Theatrum Oceani: Themes and arguments concerning the prehistory of Australia and the Pacific

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Wherever the geologist can explore the earth's surface, he can read much of its past history . . . but wherever oceans and seas now extend, he can do nothing but speculate on the very limited data afforded by the depth of the waters. Here the naturalist steps in, and enables him to fill up this great gap in the past history of the earth. (A.R. Wallace 1869, 15)

Introduction

If one were to tip a terrestrial globe so that one's perspective was centred on a location situated over Turkmenistan (lat. 40° north and long. 60° east), the subtended view would represent a hemisphere almost entirely covered by land (Fig. 1). From east to west is the mass of Eurasia, with northern Africa curving away out of view to the south. This is how the ancient Greek geographers conceived of the inhabitable world; the *ekumene* surrounded by the great circumscribing ocean. By an irony, when Aristotle's most famous student at the Lyceum, Alexander, reached the shores of the Caspian Sea, he thought that he had actually found the edge of this *okeanos*, whereas in reality he was close to the very geographical centre-point of an expanded *ekumene* (Glacken 1956). Had he in his militarized expeditions been able to travel further east beyond even *India trans Gangem*, he would indeed have reached the western edge of a great ocean that might have seemed to have circumscribed the entire world of humankind.

In its historical development, the discipline of prehistory over the past one hundred and fifty years has been largely developed from the analyses of the archaeological record of the historical events that have occurred over this vast and largely continuous terrain. In general, the oceans surrounding these central land masses have been seen to have played only a marginal influence, restricted perhaps to regional scales such as the

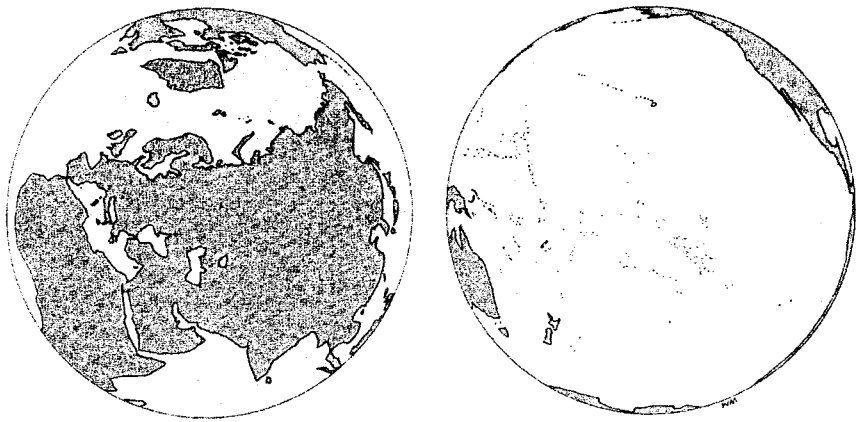

Figure 1. The terrestrial world and the marine world.

littoral shores and islands of the European Atlantic or the gulfs and northern waters of the Indian Ocean. It was only the enclosed seas, in particular the aptly named Mediterranean, which, penetrating into the western heart of the land mass, have provided major interpretive themes for its prehistory.

There is another viewpoint of the globe, that centred on Christmas (or Kiritimati) Island (lat. 2° north and long. 157° west) in the Line Islands chain of Kiribati in the central Pacific. From here, one sees a global hemisphere almost entirely covered by sea. The western coasts of the Americas fringe the right hand margin like the concave edge of a new crescent moon; to the left there is the faintest edge of the coast of China; and to the south-east, just the eastern coastline of Australia and New Guinea. The very south has the ice edge of the Antarctic shore. The centre view consists of a vast oceanic world, with a scatter shot of islands. Some of these are of course large, such as the two main islands of New Zealand; and the combined land masses of Australia and New Guinea are themselves continental in scale. Yet it is our contention that despite great differences in geographic size and isolation of the various islands, and the differences of scale in the timing and intensities of their human occupations, there still remain some unifying principles in one's interpretation of all of their prehistories. We take the term 'theatre' as used by the Renaissance geographer Abraham Ortelius of Antwerp, in his pioneering atlas *Theatrum Orbis Terrarum* of 1571, to exemplify the grand geographical terrains upon which the histories of human lives have been carried out. These reflect the prehistoric signature of an oceanic world, and it is this that we would like to attempt to explore in this present essay.

Only a very limited number of themes can be addressed within the word-length available and the vast area to be covered geographically. Archaeology is a young discipline in the Pacific region. Its history has been explored in recent essays by Golson (1986), McBryde (1986), Mulvaney (1993) and by one of us (Jones 1993, 1998, 1999). We are still much concerned with the 'when' of prehistory and still working out the implications of this for the 'why' which justifies its study. It is thus the 'when' which we stress here in an overview of the settlement of the region, and the difficulties involved in establishing acceptable chronologies. These are difficulties of techniques of dating beyond the 'radiocarbon barrier' of about 40,000 years, where small changes of parameter in experimental method can make major changes to the numbers produced. Difficulties of interpretation of stratigraphy at major sites, both in Southeast Asian and Australian fossil hominid and early occupation sites, also present major differences in the possible stories to be told. At the other end of the chronological and geographic spectrum in East Polynesia, with a less than 2000-year archaeological record and in some areas a less than 600-year prehistory prior to European contact, the problems are those of the interpretation of radiocarbon dates themselves. Problems of old wood, natural or cultural burning and proper calibration of marine shell samples loom large in sometimes spirited discussion. Figures 2, 3 and 4 display the islands and in some cases the individual sites mentioned in this paper in the Southeast Asian, Australian and New Guinea, and Pacific Islands regions.

It is our contention that to get the dates 'right' is a primary task in Oceania, and one that is not yet accomplished. The implications are enormous, as we shall show. Knowing when something happened, even if only relative to something else, itself tells you something about it — fast or slow, old or recent, same time or different. If we take an issue such as the spread of modern humans into our region, timing is critical in order to examine questions such as whether the spread was contemporary with the spread of modern humans elsewhere out of Africa, whether it related to particular world-scale glacial events or cycles, whether it was a slow adaptation or a rapid spread by an environmentally super-flexible species, whether there were absolute environmental limits to the spread or major pauses, and whether the spread coincided with the extinction of Australia and New Guinea's marsupial megafauna and thus might be implicated in that extinction. As we shall see below, when particular grades of hominid, *Homo sapiens* and before them *Homo erectus* entered the area are the subjects of major debate. Until such debates are settled, we shall have no idea of the tempo of cultural change or of its relation to environmental changes we can witness in other biological and fossil records.

Bathymetry and biological history

If we wish to consider the biological histories of this vast array of islands, it is not so much their present geographic delineation as on the pages of an atlas which is so

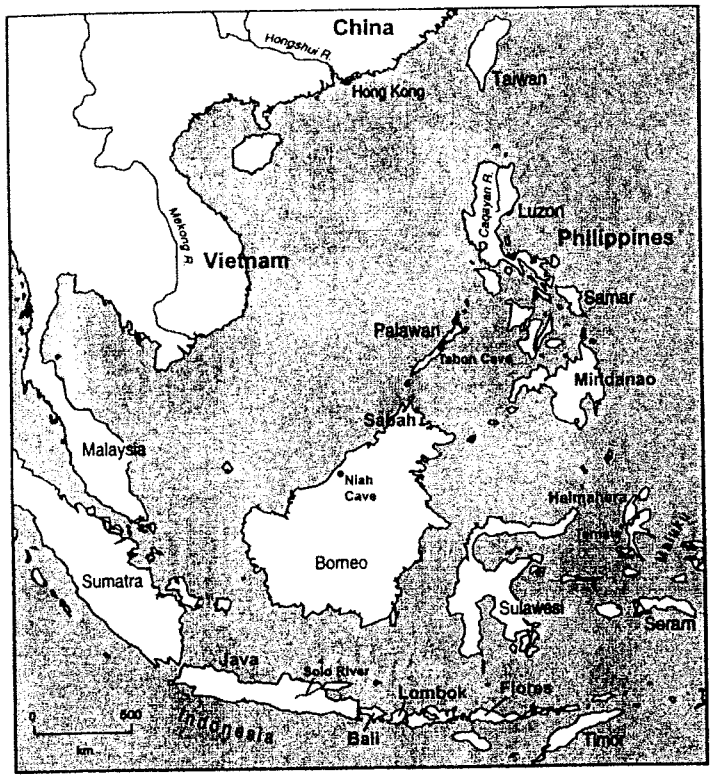

Figure 2. Islands mentioned in the text in Southeast Asia.

important, but rather the bathymetry of the shelves from which they emerge. To extend our metaphor of an observer from far out in Space, what is critically important is to be able to look down through the blue surface of the sea to its bed. Glacio-eustatic theory shows that periodically throughout the Pleistocene, glacial low sea-levels have descended to depths of about 130 m below present levels. During such phases, shallow continental shelves were exposed and islands on them were joined to their adjacent continents. This allowed periodic faunal recruitment. Conversely during periods of interglacial isolation, processes of extinction occurred due to the limiting factors of reduced habitat size, according to the laws of island biogeography succinctly enunciated by MacArthur and Wilson (1967). Beyond such continental shelves are the true oceanic islands to which faunal access has always been across water. In these cases the

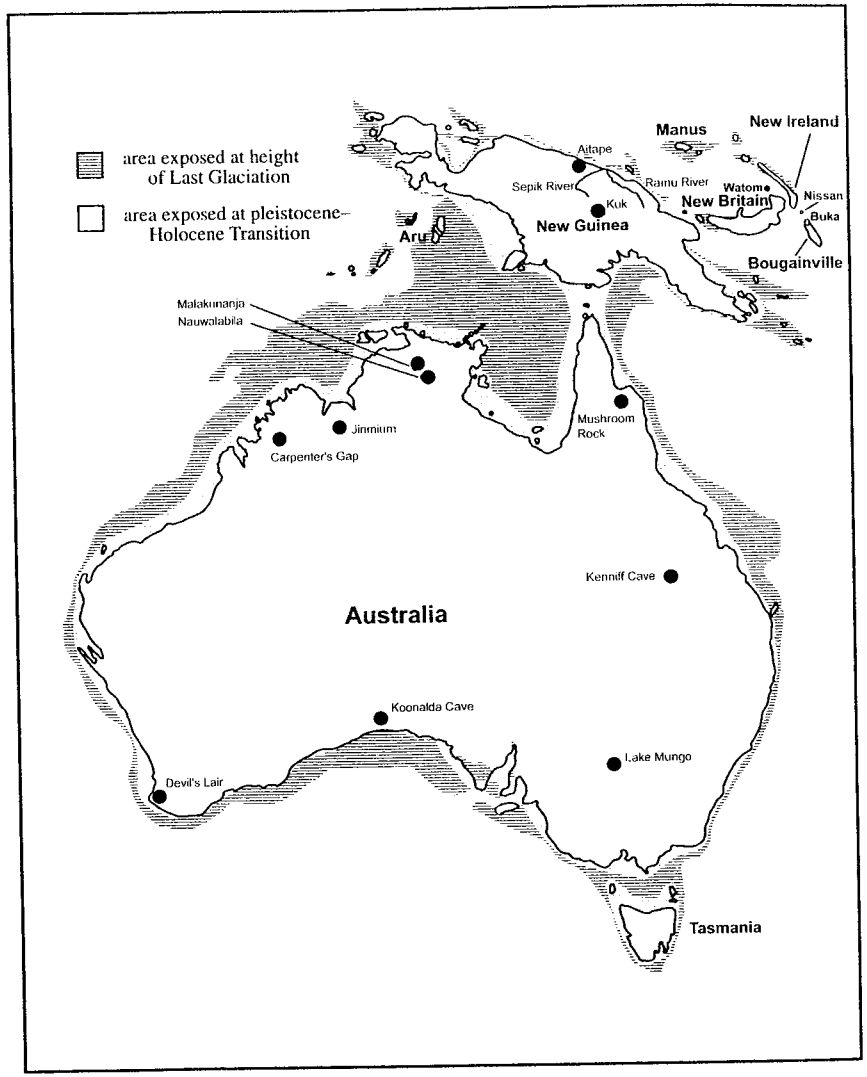

Figure 3. Sites and areas mentioned in the text in Australia and New Guinea (map after Beaton 1995).

