those changes around 40,000 and perhaps around 60,000 years ago most likely relate to times of arrival or developments in technology of people and that there is a fair possibility that the initial arrival and impact of modern people occurred much earlier, perhaps in excess of 200,000 years ago.

KEY WORDS: Late Quaternary – Human impact – Human migration – Vegetation history – Biomass burning – Australia – Southeast Asia

INTRODUCTION

One of the major questions in Australian archaeology is: When did people first colonise the continent? This question has bearing on the nature of the first occupants and the ability of people to cross ocean barriers as, even during Pleistocene low sea-level stages, there would have been several sea crossings, up to 80 kilometres in width, required from the Asian mainland.

Within the past 40 years, when evidence in the form of radiocarbon dating replaced speculation, the likely date of arrival from archaeological evidence has been progressively pushed back in time. In the 1970s and 1980s there was increasing consensus that a date of around 40,000 years BP was most realistic but within the last few years thermoluminescence dates on sites in the northern part of the continent have suggested that occupation began between 50,000 and 60,000 years ago (Roberts *et al.* 1990, 1993, Roberts, Jones 1994). Acceptance of these older dates depends upon the perceived accuracy of TL dating and the belief in a 40,000 year radiocarbon barrier and has resulted in a great deal of debate within the archaeological community (e.g. Allen, Holdaway 1995, Hiscock 1990, Bowdler 1991, Chappell *et al.* 1996).

Also debated have been claims, from substantial vegetation change associated with altered fire regimes, for much older dates based on proposed Aboriginal burning. A 125,000 year date from Lake George near Canberra (Singh *et al.* 1980, Singh, Geissler 1985) was criticised on the grounds of both the cause of the palaeoecological changes and the dating (Horton 1982, Wright 1986) although a much more 'acceptable' date of 38,000 BP on a record from Lynch's Crater in northeast Queensland using similar reasoning (Kershaw 1976, Singh *et al.* 1981) received much less attention. More recently, a date of ca 140,000 BP from an Ocean Drilling Program core off the northeast Queensland coast was suggested to indicate Aboriginal presence (Kershaw *et al.* 1993) but, despite

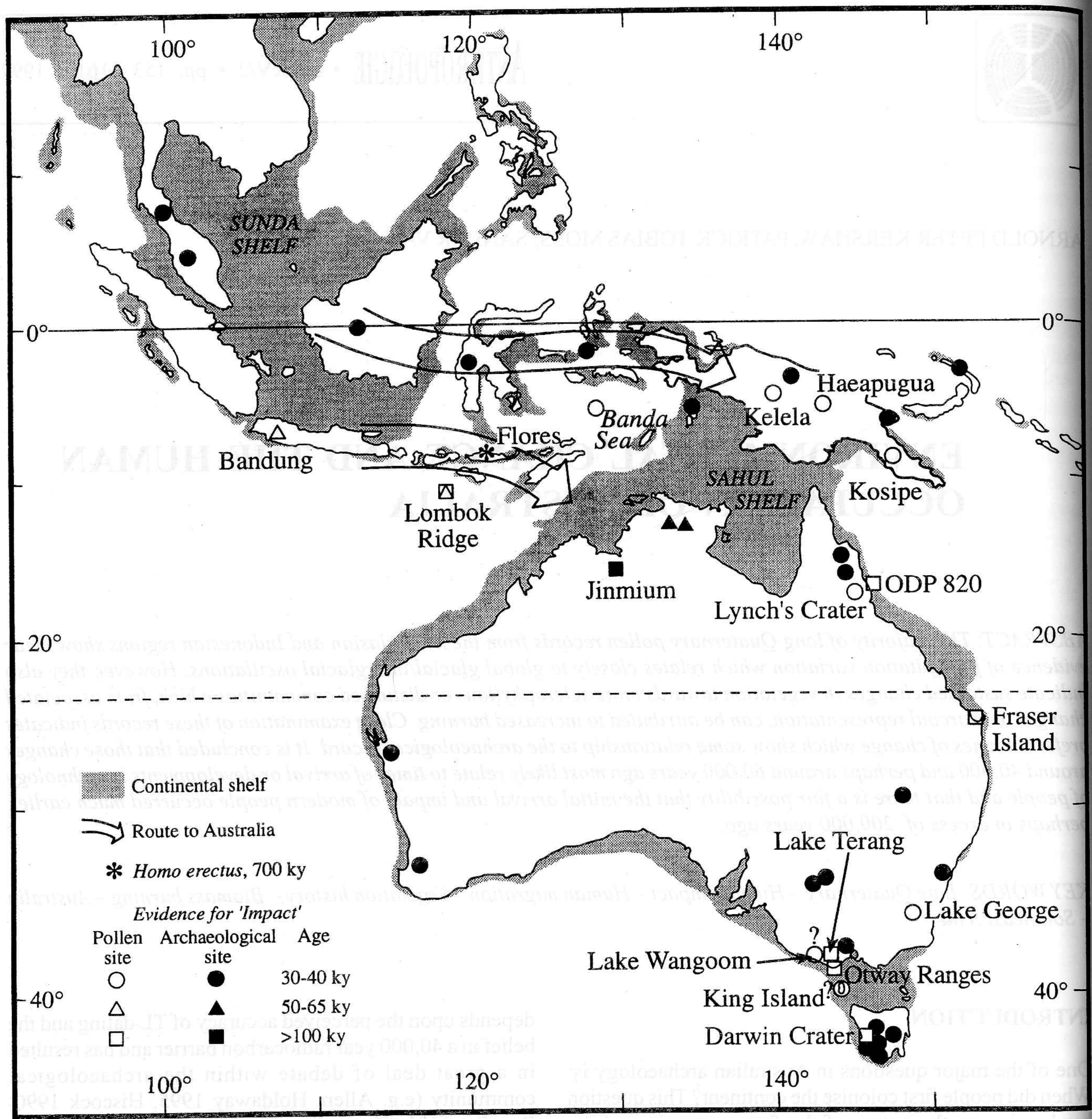

FIGURE 1. Location of palaeoecological and archaeological records relevant to the debate on the human colonisation of Australia together with possible entry routes from Southeast Asia. Archaeological data from Flood (1995) and Matthew Spriggs and Peter Bellwood (pers. comm.).

adding support to the Lake George evidence, this interpretation received essentially the same reception (Anderson 1994, Hope 1994, White 1994). However, some support for the palaeoenvironmental evidence appears to have been provided by TL dates from a new archaeological site in northern Australia, the Jinmium rock shelter, which suggests occupation began at some time between 116,000 ±12,000 and 176,000±16,000 BP (Fullagar *et al.* 1996). Inevitably, this evidence is the source of much scrutiny and debate, in the press if not yet in the journals.

In an attempt to help resolve the question of human arrival, at least from a palaeoecological perspective, effort has been focused on production of additional records, and further analysis of existing records from the northern Australian/Indonesian region. This paper presents a summary of results so far from these and previous studies followed by some interpretation of their meaning in relation to human colonisation of the Australian continent.