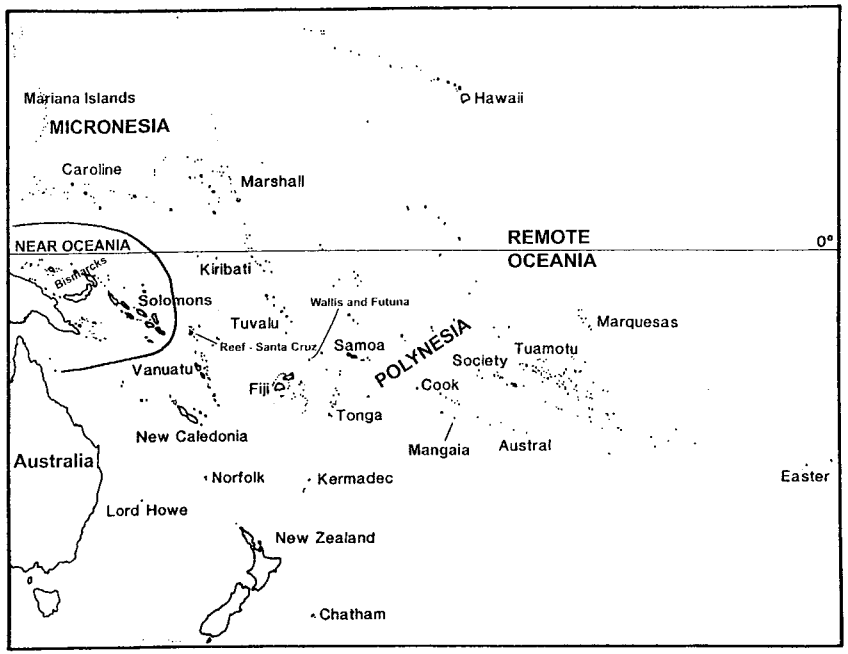

Figure 4. Islands and archipelagoes mentioned in the text in the Pacific region.

probability of any particular species being able to colonize was based on their trans-marine survival capacity and also inversely according to the distances to be travelled.

The great Victorian naturalist Alfred Russell Wallace instinctively saw some of these patterns during his travels through the Indo-Malay Archipelago in the mid-1850s. Sailing a short distance eastwards from the small spice-rich island of Ternate to Halmahera, to the west of the 'Bird's Head' or Vogelkop peninsula of the island of New Guinea, he met for the first time Papuan people, and commented on how different they seemed to be to the Malays of the eastern part of the archipelago. That, 'on drawing the line which separates these races, it is found to come near to that which divides the zoological regions, but somewhat eastwards of it; a circumstance which appears to me very significant of the same causes having influenced the distribution of mankind that have determined the range of other animal forms' (1869, 15). Wallace made explicit that his original 'conviction that the eastern and western halves of the Archipelago belonged to distinct primary regions of the earth' derived initially from these ethnological observations (ibid.). As adjusted by Thomas Huxley (1868), this

boundary has been called 'Wallace's Line' ever since and it marked the south-eastern extent of the Eurasian fauna.

The ancient fauna of Java is Eurasian. The island itself was only formed tectonically in Plio-Pleistocene times and its fossil fauna consisting of such mammalian taxa as bovids, elephants and primates resembles that of the Siwaliks on the Himalayan foothills of India. Yet between the islands of Bali and Lombok there is a profound change in faunal composition. Wallace himself put it that, 'The strait here is fifteen miles wide, so that we may pass in two hours from one great division of the earth to another, differing as essentially in their animal life as Europe does from America' (op. cit., 11). Beyond this narrow strait was a series of island chains, highly depauperate in their land fauna, and beyond these again to the east and south, the Australian continent, with its own distinctive land fauna. These great biogeographical distributions were only finally explained in the mid-1960s with the development of the theory of plate tectonics (Campbell 1975). Australia, part of the original super-continent of Gondwanaland, has never been joined to Asia. Its archaic biological affinities are with southern Africa, South America and India. Since its final separation from Antarctica, Australia has been slowly drifting northwards, and its collision with the Asian and Pacific plates has formed the spine of the New Guinea Highlands and a series of tectonically uplifted island chains (including the greater Sunda Chain containing Sumatra and Java) separated by abyssal oceanic straits. Between the continents of Asia and Australia lies a region of islands and straits, referred to as Wallacea. Here was the gateway to the human colonization of the Pacific world when moving from Sunda — the Southeast Asian continental extension of Greater Asia — to Sahul, the Pleistocene continent made up of Australia, New Guinea, the Aru Islands and Tasmania (Jones 1989, 743–6).

Ancient hominids

Ever since the discovery by Eugene Dubois of the calvaria of his original *Pithecanthropus* at Trinil on the banks of the Solo River in 1891 (Dubois 1894), the island of Java has been the source of more fossil specimens of what is now referred to as *Homo erectus* than any other part of the world. This has been partly due to taphonomic processes, whereby fluvial deposits were accumulated in shallow deltaic contexts, conducive to the accumulation of fossil bones, and then tectonically uplifted as in the deposits of the classic Sangiran Dome sequence of south central Java. Indeed during the early part of the century it was considered by some scholars including Dubois himself that Southeast Asia was the original homeland for humankind, which is why he had originally gone to the Dutch East Indies as a colonial government official in order to initiate his field enquires. Concerning the dating of these Javanese hominids, their earliest appearance is within the stratigraphic context of the uppermost part of the Pucangan beds of the Sangiran sequence.

The classic Sangiran 17 hominid fossil (*Pithecanthropus* VIII), which has its upper facial features preserved, came from the middle part of the overlying Kabuh beds. Dates obtained by the fission track method on zircon crystals within stratified tuffs in the Pucangan gave values of about one million years ago, consistent with the reverse magnetic polarity of the deposit, and the Kabuh was dated by the same methods to about 750 ka years ago (Itihara *et al.* 1985, 376; Suzuki *et al.* 1985, 329–30), a value which seemed to have support from an assessment of a normal magnetic polarity for these higher deposits. At the site of Mojokerto in north central Java, the calvaria of a *Homo erectus* child was found in 1936 within river sands intercalated in marine deposits ascribed to the Djetis beds of the Pucangan formation (Jacob 1975, 105–6) and later dated on the basis of detailed palaeomagnetic studies to *c*.970 ka (Hyodo *et al.* 1993), a figure considered by de Vos (1994) to be consistent with the faunal component of these deposits.

However, research by Swisher *et al.* (1994; Swisher 1994), based on ^{40}Argon/^{39}Argon isotope measurements of hornblende minerals within pumice recovered from both Sangiran and at Mojokerto, proposed dates some 900 ka older than either of the values quoted above, with an age for Mojokerto of 1.8 ma. In the case of Mojokerto, the argon dates were carried out on samples of pumice taken from a conglomerate which may have been substantially reworked and redeposited since the original volcanic ejection (de Vos 1994). At Sangiran, however, a new ^{40}Ar/^{39}Ar study was carried out, based on developments in laser incremental heating of hornblendes (Swisher and Curtis 1998), and this was integrated with palaeomagnetic studies based on detailed stratigraphic sampling across the critical hominid-bearing layers. This yielded a series of dates of between 1.7 ma to 1.0 ma, which were chronologically consistent with their stratigraphic positions (Swisher *et al.* 1998); and all of the *H. erectus* fossils occurred within reverse polarity rocks. The critical differences compared with the previous results from the same site were attributed, firstly, to anomalously young fission-track dates and, secondly, to a misinterpretation whereby a 'normal polarity' signal was attained by a contemporary field overprint, derived from surface weathering (Swisher *et al.* 1998). If these dates gain critical acceptance, then they establish the presence of *H. erectus* in Southeast Asia almost instantaneously, in terms of the discrimination of our dating methods, with their first appearance in Africa, and confirm the first great geographical spread of advanced hominids from their ancestral home.

There has also been recent controversy concerning the youngest age for the Javanese *erectus* hominids. At Ngandong, on the Solo River of central Java, a celebrated series of hominid fossils was recovered originally in 1931 from a high terrace of the Solo River (Oppenoorth 1932; von Koenigswald 1933). Morphologically these were considered to represent the final form of the Asian *erectus* lineage (Weidenreich 1951) and there is a general consensus that the geomorphological context of the fossils would indicate an Upper Pleistocene age. ESR and uranium series dates were assayed by Swisher *et al.* (1996) on fossil bovid tooth enamel, excavated from a small pit adjacent to the original excavations of the 1930s where some of the hominids had been found (Oppenoorth 1932; von Koenigswald 1933; Jacob 1975, 107). They gave values as recent as between 27 ka and 53 ka, the large error range reflecting uncertainties in the uranium uptake histories. If this age were true, then it would imply that the final *erectus* population had been living contemporaneously with modern *sapiens* populations within this region. This would have huge implications not only for general issues of human evolution but also specifically to the question of the colonization of Australia and the affinities of its oldest human forms (Swisher *et al.* 1996, 1870). The critical question concerning this study is the assumption that the dated bovid remains within this deposit have had a similar taphonomic history to the hominid remains (op. cit., 1871). This is unlikely to have been the case, however, since unlike the other fauna, the hominid fossils were heavily mineralized and dark, almost black in colour, and had most probably been reworked into the upper Ngandong terrace by fluvial action from older deposits (Grün and Thorne 1997). The most recent estimate, based on direct non-destructive gamma-ray spectrometric uranium series measurements on two of the skulls (Solo 1 and Sambungmacan), indicates a value older than 200 ka (Yokoyama *et al.* 1998).