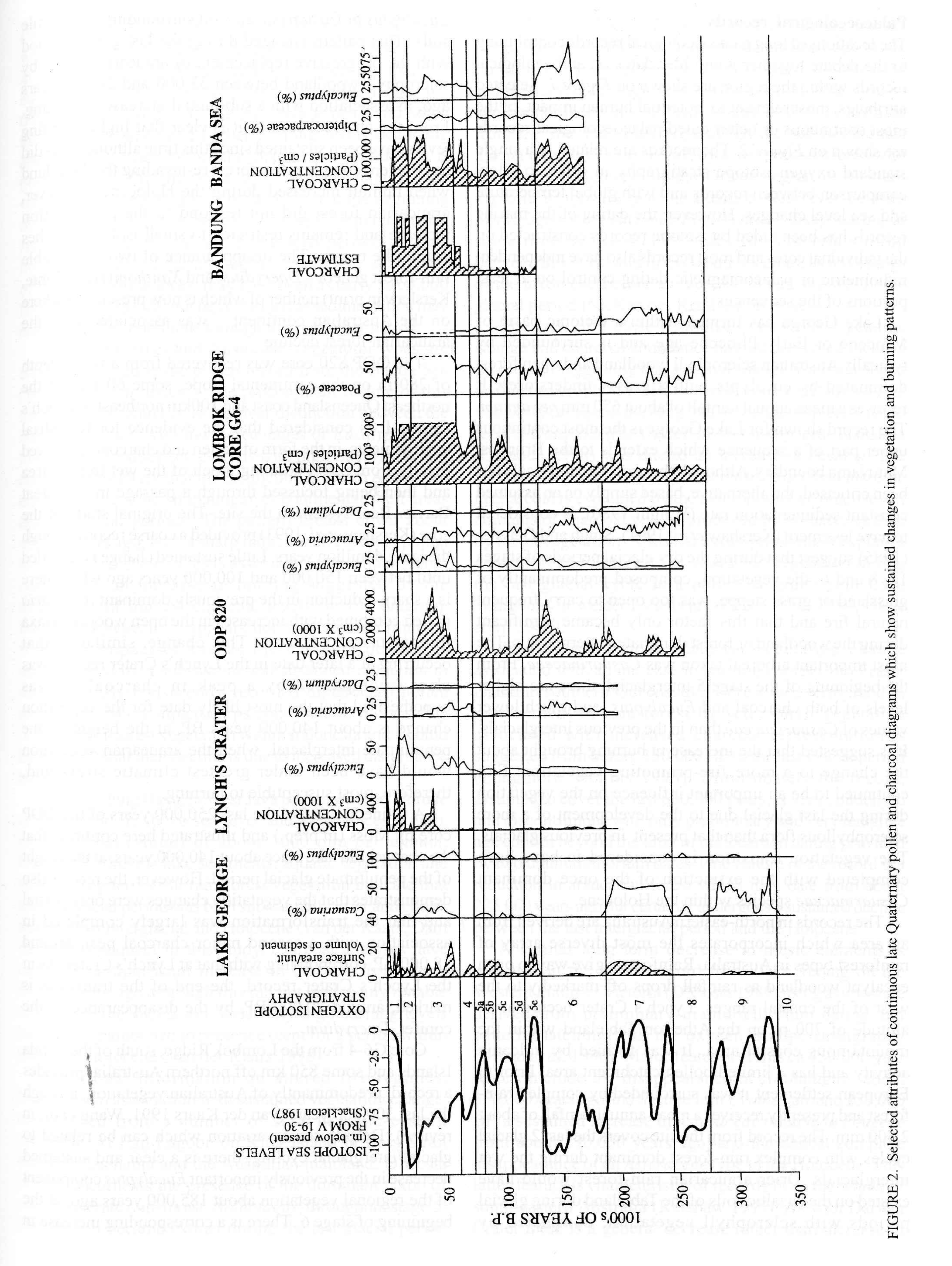

FIGURE 2. Selected attributes of continuous late Quaternary pollen and charcoal diagrams which show sustained changes in vegetation and burning patterns.

Palaeoecological records

The locations of long palaeoecological records contributing to the debate together with older dates on archaeological records within the region are shown on *Figure 1*. Selected attributes, most relevant to potential human impact, of the most continuous or better dated palaeoecological records are shown on *Figure 2*. The records are related to a single standard oxygen isotope stratigraphy in order to allow comparison between records and with global temperature and sea level changes. However, the dating of the marine records has been aided by isotope records constructed on the individual cores and most records also have independent radiometric or palaeomagnetic dating control on at least portions of the sequences.

Lake George has formed within a tectonic basin of Miocene or Early Pliocene age and is surrounded by typically Australian sclerophyll woodland and open forest dominated by eucalypts with a grassy understorey. It receives a mean annual rainfall of about 650 mm *per annum*. The record shown for Lake George is the most continuous upper part of a sequence which extends to the Brunhes/Matuyama boundary. Although the proposed timescale has been criticised, the alternative, based simply on an assumed constant sedimentation rate (Wright 1986), is considered to have less merit (Kershaw *et al.* 1991). Singh and Geissler (1985) suggest that during the dry glacial periods of stages 10, 8 and 6, the vegetation, composed predominantly of grassland or grass steppe, was too open to carry frequent natural fire and that this factor only became significant during the woodland or forest dominated interglacials. The most important arboreal taxon was *Casuarinaceae*. From the beginning of the stage 5 interglacial, there are higher levels of both charcoal and *Eucalyptus* and much lower values of *Casuarinaceae* than in the previous interglacials. It is suggested that the increase in burning brought about the change to a more fire-promoting vegetation. Fire continued to be an important influence on the vegetation during the last glacial due to the development of a more sclerophyllous flora than that present in previous glacials. The vegetation transition is considered to have been completed with the extinction of the once dominant *Casuarinaceae* species within the Holocene.

The records in north-eastern Australia are derived from an area which incorporates the most diverse array of rainforest types in Australia. Rainforests give way to open eucalypt woodland as rainfall drops off markedly to the west of the coastal ranges. Lynch's Crater occurs at an altitude of 700 m on the Atherton Tableland within the mountainous coastal area. It was formed by volcanic activity and has a limited pollen catchment area. Prior to European settlement it was surrounded by complex rain-forest and presently receives a mean annual rainfall of about 2,500 mm. The record from the site covers the last 2 glacial cycles with complex rain-forest dominant during the wet interglacials. Drier araucarian rain-forest would have existed on the basaltic soils of the Tableland during glacial periods with sclerophyll vegetation, dominated by *Eucalyptus* or *Casuarinaceae*, on surrounding, less fertile soils. This pattern changed during the last glacial period with the progressive replacement of araucarian forest by sclerophyll woodland between 38,000 and 26,000 years ago, in association with a substantial increase in burning. From the charcoal record, it is clear that higher burning levels have been sustained since this time although this did not prevent complex rain-forest re-invading the Tableland when rainfall increased during the Holocene. However, araucarian forest did not respond to the precipitation increase and remains restricted to small isolated patches within the region. The disappearance of two identifiable rain-forest genera – *Dacrydium* and *Xanthomyrtus* (Bohte, Kershaw in print) neither of which is now present anywhere on the Australian continent – was associated with the araucarian forest decline.

The ODP 820 core was recovered from a water depth of 280 m on the continental slope, some 60 km off the northeast Queensland coast and 100km northeast of Lynch's Crater. It is considered that the evidence for terrestrial environments, in the form of pollen and charcoal, is derived mainly from rivers draining much of the wet tropics area and then being focussed through a passage in the Great Barrier Reef system to the site. The original study of the core (Kershaw *et al.* 1993) provided a coarse record through the last 1.4 million years. Little sustained change is recorded until between 150,000 and 100,000 years ago when there is a sharp reduction in the previously dominant *Araucaria* pollen combined with increases in the open woodland taxa *Eucalyptus* and grasses. This change, similar to that occurring at a later date in the Lynch's Crater record, was also accompanied by a peak in charcoal. It was hypothesised that the most likely date for the vegetation change is about 140,000 years BP, at the height of the penultimate interglacial, when the araucarian vegetation would have been under greatest climatic stress and, therefore, most susceptible to burning.

A refined record of the last 250,000 years of the ODP core by Moss (in prep.) and illustrated here confirms that the changes did take place about 140,000 years, at the height of the penultimate glacial period. However, the record also demonstrates that the vegetation changes were only partial and that the transformation was largely completed in association with a second major charcoal peak around 38,000 BP, correponding with that at Lynch's Crater. As in the Lynch's Crater record, the end of the transition is marked, around 20,000 BP, by the disappearance of the conifer, *Dacrydium*.

Core G6-4 from the Lombok Ridge, south of the Sunda Islands and some 850 km off northern Australia, provides a record, predominantly of Australian vegetation, through the last 300,000 years (van der Kaars 1991, Wang *et al.* in review). Despite some variation which can be related to glacial/interglacial cycling, there is a clear and sustained decrease in the previously important *Eucalyptus* component of the regional vegetation about 185,000 years ago, at the beginning of stage 6. There is a corresponding increase in *Poaceae* indicating the development of a much more open woodland vegetation at this time. The possible role of fire in the production and maintenance of open woodland is equivocal. There is certainly a general increase in charcoal through the record with the first major peak and some indication of sustained higher burning levels occurring about 10,000 years before the change in vegetation. It is possible that this increase was only reflected in the vegetation when conditions became drier at the beginning of stage 6. After a number of subsequent charcoal peaks, relating to both glacial and interglacial periods, highest levels are recorded during stages 3 and 2. The attainment of highest burning levels may have been as early as 60,000 BP. However, this cannot be confirmed as sedimentation may not have been continuous through this particular period.