The only *Homo sapiens* fossil of substantial age from Indonesia is the Wadjak hominid, recovered from a breccia deposit within a limestone cliff crevice in southern Java and, on present evidence, dated to terminal Pleistocene times, perhaps 10 ka years ago (Jacob 1975, 115–16; von Koenigswald 1956). From its first discovery its rugged morphology has been compared to that of Australian Aborigines (Dubois 1920), and it represents a population clearly pre-dating the modern Javanese one. Elsewhere in Southeast Asia fossil skulls with sapient morphology, recovered from the caves of Niah on the island of Borneo and Tabon on Palawan island in the Philippines, have come from deposits carbon dated to *c*.40 ka and 26 ka respectively (Harrisson 1959; Fox 1970). However, given the less-precise excavation methods of a generation ago, there is a possibility that these fossils might have been inserted into older deposits due to burial customs or other taphonomic processes. There is now the urgent need to get direct dates on them using the most recent dating methods before further historical speculations are embarked upon (Jones 1989, 750–2).

Concerning the cultural capacities of the Southeast Asian *H. erectus* hominids, and their archaeological signature, there has long been controversy. Throughout most of the century it was assumed that with a primitive hominid, so also a primitive stone technology. The absence of Acheulean-type handaxes led Movius (1944) to propose an east Asian equivalent called the 'Chopper-chopping tool tradition', based largely on unifacial and bifacial flaked cobbles. Part of the formulation for this came from his study of the surface collection made by von Koenigswald and Tweedie of large core and thick flake tools from the Baksoka Valley near Pacitan in southern Java. It was originally assumed from their typological appearance of large size and simplicity of form that they were of Middle Pleistocene age (von Koenigswald 1939). However, detailed field

research by Bartstra (1984) within the type area of this industry has shown them to be derived from terminal Pleistocene times or even later. In his opinion, the oldest reliable finds of stone artefacts from Java or indeed elsewhere from Sundaland are restricted to industries consisting of small flakes and casually struck cores from locations such as the 'Old River Gravel' at Ngebung within the youngest deposits of the Sangiran sequence, and at the Solo River High Terrace, both dated to no older than the middle part of the Upper Pleistocene (Bartstra 1985, 103–8; Jones 1989, 748–50).

The issue is also potentially confused by problems concerning the identity, in some cases, of genuine humanly made stone artefacts as opposed to pieces, which, while showing some percussion fractures, were formed entirely by natural causes, in particular by being knocked against each other in high energy cobble-bedded streams. The problem partly lies in the common occurrence of easily fractured silicified tuffs, which can often show quasi-artefactual phenomena, and unfortunately there has also been a lack of analytical rigour by some observers concerning the unequivocal criteria to be applied in identifying humanly fashioned artefacts. These issues are similar to those concerning the 'eolith' problem in the early 1900s when Tertiary age artefacts were claimed from gravel deposits in England and France. Objective criteria for an unquestionable human agency for percussion have been discussed in an Australian context by Wright (1971, 50, 56–7) in his analysis of the flaked flint pieces from Koonalda Cave in the Nullarbor Plain of South Australia.

The capacities of the Southeast Asian *Homo erectus* hominids both to make stone tools and also to cross narrow oceanic barriers have been brought into focus by new examinations of the site of Mata Menge in south central Flores, situated under the shadow of a large volcano. Here claims were made as long ago as 1970 of the stratigraphic association of flaked stone tools with fossils of the now extinct elephant-like *Stegodon trigonocephalus* (Verhoeven 1958; Maringer and Verhoeven 1970; Glover 1973, 122–5). The stegodons were one of the few large Asian mammals to have been able to colonize some of the islands of Wallacea, such as Flores, Timor, Sulawesi (the Celebes) and both Luzon and Mindanao in the Philippines (Hooijer 1975), perhaps through their ability to swim substantial cross-sea distances. Reanalysis of the Mata Menge site by palaeontologists found further flaked stones within the same deposits as the *Stegodon* fossils (Sondaar *et al.* 1994), which they dated as lying immediately above the Brunhes-Matuyama magnetic reversal, indicating an age of *c.*700 ka. At least one flake illustrated by van den Bergh *et al.* (1996, fig. 5) is unquestionably an artefact. These deposits were later dated by fission track method, indicating the arrival of *H. erectus* in Flores by about 850 ka ago, with an absence in deposits slightly older (Morwood *et al.* 1997; Morwood *et al.* 1998). A further regional survey has revealed more sites within the same region, where bones of *Stegodon* have been reported associated with *in situ* flaked stone tools (Morwood *et al.* 1999, 285).

It is our responsibility to address the evidence with the utmost scrutiny because of its importance regarding the capacity of early hominids to cross sea straits (Bednarik 1997). Our final question is one of geomorphology, whether or not there have been episodes of massive regional slumping of fluvio-volcanic deposits, with resultant mixing, perhaps due to monsoonal-rain or tectonic events? (Cf. Fennema 1996.) New data indicate stratified stone tools and fauna in basal levels of the limestone cave of Liang Bua in central Flores, which will probably settle the issue (Schulz 2001).

For the record, one of us (RJ, in association with Indonesian and Australian colleagues in 1993) failed to find any stone artefacts within extensive exposed deposits, probably of Early or Middle Pleistocene age and which yielded fossils of *Stegodon*, near Atambua, in West Timor close to the border with East Timor. Other reporters have been more sanguine in this regard (Verhoeven 1964, 1968, 402; Glover and Glover 1970, 188–90): some stone tools found from surface locations in Timor, as described in these latter reports, have some typological resemblances with the Pacitanian, and are different to those excavated by Glover (1986) from limestone cave sites in East Timor and dated by him to a maximum antiquity of about 14 ka. At the cave of Lene Hara, East Timor, shell midden debris has been dated to between 30 and 35 ka ago (Dayton 2001).

The oldest Australian dates

The systematic application of radiocarbon dating, beginning in the early 1960s, caused a revolution in prehistoric research in Australia. As recently as 1961, it was considered that the oldest reliable direct dates for human occupation of the continent lay only within the mid-Holocene (Mulvaney 1961; Clark 1961, 243). A year later in 1962, a date of 12,000 years before present was obtained from Kenniff Cave in the highlands of south-east Queensland and this was quickly followed by the measurement of a slightly lower sample dated to 16,000 years ago (Mulvaney and Joyce 1965). Within the next decade, this antiquity had been extended to more than 30,000 years ago (Jones 1973).

An important discovery which dramatically tied the archaeological evidence to parallel basic discoveries which were also being made concerning the geomorphic and palaeoclimatic history of the continent was at Lake Mungo in the arid south-western corner of New South Wales (Bowler *et al.* 1970). Here, in 1969, the cremated remains of a young woman, now referred to as the Mungo 1 hominid, were found in a carbonate-encrusted pit within the core of an eroded crescent-shaped sand dune or lunette, bordering the eastern shore of a now-extinct lake. From this same eroded surface were recovered numerous *in situ* stone artefacts made from quartzite, which included dome-shaped horsehoof cores and steep-edge scrapers. A series of small hearths contained evidence of a broad spectrum foraging economy, including fishing, possibly using woven nets to drive fish such as golden perch (*Plectroplites ambiguus*)

to the shore (Allen 1998), freshwater mussel gathering and the hunting of small marsupials. Radiocarbon dates on burnt human bone, and charcoal from adjacent and stratigraphically equivalent hearths, indicated an age of *c*.26 ka (Bowler *et al.* 1972), which at that time was the oldest date for human occupation of the Australian continent. Further research showed freshwater mussel shell middens in adjacent lunettes of the same fossil lake system which dated to 32 ka (Barbetti and Allen 1972), and the oldest date for a stratified shell midden at nearby Lake Arumpo was between 34 and 37 ka bp (Bowler 1976, 59). Within the Mungo Sand Unit itself, excavations were carried out in the early 1970s, with stone artefacts found throughout its upper half. A carbon date (ANU-1263), on black organic material located above the lowest artefact, gave a value barely indistinguishable from background, with an ascribed value of '40,000 years or more' (Shawcross 1975, 30; Shawcross 1998, 190). One of us speculated a decade ago that, 'these lower artifacts (might) have a general antiquity of *c*. 40–45 ka at least' (Jones 1989, 762).

During the 1970s and 1980s, radiocarbon dates of the order of 35–37 ka were obtained from a variety of sites, mostly sandstone rockshelters or limestone caves but also including open sand dunes and swamps. These were located over the full extent of the Australian continent, and also in Papua New Guinea (Jones and Bowler 1980). Latitudinally they spanned slightly over 40° of latitude from the Equator to southern Tasmania, equivalents in the northern hemisphere being from Belfast to the Congo. Within the Sahul land mass, the ecological regions occupied during this time included all of the major ecological zones, from the montane valleys of New Guinea and the savannas of northern Australia to the desert core of the continent and to its temperate extremities, both in the extreme south-west of Western Australia, and to southern Tasmania (Jones 1989, 1995; Smith and Sharp 1993; Allen and O'Connell 1995; O'Connell and Allen 1998). Human occupation also extended to the truly oceanic islands of the Bismarck Archipelago close to New Guinea, indicating significant ocean-crossing capacities in these tropical waters at that time.

The oldest conventional radiocarbon dates from a securely stratified archaeological context in Australia have been obtained at Carpenter's Gap which is a large open rockshelter in the cliff face of a Devonian-age fossilized coral reef fringing the southern edge of the Archaean-age Kimberley massif of north-western Australia. The oldest pair of AMS dates were 39,220±870 and 39,700±1000 BP (O'Connor 1995), and work which is still in progress using the most advanced methods of charcoal sample pre-treatment (Bird *et al.* 1999; Fifield *et al.* 2001) confirms the order of magnitude of these dates.

The question remained whether this continental pattern dated the first arrival of humans or whether these values simply reflected the technical limits of the radiocarbon method? The problem lies with the physics of radiocarbon dating, so that by about 35–40 ka, we are close to the asymptote of the decay curve, whereby only one per cent potential contamination of a sample of infinite age would give a radiocarbon value of about 37 ka. This is the 'radiocarbon barrier' (Jones 1982, 30; Roberts *et al.* 1994a; Allen and Holdaway 1995; Chappell *et al.* 1996; Jones 1999, 46) which may still not be fully appreciated by some archaeological practitioners and commentators. The technical issues are complex and have been discussed with clarity by Gillespie (1998, 170–3) and Bird *et al.* (1999). There are questions concerning both the limiting capacity of the measuring system itself and also of sample purity. The absolute limit is the signal that is measured within a laboratory system when no ^{14}C has been added to it. An apparent radiocarbon age which is calculated by these measurements is described by Gillespie (op. cit., 170) as the 'system background', and it also includes a contribution from the chemical processes used in sample preparation: the more steps involved, the greater the chances of contamination. Charcoal samples may contain mobile organic compounds that at the limiting edge are extraordinarily hard to eliminate totally. As Gillespie (op. cit., 171) put it, 'A point of diminishing returns is reached with radiocarbon analysis at about 45–50 ka, beyond which both physics and chemistry are against sensible measurements being made — the absolute amount of 14 C remaining is too small and the analytical chemistry is too hard.'

Luminescence dating

A solution to this problem was offered by the application of new developments in the luminescence dating of sand sheets and other deposits (Roberts and Jones 1994; Roberts 1997). These depend on the measurement of trapped electrons within faults in the crystal lattices of grains of silica. The electrons are driven into these traps due to the effects of radiation, derived largely from the decay of primordial radionuclides within the soil, with some contribution from cosmic rays. They are bleached by a brief exposure to sunlight, and thus 'zeroed' of signal until reburied. Measurements of both the trapped electron signal and the background radiation flux will give an age estimation since the time when the sand grains were last exposed to sunlight. The trapped electrons are measured with a photomultiplier system when they are released either through heating as in thermoluminescence (TL) or by light in optically stimulated luminescence (OSL).

A series of luminescence dates were obtained from deep sand sheet deposits within two occupied sandstone rockshelters in the Kakadu region in the Top End of the Northern Territory. At Malakunanja, a column of 4.6 m of sand had 10 TL dates with a basal value of 107 ka (Roberts *et al.* 1990; Roberts and Jones 1994, 14). Within every excavation unit of the upper 2.60 m of the deposit there were numerous flaked stone artefacts, with the lowest ones bracketed by TL dates of between 53 and 60 ka ago. Where charcoal was available in higher levels, a series of cross-checks was carried out, with good concordance between TL and ^{14}C values. Underneath the lowest artefacts was a further 2.0 m of sand utterly devoid of any cultural evidence. The absence of human

evidence within the time period of slightly older than 60 ka to 110 ka, as opposed to the upper half of this sequence, is critically important. At Nauwalabila, paired OSL and ^{14}C dates back to *c*.25 ka were in excellent concordance, but below that visible charcoal ceased to exist. OSL dates from the basal part of the deposit, including a tightly packed rubble which contained flaked artefacts down to the bottom, were again between 53 and 60 ka (Roberts *et al.* 1993; Roberts *et al.* 1994b).

These results, adding as they did some 50 per cent on to the previously accepted age of human occupation of the Australian continent, have not met universal acceptance (Bowdler 1990; Mulvaney and Kamminga 1999, 142; O'Connell and Allen 1998, 139). A constructive criticism by Hiscock (1990) was based on whether or not artefacts might have been displaced by human or other taphonomic agencies into lower and older sand levels. This is of course potentially the case in all archaeological deposits, and paradoxically the luminescence dating methods are superior in this regard to radiocarbon, in that what is dated is the last time that the silica grains in the deposits have been exposed to sunlight. Any reworking of the surface due to human or animal disturbance would thus result in an almost instantaneous zeroing of its luminescence signal, whereas charcoal pieces can be endlessly recycled without changing their age.

Potential problems with the application of some luminescence methods in Australian field conditions were experienced in the dating of the site of Jinmium, situated near the Keep River on the border of the Northern Territory and Western Australia. This was a slanting sandstone slab, sticking out of a sand sheet, and its sheltered face was covered with pecked, shallow, semi-circular 'cupules' which were weathered and believed on comparative rock art studies to be ancient. The sand deposit in this shelter was only 1.50 m deep and it showed no particular pedological evidence of great age, such as oxidized orange weathering of the sands.

However, TL dates suggested that a fallen fragment of rock within the deposit featuring some of these cupules was bracketed between 58 and 75 ka; that red ochre existed in levels dated to between 75 and 116 ka; and that there were flaked stone artefacts below 116 ka, with the very base of deposits dated to 176 ka (Fullagar *et al.* 1996, 764–5, 771). If this was true, the implications would have been not only a huge antiquity for art, but also that the colonization of the Australian continent might have been carried out prior to the appearance of *Homo sapiens*. Naturally this caused immediate international controversy both in the popular science press (Dayton and Woodford 1996; Wilford 1996) and in academic reviews (Bahn 1996; O'Connell and Allen 1998).

The problem with these TL dates was that they had been distorted by the inclusion of sand which had been derived from friable *in situ* weathered bedrock, which had never been exposed to sunlight and which therefore carried a large residual signal (Spooner 1998). This presented a serious methodological challenge for the reliable

application of the luminescence method within tropical Australian archaeological sites. The solution lay in the development of sophisticated methods of dating of an array of individual grains of sand so that those which had been fully bleached before burial could be distinguished from those which carried an older signal (Galbraith *et al.* 1999; Roberts *et al.* 1999). Single-grain OSL dating, backed by AMS radiocarbon with a rigorous pre-treatment of the samples to remove contaminants, showed that none of this deposit was older than 20 ka, and that most of it probably dated to less than 10 ka (Roberts *et al.* 1998).

The question then obviously extended to the original Malakunanja claims, which had also been based on TL dating, although here the sand column consisted of homogeneous sand with no rubble. Nevertheless, another programme of dating was carried out on the two critical samples at Malakunanja that bracketed the first stratigraphic appearance of flaked stone artefacts. These confirmed the general order of the original results, with values from the multiple aliquot (*c*.800 quartz grains) assays of between 46±4 and 61±8 ka and values of 44±5 ka and 56±8 ka respectively from the same samples according to single-grain measurements (Roberts *et al.* 1998, 22; Jones 1999, 52–3; Roberts and Jones 2001). Both the consistency of palaeodose estimates for single grains from these samples and the fact that the flakes were found flat within tightly bound, lightly cemented sands indicate the lack of any significant post-depositional disturbance of these sediments and that the artefacts were highly unlikely to have been intruded from above into these lower levels (Roberts and Jones 2001).

The dating of the Mungo 3 hominid

The application of this arsenal of new dating techniques has also recently transformed our views of the chronology of the critical Mungo–Willandra Lakes sequence discussed above. Detailed geomorphological studies by Bowler (1998) have refined this sequence and here we will concentrate on the uppermost part of the Lower Mungo Sedimentary Unit (Unit C), where some of the oldest archaeological finds are located. This unit consists of pure quartz beach sands, reflecting a lake full stage.

The transition to the Upper Mungo Unit D was a gradual one, with a low percentage of poorly sorted sands and clay pellets mixed with beach sands. There is also the first appearance of long-distance desert-derived *wüstenquarz* dust, the term coming from the German word *wüst*, namely wilderness or wasteland. These mineralogical indicators reflect the first subtle onset of arid conditions. A soil was formed and, as Bowler (op. cit., 138) put it, this was 'the land surface which sustained many human generations'. Eventually, arid conditions increased with the abrupt formation of the overlying Upper Mungo Unit when the prevailing westerly winds blew from the floor

of the often-dry lake bed the greyish brown sandy clays (PCD: namely pelletal clay dunes) which mantled the Mungo stratigraphic complex (Bowler op. cit., 130, fig. 9). On the grounds of regional correlation with other critical sections in the Willandra Lakes system, the onset of the full Upper Mungo arid phase occurred about 40 ka years ago (Bowler op. cit., 150).

On stratigraphic grounds, Bowler believed that it was during this transitional phase of the beginning of aridification at the very end of the Lower Mungo phase that the grave of the extended burial called the Mungo 3 hominid was dug. In part, the evidence for this was calcareous deposition around the bones showing that the burial event pre-dated major carbonate mobilization associated with the process of soil formation (Bowler 1998, 150). In the original publication of this find, based on conventional radiocarbon chronology, it was estimated to have occurred between 28 ka and 30 ka ago, a value then considered to be 'as precise as both present and future circumstances will allow' (Bowler and Thorne 1976, 138). In his paper published in 1998, Bowler stated that thin sections of the grave fill (sample MP 55) and also of the surrounding quartz sands (sample MP 54) were 'almost entirely free of both Wüstenquarz and PCD facies indicating burial before any such onset of PCD deposition' (1998, 150). The small percentage represented in the mineral counts 'is attributed simply to later bioturbation in the upper metre of Unit C sediments near the contact with the higher Unit D deposits' (Bowler 1998, 150, 130 and fig. 9). Yet in a response to new independent dating results, discussed below, Bowler and Magee (2000) have since revised this analysis, stating that the above explanation was incorrect. Their new stratigraphic drawing (Bowler and Magee 2000, fig. 2: based on Bowler 1998, fig. 9) now shows the pelletal clays to extend not only within the grave fill itself, but also within the surrounding deposit into which it had been dug, whereas in the original drawing they did not.

A new dynamic has been injected by the application of luminescence and other dating techniques to this and other critical sites within the Mungo sequence. Concerning the Mungo 3 burial itself, Oyston (1996) obtained three samples that he dated with the TL method. Two superimposed samples from the Upper Mungo Unit gave values of 19.5±2.3 and 24.6±2.4 ka in the correct stratigraphic order. The critically important sample J 3 from the Lower Mungo Unit, only two metres away from the feet of the burial, gave a value of 43±3.8 ka (Oyston 1996, 748). An independent study was done by Price from these same locations and this gave values respectively of 22.4±2.1 ka, 29.3±3.1 ka and 41.4±6.7 ka, which were all within acceptable error limits of the previous series (Bowler and Price 1998, 160). Bowler's conclusion as recently as 1998 (1998, 150) was that the Mungo 3 burial had occurred within the time range of 42 to 45 ka ago.

This evaluation has, however, been put into serious doubt by yet another independent multi-method dating programme (Simpson and Grün 1998; Thorne *et al.* 1999). This consisted of OSL measurements of the Lower Mungo sands and, for the

first time, direct dating of the bones themselves using electron spin resonance (ESR) on tooth enamel and uranium series dating. The latter involved using both thermal ionization mass spectrometry (TIMS) methods on shavings from long bones and gamma-ray spectrometry (Th/U and Pa/U) on the cranium itself (Simpson and Grün 1998, 1009). The U-series work was at the technical limits of the method and this constitutes the first multiple, direct-dating study of a hominid fossil undertaken anywhere in the world. Because of the ethics of the situation concerning permission from the relevant Aboriginal communities, these involved the use either of minimal samples or, in the case of the gamma-ray work, of non-destructive methods.

Mass spectrometric results on four samples of bone shavings gave values of *c.*50, 55, 58 and 70 ka respectively (Thorne *et al.* 1999, table 1 and fig. 4a). This range shows that some uranium mobilization had taken place, the sequence of ages being explained both by delayed U-uptake and recent U-loss (op. cit., 598). There are two fundamental problems with uranium dating: namely whether or not there had been early or linear uptake, and also the question of more recent leaching. To attempt to assess these issues, Grün and his team measured the ratios of the daughter chains of two separate isotopes ^{234}U and ^{238}U which showed that the uranium had migrated into the bones at about the same time that the carbonate around them was precipitated. The carbonate matrix itself was dated to 82±21 ka, the large error being due to the low uranium concentration and also the small spread in the ratios of two isotopes of thorium ($^{230}Th/^{232}Th$) (ibid., 601).