Both Indonesian and Australian vegetation types are well represented in the pollen record from the Banda Sea (Wang *et al.*, in review). The predominant feature of this 180,000 year sequence is the clear distinction between the wet interglacials with low percentages of *Eucalyptus* and low charcoal values and glacials with high *Eucalyptus* and charcoal. It is likely that the distinction is due to Australian eucalypt vegetation spreading over continental shelf areas during glacial periods. The pattern breaks down about 40,000 years ago, with a sharp reduction in eucalypt pollen to interglacial levels. This is associated with, and possibly caused by, an increase in burning suggested by the attainment of highest charcoal levels for the diagram. Indonesian vegetation appears not to have been immune from the impact of fire as the eucalypt decline is accompanied by a substantial and sustained reduction in the previously consistently recorded dipterocarp pollen proportion. Many dipterocarps contribute to more stable 'climax' rain-forest vegetation within Indonesia and it could be expected that their decline is due to increased disturbance levels.

The Bandung Basin in West Java is situated at an altitude of about 650 m above sea level and experiences a high, non-seasonal rainfall of about 3000 mm *per annum*. Changes within the lake sediments, aquatic vegetation and surrounding terrestrial rain-forest vegetation indicate that the last glacial period was both substantially drier and cooler than the last interglacial and Holocene (van der Kaars, Dam 1995). Subsequent to this study, charcoal analyses have indicated a significant increase in burning from about 65,000 years ago although this did not lead to any notable changes in the vegetation. Relatively high burning levels have been maintained to present except for a period within the early Holocene (van der Kaars 1998).

Additional information on altered fire regimes, frequently in association with sustained vegetation change, is provided from a number of sites in south-eastern Australia. At Egg Lagoon on King Island in Bass Strait between Tasmania and the Australian mainland, D'Costa (1997) documents the presence of the dominant taxon of cool temperate rain-forest, *Nothofagus*, throughout stage 5. This taxon became extinct during the last glacial period when there is evidence for an increase in burning, but the actual date of extinction cannot be determined due to the condensed and probably discontinuous nature of sedimentation through this period. A major decline in another rainforest taxon, *Phyllocladus*, is also documented from the site, but small populations did survive the last glacial only to be finished off by activities associated with European settlement. In the Otway region of western Victoria it appears that the position was reversed with *Nothofagus* surviving but *Phyllocladus* disappearing at some time before 40,000 years BP. The relationship between this event and fire is again uncertain as recordings of the taxon end before an increase in burning within the glacial period (McKenzie, Kershaw, in review).

The lack of a close relationship between vegetation change and charcoal abundance has not prevented Jackson (in review) suggesting that a partial change from rain-forest and wet sclerophyll forest to herbaceous vegetation about 160,000 year ago in the long, but as yet incompletely dated record from Darwin Crater in south-western Tasmania (Colhoun 1998) was due to an increase in burning. The fact that, in general, there is a decrease rather than increase in charcoal is explained by the assumption that much lower amounts of charcoal will be produced by herbaceous than by forest vegetation. A similar assumption might explain a general trend to more open woodland vegetation during the last glacial cycle in a pollen diagram from Lake Wangoom in western Victoria (Edney *et al.* 1989, Harle *et al.* 1998).

The oldest proposed date for vegetation change associated with an increase in burning comes from Fraser Island in southern Queensland. Here a long term trend in replacement of rain-forest by sclerophyll vegetation associated with increased charcoal representation is suggested from before 350,000 BP to the last glacial period (Longmore, Heijnis 1998). Unfortunately the record, assumed to cover the last 600,000 years, is very condensed and discontinuous with only preliminary and very tentative age control beyond the limit of radiocarbon dating provided by two uranium/thorium dates. One feature of the record is a reduction in araucarian forest which may date from about 225,000 years ago but certainly undergoes a sustained decline between the last interglacial period and the Holocene.