Combining the ESR and U-series dating, the mean age of the Mungo 3 skeleton was estimated as 62±6 ka, the ESR estimate being significantly less affected by uranium mobilization than the U-series results. While it was acknowledged that, given the possibility of uranium loss, the correct age of the sample might be younger, the authors nevertheless considered that it was difficult 'to invent explanations that could accommodate combined U-series/ESR ages of less than 50 ka' (Thorne *et al.* 1999, 605).

Two OSL samples ($ANU_{OD}174a$ and $ANU_{OD}174d$) were collected by Spooner from the Lower Mungo Unit, 350 m and 450 m east and west respectively from the LM3 burial, in stratigraphic locations 30 cm below the carbonate horizon. Mineralogically, they consisted entirely of beach sands, with the absence of clay pellets. These gave age estimates of 59±3 and 63±4 ka respectively, with a weighted mean of 61±2 ka. This is the maximum constraining age for the LM3 human, since the deposition of this sediment unit obviously pre-dated the burial event (Thorne *et al.* 1999, 605). These values are significantly older than those of Oyston and Price quoted above. A possible explanation for the discrepancy may be due to different assessments of the extremely low background radiation levels from the almost pure sand, where cosmic ray contribution may be as much as 40 per cent of total dose. The issues are beyond the scope of this present paper and have been addressed in a series of recent arguments (Bowler and Magee 2000; Gillespie and Roberts 2000; Grün *et al.* 2000).

The direct dating of the LM3 hominid has removed any possible doubt that it had been interred into old deposits from a much more recent ground level and, at the very least, has securely placed it in the time of the Lower Mungo transition some 43 ka ago. The calibre of the multi-method dating methods involved, combining both ESR and U-series, is a powerful approach and allows for an accurate assessment of U-mobilization. Considering the limiting constraint of the OSL dates on the deposits, the broad concordance of direct-dating results gives support to a conclusion that the LM3 hominid may lie between 56 ka and 61 ka.

Burial and ochre

The grave was that of an extended male skeleton, his hands arranged to cover his pelvic region. Anatomically it conforms with a modern Aboriginal morphology, and as such represents one of the oldest examples of *Homo sapiens* in the world (Bowler and Thorne 1976; Thorne *et al.* 1999, 610; Thorne and Curnoe 2000). Palaeogenetics of this skeleton indicates the presence of an mtDNA lineage not present in any modern human population (Adcock *et al.* 2001). Critically important from a cultural point of view was that the body had been covered from head to groin with ochre, calculated to have required at least a kilogram of haematitic minerals (Bowler 1998, 151). The closest source of such material was within mineralized veins in Proterozoic rocks near Broken Hill, some 200 km to the west. A large lump of such haematite, showing clear grinding facets, was found by Bowler (ibid.) on the surface of the eroding Lower Mungo soil surface and is believed to date from the same cultural phase as that involved in the mortuary decoration of the LM3 person. This corresponds in age with similar ground haematite pieces from the Kakadu sites in northern Australia (Jones 1999, 57; Jones and Johnson 1985). Concerning the archaeological evidence contained within the Upper Mungo soil, here was a palimpsest of both the economic and ritual lives of ancient Australian people, pushed back by a time period of almost 20 ka, through a new revolution in dating technology, from previous assessments made only 25 years ago.

Human occupation at Isotope Stage 3

The oldest stone artefacts at the site were recovered by excavation below this soil, down to a depth of 1.50 m within the Lower Mungo Unit (Bowler and Price 1998, 162; Shawcross and Kaye 1980; Shawcross 1998, 191–3). Six TL dates (W1801–6) were obtained from an auger column adjacent to the excavation, and a date (W1804), equivalent to a stratigraphic position just above the lowest artefact, was assayed at 61±8 ka

(Bowler and Price 1998, 159). Because of the large error estimates from each of these individual TL dates, a depth–age regression line was drawn derived from the entire dataset (op. cit., 162). According to this, and taking into account Spooner's additional OSL data, we estimate that the first occurrence of stone artefacts at this site probably occurred within the time envelope of 55±5 ka near the beginning of Isotope Stage 3. Also, significantly, the basal half of the Lower Mungo Unit was entirely devoid of artefacts. So here as at other sites, such as Malakunanja, Devil's Lair in the extreme south-west of Western Australia (Turney *et al.* 2001), and Mushroom Rock in Cape York (Wright 1964; Morwood *et al.* 1995; Roberts 1997, 860), we have stratigraphic sequences which precisely mark the first indications of human presence. We are now confident in positing the human colonization of Australia within the probable time envelope of between 55 ka and 60 ka at the beginning of Isotope Stage 3. It is also likely that core areas of the continent such as the braided river systems of the eastern interior were occupied relatively swiftly; perhaps even to be seen as an archaeologically 'instantaneous' event, given the large error bars of the dating methods.

It is also important at this point to consider the question of a proven absence of human occupation at a certain time period, an issue raised originally by Bowler (1976). We may say that there has been no hint of any evidence of hominid presence in Australia within deposits dated to the Last Interglacial. Some of these relate to what might have been highly desirable locations, had there been people here at that time. Key locations would include the Gol Gol formation, underlying the Mungo sequence and dated by TL to *c.*140 ka–180 ka (Oyston 1996, table 4), and an extensive system of fossil beach ridges inland of old coastal lagoons associated with the higher Last Interglacial sea-level, and which extend as extensive landforms over hundreds of kilometres along the coasts of southern Queensland and New South Wales. The contrast with the situation at the Cape of Good Hope in South Africa is striking. Here, west of the Cape, sparse shell middens have been consistently found within Last Interglacial dunes, indicating sea shore exploitation dated back to 120 ka (Parkington 1999, 27). One could find close environmental and geomorphic equivalents in such locations as the perched coastal dunes in north-west Tasmania, western Victoria or the south-west of Western Australia. Yet here, nothing has ever been found. We are confident in asserting that there has not been any hominid incursion into the Australian–New Guinea continent as far back as Last Interglacial times.

Homo sapiens expansion

A secure dating for this first occupation is important, not only for its own sake but also for more general issues concerning the origins and the first global geographical spread of *Homo sapiens*. The central premise of what has been tagged the 'out of Africa' model,

which was derived from studies both in DNA genetics and palaeo-anatomy, is that modern *sapiens* people first emerged in sub-Saharan Africa within the savanna region perhaps 150 ka ago (Cann *et al.* 1987; Stringer 1992; Clark and Willermet 1997; Foley this volume). This has gained archaeological support with the ESR re-dating programme at Border Cave in the Kwa-Zulu land of South Africa, confirming the presence of anatomically modern human fossils by about 130 ka ago, and the typologically advanced Howiesons Poort stone industry with its standardized tools of flake-blades, backed or blunted into geometrical shapes that implies hafting (Deacon 1989, 559–60) and dated to *c.*66±5 ka (Grün and Beaumont in press; Miller *et al.* in press). The conclusion of a review by Deacon, written over a decade ago (1989, 561), was that 'not only were people in the Southern Cape some 100,000 years ago anatomically modern, but they were also behaviourally modern'. Their descendants may have extended their geographic range northwards, with several severe genetic bottlenecks, out of north-east Africa into the Arabian–Levantine region some 80–50 ka ago (Tishkoff *et al.* 1996).

Some would wish to date the spread beyond this point according to the west Eurasian chronology of the appearance of the Upper Palaeolithic (Klein 1995). Here, apparently, there is a 'consensus model' whereby there was 'a rapid expansion of anatomically and behaviorally modern humans out of Africa into southwest Asia 45,000 to 50,000 years ago, then into Europe and the southern margins of Siberia and across to east and southeast Asia by about 40,000 years ago' (O'Connell and Allen 1998, 143). Let us briefly examine the basis of these statements. On the coast of the Levant, the key land link between Africa and Eurasia, the earliest Upper Palaeolithic is characterized by the production of flake-blades which still carry some elements of the preceding Levallois technology such as faceted platforms. But the formal retouched tools are dominated by Upper Palaeolithic forms such as end scrapers and burins (Kuhn *et al.* 1999, 506).

Concerning absolute dating, there are some revealing admissions that 'most investigators assume that the earliest Upper Palaeolithic dates to sometime between 40,000 and 45,000 years ago' (Kuhn *et al.* 1999, 507; cf. Bar-Yosef *et al.* 1996); and that 'not coincidentally, this interval corresponds with the conventional dates for the Middle–Upper Palaeolithic transition throughout Eurasia' (Kuhn *et al.* op. cit., 507). Indeed! But this concordance may also be a reflection of the technical limits of the radiocarbon dating methods that had been applied at these sites.

As regards actual radiometric dates, a study published in 1983 at the open air site of Boker Tachtit in the Israeli Negev yielded radiocarbon dates extending back to 45 ka at the base and one of 33.1±4.1 ka at the top (Marks 1983; Kuhn *et al.* 1999, 507). At the rockshelter site of Ksar Akil, near the Lebanon coast, there is one of the longest archaeological sequences of the Upper Pleistocene of Eurasia, with no less than 22 m of deposit, spanning the transition from the Mousterian throughout the Upper Palaeolithic. A dating programme of ^{14}C dates from two separate laboratories, using both

conventional and AMS methods on charcoal, established a coherent age–depth sequence within its upper part which extended back to 31–32 ka ago (Mellars and Tixier 1989, 763–5). Concerning the deposit which underlay this, spanning no less than 10 m and which included both the earliest Aurignacian and the transitional industries from the underlying Middle Palaeolithic, an assessment of its antiquity was made by extrapolating the average age–depth relationship derived from higher up in the sequence and taking into account relevant depositional regimes. This implied an age for the boundary between the 'transitional' and the underlying Middle Palaeolithic industries of *c.*50–52 ka (op. cit., 766). A single radiocarbon date of 44 ka which was obtained from a late Mousterian layer stratigraphically beneath this served to stress only that such a number merely reflected the methodological limits of the ^{14}C-method. At the recently reported cave of Üçagizli in Turkey, located where the ancient Orontes River reaches the Mediterranean coast close to Antioch, two AMS radiocarbon determinations were made of the initial Upper Palaeolithic levels at 39.4±1.2 and 38.9±1.1 ka ago (Kuhn *et al.* 1999, 514–15).

Finally, concerning Europe itself, the oldest typologically distinctive industry made by fully modern sapient people is the Aurignacian. It may be that there was an autochtonous European expression with its earliest manifestation either in the south-eastern Balkans or on the plains of western Eurasia. If this were the case, then the cave sites of Bacho Kiro and Temnata in Bulgaria are of critical importance. Here AMS dates for the Aurignacian layers were obtained of *c.*38 ka to 46 ka, and 44 ka from Istállóskö in Hungary with large error bars (Straus 1997, 241). Elsewhere in western Europe, Straus (op. cit., 241–2) has listed 24 sites from which the carbon dates for the earliest Aurignacian or equivalent industries have been bracketed as between 37 ka and 43 ka ago. At first glance this may seem to be an extremely impressive conclusion, or is it only another example of the 'event horizon' phenomenon discussed above? Some internal causes for doubt might come from the first TL dates obtained from Temnata which were 45 to 46 ka in age.

Our view is that the security of the earliest dating of the Upper Palaeolithic in west Eurasia might be more illusory than would first appear from the vast published literature on the subject. From our perspective, very old carbon dates seem to be published and discussed with an insouciance that does not belie much anxiety as to the limits of the dating method itself, issues which are central in the hard-contested field of Australia. Our experience convinces us that a reappraisal of the dating of the transition from the Middle to the Upper Palaeolithic of Europe and the Middle East is now required, using the same range of methods and intensity of dating techniques that have been discussed above.

Even if the European chronological scenario survives the new inspection, it has no dominant relevance to the issue of the first human colonization of Australia which as all scholars are agreed was carried out by modern *sapiens* people. There is no coherent

reason why Australia should have been settled at some respectful time after Europe, nor that the oldest Australian dates should be discarded merely to fit with some preconceived theoretical time framework (O'Connell and Allen 1998, 143; Allen 2000, 68). A case can be made for the first spread of modern *sapiens* out of Africa, extending from west to east along the Parallel of the tropical savanna. This was the obvious new terrain, involving little ecological adaptation for peoples emerging from similar conditions in East Africa (Jones 1999, 55). There is much genetic support for this view that both New Guineans and Australian Aborigines have ancient lineages that might reflect such an early migration event (Wood 1997, 120). To cross to the Sahul continent, the critical new invention was that of watercraft, competent enough to transport people across substantial cross-sea distances within tropical waters. It is highly possible that the first occupation of the higher latitudes of the Eurasian continent by modern *sapiens* people may well have occurred a substantial time period after this initial latitudinal spread across the route of the tropical savannas.

Extinction of the giant marsupials

During the Late Quaternary, there occurred a massive phase of extinction of the Australian land fauna. During that time, all Australian land mammals, reptiles and birds weighing over 100 kg became extinct, as did about 60 per cent of those within the weight range of 10–100 kg (Flannery 1990). Of this megafauna, over 90 per cent of species were marsupials. About a third of all marsupial genera became extinct during this time. These included the cow-like *Diprotodonts*, the stocky, kangaroo-like *Sthenurids* and short faced *Protemnodons*, as well as much larger species within some existing genera such as the *Macropod* kangaroos. This megafauna had been palaeontologically recognized and described from fossil and other deposits from as far back as the middle of the nineteenth century. Richard Owen, who made the original descriptions, even then had considered that they had survived into the Upper Pleistocene and that the probable cause for their extinction had been due to human hunting influence (1877). His views fell into obscurity over the following century, largely because it became widely believed that Aboriginal people had only a short antiquity on the continent.

Despite numerous field discoveries, including those of full skeletons of *Diprotodonts*, the dating of the extinction event or events has proved extremely elusive. Two independent reviews of the data published over 30 years ago by Merrilees (1968) and one of us (Jones 1968) came to similar conclusions that a wide suite of the extinct megafauna had existed across the entire range of Australian and New Guinean ecological zones until tantalizingly recent times; seemingly always just beyond the first appearance of human artefacts such as stone tools, which were present and sometimes

numerous in deposits immediately overlying the megafaunal ones. This was the case in stratigraphic sequences within fossil dunes bordering lake systems in western New South Wales; in the dry lake bed deposits of the arid core of the continent near Lake Eyre; in limestone cave deposits; and in peat lake beds of the wet temperate south-east of the continent. In our separate reviews, we both considered that the giant marsupials had survived just up to the time of the arrival of people on the continent, and since this event seemed not to be associated with any great climatic or environmental crisis, such as the height of the Last Ice Age, then the primary cause for the extinction event must be pointed towards a human impact. A problem for this theory was that at the time of writing these papers, as is still the case, there is no convincing direct field association of megafaunal remains within the structure of a human kill or other prey-processing archaeological site. Jones' (1968) assessment of the timing of these events was predicated on the available chronometric data at that early research phase in the application of ^{14}C dating techniques to Australian archaeological and geomorphological sites. In the same way that the earliest dates for human arrival seemed to lie within the time range of about 25 to 30 ka, so also the available dates for the last megafaunal remains were also seen within this time frame (op. cit., 202–5); both sets of data are now seen to have been false.

The past 30 years of research have stubbornly refused to yield convincing direct associations of the megafaunal remains within Australian archaeological sites. The situation has been made more frustrating in that a series of such claims, initially convincing (Flood 1995, 183), have consistently failed the tests of further stratigraphic or chronometric analyses. A single *Sthenurus* bone from levels dated to 23 ka containing flaked stone artefacts at the limestone cave of Cloggs Cave in south-east Victoria was almost certainly derived from an older deposit within the cave system. Fossilized *Diprotodont* teeth fragments associated with numerous stone artefacts in the mound spring site at Tambar Springs in north-east New South Wales were excavated from deposits dated to as recently as about 6 ka ago, yet direct Ur dating on the teeth showed them to be older than 60 ka, indicating that they had been reworked into the younger deposits through fluvial processes of the mound springs themselves. Swamp sites have also proved elusive. Perhaps the best researched have been those in southern Victoria, such as Spring Creek (White and Flannery 1995), and at Lancefield (Van Huet *et al.* 1998). At the latter site, excellent excavations by archaeological and palaeontological specialists in their fields (Gillespie *et al.* 1978) seemed to show unequivocal stratigraphical association between *Diprotodont* remains and stone artefacts, within swamp deposits dated by radiocarbon on various materials to between 20 and 27 ka. Subsequent work showed that there may have been slumping of older swamp deposits, and that the bones came from a quite older facies. Direct ESR dating on a *Diprotodont* incisor at this site gave decisive values of 50 to 56 ka, which is probably the true age of the bone (Van Huet *et al.* 1998). Association has been proposed at Cuddie Springs, a swamp

at the very end of the Macquarie river system in north-western New South Wales (Field and Dodson 1999). Here numerous stone artefacts have been found in close stratigraphic association with long bones of *Diprotodont* and the giant *Genyornis* bird. The association was within a sticky clay, overlain by deposits dated to the last Glacial Maximum. The clay had charcoal, AMS dated to between 29 and 33.5 ka BP, and an OSL date of 35.5 ka BP. It might seem thus to be a secure case. But in the opinion of one of us (RJ), the issue is far from concluded. The bones themselves are heavily mineralized and are devoid of all but traces of amino acids; there is no hint of the smashing of bones, typical of a human midden; and in the critical level, many are aligned at random oblique angles into the sticky clay. It is possible that these bones have been derived from an adjacent older deposit within the swamp system. At the very least, direct dates on these bones using Ur and ESR methods now need to be obtained.

The fundamental problem with the dating of the extinction of the megafauna has been exactly the same as that of the arrival of the first humans — that it occurred beyond the 'event horizon' of conventional radiocarbon dating. As with the archaeological issues, new dating technologies have had to be deployed. The first systematic demonstration of the chronology of extinction of any of this megafauna has been done in the case of the giant bird, *Genyornis newtoni*. Biologically related to the goose family and weighing about twice the weight of an emu, its egg shells, as is the case with emus, are common within Upper Pleistocene sand deposits in central Australia. A dating study on over 1000 egg shells from both species, using amino acid racemization, showed that whereas the emu survived all of the changes of climate and environment, including the extremely arid phase of the Last Glacial Maximum, the *Genyornis* suddenly collapsed across all regions studied during the time period of 50±5 ka years ago (Miller *et al.* 1999).

A systematic study has also been carried out using both OSL and Ur dating on articulated remains of giant marsupials from a variety of sites across the south of the continent (Roberts *et al.* 2001). By restricting the study to fossils which had bones in articulated anatomical positions, this ensured that the animals had died close to the site and time of their ultimate burial. There was a continental-wide extinction event within a period of about 46.5±5 ka BP. The conjunction of this timing with the *Genyornis* extinction is striking. The dates rule out the Last Glacial Maximum as the cause of extinction. However they do coincide closely with the time of initial spread of people throughout the continent, which after an initial landfall was probably occurring within the same time envelope of 55±5 ka. The hand of humans as the ultimate cause of this extinction event seems inescapable.

Fire

The issue of how this might have occurred has been discussed extensively (e.g. Flood 1995, 182–7). There was the direct impact of hunting, with the arrival on the isolated continent of a supremely intelligent placental predator, heavier than any existing marsupial predator, and one armed with a sophisticated hunting technology and a culture of the chase. There was also perhaps the more profound impact of the systematic use of fire. Fire has been a natural feature of the Australian landscape since Tertiary times, with key elements of its biota, such as the radiation of Eucalypt tree species, responding to a progressively drier and more fire-prone climate, as the continent itself has experienced a long-term trend of desertification. However the arrival of people would have increased the fire frequency within any one area by orders of magnitude. Ethnographic studies have shown the systematic use of fire by Aborigines across the entire continent. Few parts of contemporary Arnhem Land in the tropical north were not burnt every year. The reasons for burning were manifold, the key factor being the desire to burn off tall dry grass at the beginning of the dry season, to give access for movement, and to reduce mosquitoes and the danger of snakes. The green regrowth which often occurred after early season fires provided a new feed for wallabies, which in their own turn were hunted (Jones 1969).

Such an impact would have had ecological consequences, capable of being analysed within the pollen record, and numerous detailed studies on past fire regimes have been carried out. Some of these sequences come from deep terrestrial lake cores (Singh and Geissler 1985), and also from offshore marine cores, both off the north-east Australian coast and also within the shallow neighbouring Indonesian seas (Wang *et al.* 1999). The modern consensus is that fire frequency on the Australian continent increased markedly in Upper Pleistocene times, and that this increase cannot solely be ascribed to climatic changes (Kershaw *et al.* in press). One can argue for a significant human component, one that changed the distribution of major vegetation communities: in the tropical north extending the range of fire-adapted savanna at the expense of the fire-sensitive vine thickets and rain forest communities; in the centre, aiding the spread of the fire-adapted spinifex landscape. These issues are hotly debated and a full exposition is beyond the range of this paper. From our broadest archaeological perspective, however, our region can be looked at as a 'natural laboratory' for the discussion of the impact of the geographical spread of modern humans into new areas, with their native faunas.

The Australian case has been at a continental scale, and some of the main events may have taken place early within the process of the global expansion of our species. We turn now to the vast oceanic spaces of the Pacific, and to time scales one and two orders of magnitude less than the ones which dominate the prehistoric research agenda of Australia. The processes of colonization and of impact however show remarkable similarities.