A similar long term decrease in mesic elements is recorded in the pollen record from Lake Terang on the Western Plains of Victoria (D'Costa 1989) using a timescale derived from preliminary uranium/thorium dating and pattern matching with the oxygen isotope stratigraphy (Urban *et al.* 1996). Major features of this ca 450,000 year record include the disappearance of *Nothofagus* about 350,000 years ago and the tree fern *Cyathea* around 250,000 BP, a sustained increase in *Asteraceae* relative to *Poaceae* from about 190,000 years ago, and the almost complete disappearance of an *Asteraceae* type in the Holocene. This latter feature is characteristic of records from the whole of south-eastern Australia (Kershaw 1995). As with Darwin Crater there is a general decrease rather than increase in charcoal through the sequence. This trend may similarly be interpreted as a result of the vegetation becoming more open rather than an actual decrease in burning. Alternatively, it may also reflect generally lower lake levels due to sediment infilling or regional drying which reduced charcoal inwash into the basin.

New Guinea, which has been part of the Australian landmass except during high sea level interglacial periods, has revealed few long records and no clear indications of sustained vegetation change except for those associated with Holocene agriculture. However, there are increases in, or first significant representation of, charcoal in Late Pleistocene records from the highlands. The earliest of these are around 30,000 BP at Kosipe (Hope 1980), and about 34,000 BP in the combined sites of Kelela and Supulah Hill (Swadling, Hope 1992).

DISCUSSION

Before a detailed consideration of the possible role of people in bringing about changes to landscape patterns and processes, it is wise to examine any alternative possible explanations. As the changes appear to have covered a large region and to have occurred at different times, it would suggest that alternative explanations must involve processes which are both wide ranging and exhibit variability on an appropriate scale. Climate would appear to be the only realistic candidate.

The case for climate

It is clear from the records that the dominant influence on vegetation variation is glacial/interglacial cycling with all longer records exhibiting expansion of communities adapted to lower rainfall during glacial periods. Within wetter areas, there are also generally higher charcoal levels during glacials when drier conditions would have facilitated burning. One notable exception is Darwin Crater where higher charcoal levels during interglacials are explained by greater charcoal production from predominantly forest vegetation. In the lower rainfall area around Lake George, it is hypothesised that during earlier glacial periods, the vegetation was too open to carry frequent or intense fire. Changes in depositional characteristics may be an additional factor contributing to charcoal representation within sites on the Western Plains of Victoria.

Despite this variation in charcoal representation, there is an inferred increase in burning through, or at particular stages within, all records. In many records there is also a close relationship between an increase in fire activity and sustained vegetation change including plant extinction. These are features which have not been widely demonstrated outside of the Australian region and therefore cannot easily be attributed to the global pattern of climate change.

However, the patterns do conform with a general late Cainozoic trend towards increasing sclerophylly of Australian vegetation with changes from less to more fire tolerant vegetation. It is possible that, in these more humid parts of the region where pollen evidence is preserved, we are witnessing the latter part of a process which has already transformed drier parts of the continent (Kershaw *et al.* 1994). The mechanism for continuing change could be that of ecological drift as proposed by Jackson (1968) whereby, through positive feedbacks between fire, vegetation, soil nutrient status and water balance (Kershaw 1989), 'fire-adapted' sclerophyll vegetation gradually replaced more fire-sensitive communities. The extreme climatic variability of Australian climate (Nicholls 1992) combined with the, possibly related, evolution of a fire-promoting flora, would have contributed to the drift process. Although the Indonesian region does not share this fire-promoting flora, it is affected by El Nino-Southern Oscillation (ENSO) variability and consequently the potential for natural fires to occur during dry periods.

There is also some independent evidence of an acceleration in continental drying within the last 400,000–500,000 years which has been used to support predominantly climatic interpretations of the Fraser Island and Lake Terang records. Bowler (1982) documents the onset of dune mobilisation in the Murray Basin of south-eastern Australia about 400,000 BP while Hesse (1994) records an increase in dust deposits during glacial periods in marine cores, from isotope stage 12 onwards, from the Tasman Sea. However, patterns during this period may simply be a reflection of longer term cycles such as the megacycles of Kukla and Cilek (1996) in which, during the Quaternary, terrestrial climates at least appear to have been more extreme in some glacial and interglacial periods than in others. Within the period of interest, one megacycle is defined between the glacials of stage 12, culminating about 410,000 BP and stage 6 culminating about 140,000 BP. The interglacials succeeding these glacials were also most extreme. Consequently, a general drying trend might be evident from the interglacial of stage 11 to the penultimate glacial. There might also be a significant drying trend from the height of the last interglacial period. Such a pattern has been tentatively suggested for the Fraser Island record (Longmore, Heijnis 1997) and is more clearly demonstrated in the Lake Terang record which shows good correlations with a record from Germany which was used in the formulation of the megacycle hypothesis (Urban *et al.* 1996). This pattern may explain why changes are most evident around the height of the penultimate glacial and during the last glacial period.