Pauses and pulses in human colonization of the Pacific

The human colonization of the Pacific Islands beyond what is now the island of New Guinea shows an interesting pattern of pauses and then rapid pulses of migration. Whether the initial move beyond what was then the continent of Sahul represents the first such pause is as yet unclear. There are radiocarbon dates of 35,000 BP from both New Britain and New Ireland, with the only-known Pleistocene site in the Solomon Islands dating to 29,000 BP (Spriggs 1997a, chapter 2; Leavesley and Allen 1998). As the other dating techniques mentioned above which can go beyond the radiocarbon barrier have not yet been deployed in this relatively little-studied part of the Pacific, it is impossible to know if there was any significant pause before this part of Near Oceania was settled after New Guinea was reached. Near Oceania is defined as that part of the western Pacific settled prior to the spread of the agricultural and pottery-using Lapita culture: the Bismarck Archipelago and the main Solomon Islands (the definition is by Green 1991a). Recent intensive work across that boundary in 'Remote Oceania' (the rest of the Pacific beyond the Solomons) in Vanuatu and New Caledonia now makes it seem most unlikely that humans penetrated beyond the main Solomons until around 3000 years ago. As sea gaps are very small along the main Solomons chain (indeed for most of the Pleistocene a lot of the chain was joined as the island of 'Greater Bougainville'), it would seem likely that the Near Oceania boundary at its southern end on the island of Makira (San Cristobal) would have been reached soon after 29,000 BP at the latest. It remained an impermeable barrier for a further 26,000 years of hunting and gathering occupation of the Solomons and Bismarcks.

A recent feature of the study of colonization of the Pacific region is that as well as the dates getting earlier at the lower end, now extending beyond the 'radiocarbon barrier' in the case of the Australian dates as we have discussed above, they are now getting ever younger as we move east and into Polynesia. Dates for the founding Lapita culture in Near and Remote Oceania are also becoming constricted, both in terms of start date and in terms of the end of the distinctive Lapita design system and its most common expression on dentate-stamped decorated vessels. A few years ago dates back to about 4000 BP were being posited for the start of Lapita culture in Island Melanesia. Now, even 3500 BP seems too early and 3300 BP seems more likely in the Bismarck Archipelago 'homeland' (Specht and Gosden 1997). The spread of this culture beyond Near Oceania is now thought to start about 3100 BP in the Reef-Santa Cruz Group of the south-east Solomons, 3000 BP in Vanuatu and New Caledonia and 2900 to 2800 BP in Fiji and Western Polynesia (primarily Tonga and Samoa). Relevant recent references include Bedford *et al.* (1998) for Vanuatu, Sand (1997) for New Caledonia, Anderson and Clark (1999) for Fiji, and Burley *et al.* (1999) for Western Polynesia.

In Island Southeast Asia too, as discussed by Peter Bellwood in his contribution to this volume (see also Bellwood 1997; Spriggs 1999a), the timing of the spread of pottery-using Neolithic cultures is being tightened (Spriggs 1989) and pauses are becoming evident there as well, the first between the settlement of Taiwan perhaps 6500 to 6000 BP (the earliest phases of occupation are extensive but virtually undated) and points south, the second between the settlement of Northern Luzon at about 5000 BP and soon after it the Mariana Islands in Western Micronesia, and the settlement of Sulawesi and Eastern Indonesia beginning about 4000 BP. The extension of this Island Southeast Asian Neolithic culture into the Pacific (excluding earlier-settled Western Micronesia) is the Lapita culture. From Sulawesi to Samoa the spread takes just over a thousand years. A thousand-year pause then takes place in Western Polynesia before the first well-attested evidence of Eastern Polynesian settlement, which again represents a rapid expansion across a vast area.

Lapita-style dentate-stamping has been claimed previously to continue in some areas of the western Pacific to 2000 BP or later. An end everywhere to the Lapita distribution now seems likely about 2800 to 2700 BP, with cultural continuity to 'post-Lapita' cultures becoming more obvious as key sites in Island Melanesia and Fiji are explored in more detail and redated. Although the evidence is by no means all in, it seems a plausible hypothesis to suggest that a wide area of the western Pacific remained in interaction, albeit perhaps increasingly sporadic, until at least 1500 BP. Much of the extreme regionalization in pottery, artistic styles, and social and religious systems in the Island Melanesian region seems to be a product of 'cultural drift' since that time period (Spriggs 1997a, chapter 6). First to drop out of the interaction system was Western Polynesia, recalling that East Polynesia was still uninhabited at the time. Indeed one can only really define Polynesia in opposition to Melanesia in cultural terms from about 2300 BP onwards. Fiji remained part of the western Pacific mainstream for some centuries and occasional interaction with areas to the west, including probably significant in-migration, continued even later. As late as 1500 BP in areas from Central Vanuatu through to Buka and Manus in the north there are remarkable parallels in pottery decoration which must betoken continued even if irregular contact between potting communities over thousands of kilometres.

Pottery-making eventually died out throughout all areas of Polynesia where it had previously been practised and indeed in many parts of Island Melanesia too. Cultural 'drift' in pottery styles developed as potters across the region no longer saw each other's products when intermediary centres ceased production. Isolation then set in, particularly after 1000 BP (see below).

A growing consensus seemed to be developing by the beginning of the 1990s that earlier dates than those conventionally accepted for the settlement of Western and Eastern Polynesia would be substantiated by further work. The high water mark of this optimism was reached in 1991 with palaeoenvironmental evidence from Mangaia in the Cook Islands suggesting to Kirch and his colleagues (1991) that people had reached the Southern Cooks by 2500 BP, some 1500 years earlier than the first direct evidence for

occupation of the island in the form of cultural deposits in a rockshelter. They used this evidence to support the arguments of Irwin (1980, 1992) that there was no pause between the settlement of West and East Polynesia. The growing consensus was shattered in 1993 with the publication of a critical review of all early dates for Eastern Polynesia (Spriggs and Anderson 1993; see also Anderson 1995) which suggested that a much shorter chronology was likely. Since that date all 'early' dates for Fiji, West and East Polynesia have confirmed this conservative position. The current picture is that areas of Central-East Polynesia were first settled between AD 300 to 600, with the fringes settled much later: Hawaii after about AD 800, Easter Island perhaps as late as AD 800 (Skjølsvold 1994, 105–7, 113–14; Steadman *et al.* 1994), and New Zealand at about AD 1250 (Higham *et al.* 1999).

The implications of a short chronology for Eastern Polynesia are profound. The large populations attested in places such as Hawaii built up in only 1000 years. The New Zealand evidence suggests the construction of forts as a witness of increasing internecine warfare began only 200–300 years after first landfall. The hierarchical political systems of much of the region must owe more to ancestral forms than, as some have seen them, to inevitable and largely independent evolutionary trajectories in the different island groups. In addition, human impacts on the biotic and non-biotic environments of the various island groups were often rapid and catastrophic in their effects. Even in the case of the large forested island of New Ireland, close to New Guinea and with a modern bird fauna rich in comparison with those of the more remote Pacific islands, at least 12 species out of a total of 50 recorded from all of the excavated sites became extinct in the time period since 15 ka ago (Steadman *et al.* 1999). On the evidence presented, they may well have become extinct only within the last 3000 years. Further out into Oceania, it has been claimed that the extinction of bird species on Pacific Islands attendant upon human expansion represents the greatest vertebrate extinction 'event' since the demise of the dinosaurs (Steadman 1995).

The very pattern of early human impacts suggests in part a 'push' factor to continued settlement. Many species of birds disappear within two to three hundred years of initial human colonization. Pollen and geomorphological evidence suggests that deforestation was rapid on many islands and led to increased landscape instability. A sequence of initial settlement, destruction of much of the local fauna, increased erosion rates and subsequent local abandonment sometimes for hundreds of years is commonly found in the histories of many island groups (Spriggs 1997b). But after a while, moving on to the next valley or next island was no longer an option, and more conservation-oriented land management practices came into operation. It is probably no coincidence that we start to see the first evidence of human occupation in Eastern Polynesia precisely at the point in time that Western Polynesian islands appear to become fully occupied, with substantial inland as well as coastal populations. At the time of European contact it was often the Eastern Polynesian islands that had the most impressive intensive agricultural systems of irrigated taro gardens or managed tree-cropping. Once the fringes were settled, there was nowhere else to go.

Having got people out to all the Pacific Islands over a period from at least 35,000 to 700 years ago, let us examine some findings on their various lifestyles over that period.

Innovative hunter-gatherers and the 'game park' strategy

Any constraints posed to a hunter-gatherer existence in northern Sahul (now New Guinea) are multiplied considerably in Island Melanesia (Chappell *et al.* 1994). If early hunter-gatherers could live in Island Melanesian rainforests then they could certainly live in New Guinea. This is because of the relative poverty of the natural flora and fauna of Island Melanesia compared to New Guinea. The boundary between the latter island and New Britain marks the end of the distribution of primary division freshwater fish, some 265 extant bird species found on the east coast of New Guinea are reduced to 80 in New Britain, and very few terrestrial mammals crossed the same gap unassisted by humans (Green 1991a). The flora is also considerably depauperate compared to New Guinea.

Within Island Melanesia there are two further major biogeographic boundaries: the Remote Oceania boundary between the main Solomons and the Santa Cruz group to the south, and that between Vanuatu and New Caledonia. Beyond the main Solomons chain in the nearest regions of Remote Oceania all terrestrial mammals except bats have been humanly transported, 30 genera of extant land birds and 162 genera of seed plants find their eastern limits, and major disjunctions occur in the natural distribution of other fauna and flora. It is very unlikely that a hunter-gatherer way of life was viable beyond Near Oceania and this, rather than questions of voyaging capability, delayed settlement until a fully-agricultural way of life became available with the spread of the Lapita culture about 3000 years ago.

The area inhabited by humans in the Pleistocene — the Bismarck Archipelago and the main Solomons — was almost certainly rainforest throughout the period of human settlement, although this may not have been the case for Vanuatu and New Caledonia further south. In the Bismarcks and Solomons we are within a few degrees of the equator and it is postulated that there was no major difference in the Pleistocene from the weather systems existing today (Enright and Gosden 1992). There would still have been an equatorial band of shelter between cyclone belts. Warm air would still have risen in the region of the equator, drawing in the wind from north and south. The rotation of the earth created the same prevailing trade winds. The faunal and limited pollen evidence from the region also suggest continuity in rain forest habitat from the Pleistocene to the last few thousand years.

There are at present less than ten Pleistocene archaeological sites known in the Island Melanesian region and so our reconstructions of lifestyle are tentative. All of

the sites bar one are rockshelters and only four are any significant distance from the coast. What are the frameworks for interpretation of what we might find as more sites are investigated? In previous publications, one of us (Spriggs 1993, 1996a) has gone into the terminological distinctions needed to consider the range of behaviours which occur between the poles of simple foraging and intensive agriculture, that grey area where live Zvelebil's (1986) 'complex hunter gatherers' and Guddemi's (1992) 'hunter-horticulturists'.