It is unlikely, though, that megacycles can explain sustained vegetation changes on their own as there is no evidence for similar changes during earlier parts of the Quaternary, at least from the limited available evidence. Certainly the long ODP record shows no major sustained changes in terrestrial vegetation from 1.4 million to 140,000 years BP, while a recently constructed long record from the Western Plains of Victoria, which covers a number of glacial cycles probably of Mid to Early Pleistocene age (Barbara Wagstaff, pers. comm.), is monotonously consistent.

The case for people

Two hypotheses have been forwarded in support of a human cause for increased burning and vegetation modification. The first considers that the initial impact of people was on the megafauna and through direct killing most of this fauna was driven to extinction. This process resulted in a lack of grazing pressure allowing the build up of fuel to produce more frequent and intense fires (Flannery 1989). This view assumes that people were interested in and capable of effective slaughter on a large scale, but in contrast with the North America situation (Martin 1984), most researchers feel that it is unlikely that the first inhabitants of Australia were big game hunters. The second hypothesis is that people, through their use of fire, directly increased the level of burning on the continent resulting in vegetation change. Flannery (1989, 1994) opposes this idea on the grounds that it would not result in the necessary increase in fuel to allow higher burning levels. However, changes in fire regimes could have increased the availability of fuel through ecological drift towards more sclerophyllous and fire-promoting vegetation and this is certainly a feature of most palynological records. It is possible, however, that habitat change contributed towards or even caused megafaunal extinction, in which case the resulting increase in fuel could have resulted in higher burning levels and an acceleration in the drift process.

There is no doubt that the mechanisms exist for landscape change as a result of Aboriginal activity and there is substantial anthropological evidence that fire was an essential part of the Aboriginal way of life (e.g. Nicholson 1981). On the other hand, there is ample evidence for a close association between climate, fire and vegetation through at least the last 20 million years (e.g. Kershaw *et al.* 1994). The argument for the involvement of people rests predominantly on a geologically late acceleration in rates of landscape change and disruption of previous vegetation-environment relationships. Although there is some suggestion of a general drying trend within the last 400,000–500,000 years and that a vegetation response to this, through ecological drift, may have been markedly time transgressive, the fact that almost all changes from environments as different as rain-forest and open woodland, occurred within the last 200,000 years, appears to demand an alternative cause to climate.

The evidence for a human cause does become more substantial from the older to younger records. The earliest evidence from a relatively continuous sequence with good chronological control is that from Lombok Ridge. Here there is a lack of temporal correspondence between an increase in burning and vegetation change. The connection between these events clearly depends on an associated reduction in rainfall from the stage 7 interglacial to the stage 6 interglacial although the stable isotopic composition of elemental carbon shows that from 190,000 to 160,000 years ago burning was predominantly from arboreal vegetation suggesting that fire did play a role in the reduction of forest cover. A similar involvement of climate is suggested for the Lake George event, where the timing of the increase in burning and associated vegetation change is dependent more on an increase in fuel with precipitation increase at the stage 6–5 boundary than the arrival of people. Consequently, it is inferred that humans arrived prior to 125,000 BP, at some time during the preceding glacial period. An arrival during the height of this glacial period would perhaps be most likely as entry from the Indonesian region would be facilitated by lowest sea levels and, consequently, shortest sea crossings. A similar argument can be proposed for the ODP core record where the initial major peak in burning associated with some sustained vegetation change is dated to the height of the penultimate glacial period. However, it is possible that the event is a function of dry conditions when the araucarian forest would have been under greatest stress and most susceptible to destruction under increased burning pressure.

Vegetation and burning patterns during the last glacial period do not show the same degree of correlation with climate. The stepwise increases in burning at Bandung are clearly out of phase with the isotope record. The initial increase occurs after the beginning of drier condition in stage 4 while maximum burning is achieved during the subsequent wetter period of stage 3. At Lombok Ridge, highest sustained charcoal levels relate to stage 3 rather than the preceding drier stage 4. However, within this record, most charcoal peaks relate to higher, though not the highest, sea level phases and this pattern may relate as much to fuel availability as to climatic conditions.

There is little correspondence at all between climate and increased charcoal and vegetation change around 40,000 years ago in the north-east Queensland and Banda Sea records. Consequently, it is difficult even to bring climate into the debate.

Multiple human arrivals

Anthropometric analyses of variation within and between modern and fossil human assemblages have led to a great deal of speculation on the number of different populations that colonised Australia (e.g. Thorne 1971, 1983) although this debate has been overshadowed recently by that of the timing of initial entry. Discussion has certainly been inhibited by the uncertainties in the time of arrival and also in the time of evolution of modern people and their global migration patterns.

Until recently, it was considered by the majority of archaeologists and physical anthropologists that *Homo sapiens* evolved in Africa about 100,000 years ago and then quickly spread around the world. It has also been assumed that only these modern humans were capable of crossing sea barriers to allow entry into Australia. Consequently, it has been difficult to conceive of any arrival prior to the last glacial period. However, two significant developments have complicated the picture. The first is that the 'out of Africa' hypothesis has become diluted by the recognition of genetic variability that may involve Asian people in the emergence of modern humans and a widely dispersed human population by 200,000 years ago (e.g. Hammer *et al.* 1997, Harding *et al.* 1997).The second development is the dating of human artefacts to 700,000 years on the island of Flores within the lesser Sunda Islands (Sondaar *et al.* 1994). This date demonstrates that *Homo erectus* had the ability to cross water gaps and that it would have been only one more step into Australia.

The available archaeological and anthropological data, combined with the palaeoecological records, make it possible to construct a very tentative picture of possible patterns of human arrival in Australia *(Figure 1)*.The earliest proposed date of about 200,000 years for entry would bring Australia into the early period for the geographical spread of *Homo sapiens* while older evidence for landscape changes in Australia could be accommodated by the arrival of *Homo erectus*. The location of relevant sites would suggest entry through the Lesser Sunda Islands *(Figure 1)*. A subsequent entry around 140,000 years ago would have been facilitated by low sea levels and, based on the proposed impact in north-eastern Queensland, may have involved a northern, rather than a western, entry through New Guinea. Technologically more advanced populations may then have migrated through Java and the Lesser Sundas to northern Australia between about 65,000 and 60,000 years ago with a final and rapid Pleistocene invasion through the northern New Guinea route around 40,000 BP. Such a scenario accommodates, to a certain degree, the range of archaeological views on arrival times in Australia – namely a late (40,000 year) arrival, a medium (55–60,000 year) arrival and an early (pre-100,000 year) arrival.

CONCLUSIONS

Australia is unusual in the extent to which the vegetation cover has been altered within the later part of the Quaternary and the substantial replacement of fire-sensitive by fire-promoting vegetation in many areas suggests that the pre-existing balance between climate, vegetation and fire has been disrupted, or that the gradual long-term trend towards fire-promoting vegetation has been accelerated, by an increase in fire activity. A general drying of the continent combined with ecological drift is one possible explanation for such a change but the patterns of replacement of fire-sensitive by fire-promoting vegetation in different climatic regions are not totally consistent with such a hypothesis. We believe that the alternative view that people were involved in this process through their use of fire has been clearly demonstrated for the last 60,000 years and particularly the last 40,000 years for which there is substantial collaborative archaeological evidence and where impact extended to at least part of Indonesia which lacks a substantial fire-promoting flora. Prior to this time, the evidence is equivocal though it is difficult to accept that the extent of change evident in north-east Queensland, around Lake George, and perhaps also in the Lombok Ridge core, were not influenced by human activity. Even in those sequences which demonstrate a general drying through more than the last 200,000 years, the suggested climate changes could have resulted from regional landscape alteration promoted by human fires.

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