Spriggs has largely followed the lead of David Harris' discussions (1989, 1996) on the subject. Rather than seeing the presence of domesticated plants and animals as the important threshold between hunter-gatherers and agriculturists, it is important to identify for any given cultural sequence when dependence upon agriculture began, defined in terms of the creation of agro-ecosystems which limit subsistence choice because of environmental transformation or labour demands (Yen 1995). This threshold has greater implications for changes in human behaviour and organization than whether cultivated plants are 'domesticated' in the morphological sense or whether indeed some form of cultivation of crops is being carried out. None of the sites known in the Bismarcks and Solomons had crossed the agricultural threshold during the period under consideration. A fully agricultural lifestyle did not come into being in Island Melanesia until about 3300 BP with the advent of the Lapita culture (Bellwood 1996).

For the Bismarck Archipelago, the pre-20,000 BP fauna of New Ireland is the best known (Flannery 1995; Flannery and White 1991). The island's vertebrate fauna consisted of a narrow range of edible species of lizards and snakes, a single large rat species (*Rattus sanila*), a small rat *Melomys rufescens*, and an unknown number of species of birds. Exploitation of various local species of bats completes the list of hunted mammals. Some of these were quite large, such as the fruit bats *Pteropus neohibernicus* and *Dobsonia anderseni*. At 2–4 kilograms *Varanus indicus*, the biggest of the lizards, was one of the largest sized land animals around, and its importance as a protein source should not be underestimated. The rest of the Bismarck Archipelago was probably comparably endowed in edible terrestrial fauna.

The Solomon Islands were considerably better provided with edible species, with a rich fauna of bush rats, including an endemic genus *Solomys* (Flannery and Wickler 1990). These rats and various fruit bats, lizards (including *Varanus indicus*), snakes and birds would have provided valuable protein sources for the archipelago's early human inhabitants. The reasons for this difference in natural endowment are unclear, although the Solomons appear to have received some of their species from an Australian source. Both the Bismarcks and the Solomons have a comparatively rich marine fauna, similar in many ways to New Guinea and tropical Asia and therefore familiar to the first colonists.

Our knowledge of this critical formative period of settlement of Island Melanesia is very scant at present. Gosden (Enright and Gosden 1992, 173; cf. Gosden 1995) has put

forward an interesting overall model of this period, in part based on certain contrasts with the period that succeeds it. He notes that despite the lack of land resources, the early colonists would have had two factors in their favour: by moving into an uninhabited area they could live where they liked, and they could balance the poverty of the land resources with the richness of those of the sea.

Gosden argues that for the first few thousand years the sea was important for the mobility it allowed in moving between scarce resources as well as being an important food source. Low population densities would have given people room to move through the landscape between its dispersed resources, but on the other hand would have made human contacts extremely important for securing necessary marriage partners and for keeping in touch with the wider world. The lack of land resources may be more apparent than real, given the evidence for plant exploitation at the Pleistocene site of Kilu on Buka in the northern Solomons (Loy *et al.* 1992; Wickler and Spriggs 1988), or there may be a real difference between the Solomons and the Bismarcks in this respect (Wickler 1990). The richer fauna of the Solomons may have provided a less precarious existence for its human inhabitants at this period.

It was mentioned earlier that pre-agricultural settlement does not appear to have extended south of the main Solomons. Although it is harder to get to Vanuatu and New Caledonia, they may not have been outside the technological ability of Pleistocene voyaging. The real problem is lack of food. Wild relatives of major food plants such as *Colocasia* and *Cyrtosperma* taros do not occur in Vanuatu forests. In the absence of introduced plants and animals, sustained human occupation of Remote Oceania may have been impossible. Bailey *et al.*'s (1989) judgment on the lack of edible plant food in tropical rainforests in general applies most forcefully to Vanuatu. As far as the early inhabitants of Island Melanesia were concerned, the archipelago may indeed have been a 'green desert'.

Gosden's model of contrast between the archaeological record before and after 20,000 BP forms a useful starting point for consideration of economic change during this period. In the pre-20,000 BP period he detects a strategy whereby people moved themselves between scarce resources. In the subsequent period there is evidence that resources are being moved, possibly between more settled groups.

The major changes were the apparently deliberate introduction of wild animal species such as the marsupial possum *Phalanger orientalis* into the New Ireland forests from 20,000 BP onwards and a different species of phalangerid and a bandicoot into Manus before 13,000 BP, the transplantation of nut trees such as *Canarium* to New Ireland and Buka by the end of the Pleistocene and perhaps much earlier in Manus, and the movement of obsidian from New Britain to New Ireland from 20,000 BP onwards and from offshore islands to the Manus mainland from 13,000 BP (summarized in Spriggs 1997a, chapter 3). Making a conscious move to recreate the richer environment of the New Guinea forests or at least to compensate for the poverty of the ones they fetched

up in, the early Island Melanesians overcame the natural productivity limits of the forest environment and took an active part in shaping it. Although foraging to wild food production as a sequence demonstrates a continuum rather than a sharp break, it is clear that the system from 20,000 BP represents the latter kind of economy. The economy of the first settlers may also have gone beyond simple foraging by necessity, but the evidence is much clearer for this later period.

If we look at the period from 10,000 BP to the first evidence of an agricultural lifestyle in the region after 3300 BP we find that agriculture did not represent an inevitable development from what had gone before. There was no period of 'incipient agriculture' leading up to the adoption of full-on agriculture in the region. It arrived with new migrants bringing domesticated animals and a suite of plants with them from Southeast Asia, the makers and users of Lapita pottery and its associated material culture (Spriggs 1996b). They also brought with them a totally different attitude to the landscape and the place of humans within it. Their environmental impact was sudden and dramatic, and it quickly so transformed Island Melanesian landscapes that a hunter-gatherer lifestyle was no longer sustainable for the region's inhabitants. Subsistence choice rapidly narrowed towards a fully agricultural economy throughout Island Melanesia.

In the depauperate forests of Island Melanesia, transplanting of useful plant species from more productive habitats may have been necessary from initial occupation of areas beyond the coastal fringe. Thus, there may never have been true foragers in the region's rainforests, a condition of regular exploitation being a form of wild plant-food production from the beginning. The overall effect of this and the introduction of wild animal species beyond their natural range were to mimic the diversity of the New Guinea forests from whence the early settlers presumably came.

Bailey and his colleagues (1989) therefore may be right in one sense. Perhaps foragers could not have lived in these forests, but people did not have to wait for the advent of agricultural colonists to open up the canopy through clearance for gardens. Wild plant-food production and cultivation may have been developed early on as a set of strategies to allow occupation of the forests, starting with initial settlement in Island Melanesia (cf. Groube 1989 for mainland New Guinea).

There is a vast gulf in lifestyle implied by the terms hunter-gatherer and agriculturalist, and a vast gulf in attitude to the environment. The Pacific Islands are a good place to demonstrate this. When full-on agriculture did reach the area with the Lapita culture, patterns of settlement, population density, land use, degree of human impact on the environment and material culture were radically changed. The obvious continuities in Island Melanesian cultural sequences from at least 20,000 BP onwards until the moment of agriculture at about 3300 BP, and the radical re-assortment that followed, are eloquent witness to the gulf between two very different ways of life.

The presence of swamp cultivation systems evident in the New Guinea Highlands from at least the mid-Holocene and possibly back as far as 9000 BP (Golson 1977; Hope and Golson 1995) has been taken by some to suggest that an agricultural lifestyle was general throughout the region pre-Lapita. But there are questions as to the scale of the systems and the specificity of Highland adaptations. Were such swampland garden systems within the capabilities of low-population hunter-horticultural groups, just another local response to the challenges of the region's environments? The Highland environments of New Guinea may have necessitated specialized subsistence systems to allow sustained human use of the area. The remains at Kuk and other Highland swamps may, in their early phases, represent one such system just as the transport of plants and animals into the Bismarcks allowed greater certainty of human tenure there in the face of particular environmental challenges. The question is whether the dense populations of the Highlands 'discovered' by white explorers in the 1930s resulted from these early subsistence innovations. Or whether some further input of crops and domestic animals, ultimately of Southeast Asian origin and associated with the spread of the Lapita culture, changed population and cultural directions to the fully-agricultural lifestyle of recent observation there (Bayliss-Smith 1996). A challenge for the future of New Guinea archaeology is to give context to what remain isolated incidents of swamp drainage with no associated settlements and thus no idea of settlement pattern or population densities in the pre-2000 BP period. The articulation of early Highlands societies with the lowlands and possible pathways of agricultural spread from coastal entry points will also occupy researchers well into the next century.

The origins and spread of the Lapita culture

This is a difficult time to write a neatly encapsulated description of the Lapita phenomenon, as we have reached the end of a cycle of study and publication, represented by major syntheses of the 'orthodox' view of Lapita culture and its origins (Bellwood 1997, chapter 7; Kirch 1997; Spriggs 1997a, chapters 3 and 4). The arguments of the proponents of this view are well known, as are those of its detractors (most recently Ambrose 1997; Terrell and Welsch 1997; Terrell *et al.* 1997). It is time to move on, but the new cycle of research and model-building is only nascent.

In this review of the evidence we will (briefly) go over the old ground and then attempt to chart where the discussion of Lapita might be headed. The main ammunition for a new direction is provided by a series of intensive field projects currently under way in Vanuatu, New Caledonia, Fiji and Tonga, along with the presentation of detailed results from earlier research in the Bismarck Archipelago in a recently-presented Ph.D. thesis by Summerhayes (1996, 2000). Summerhayes' thesis represents an important reinterpretation of stylistic change in Lapita pottery. Taken together, the new research requires a major rethink of the nature of Lapita. But first to what we think we know.

Early recognition of Lapita was based on the elaborately decorated pottery, much of it executed by what was later recognized as a series of small toothed or 'dentate' stamps, perhaps resembling in form tattooing chisels. Much of the pottery found in association was undecorated. Lapita pottery was generally coated with a red slip and some designs were highlighted using a white infill of clay or lime.

Lapita was first reported in the literature before the First World War by Father Meyer, a Catholic missionary on the island of Watom off the north-east coast of New Britain (Meyer 1909). Subsequently similarities were recognized between this and pottery recovered from New Caledonia (from the site of Lapita itself) and Tonga between the wars. Gifford and Shutler's 1952 excavations at the site of Lapita and the recognition of these wide-ranging similarities led to the definition of a Lapita style which had been distributed from the Bismarcks to Polynesia prior to the Christian era (Gifford and Shutler 1956).

This distribution immediately became the main puzzle of Pacific archaeology, and a focus on Lapita and its distribution has remained central to Pacific archaeology to this day. Since that time a suite of associated artefacts and a distinct settlement pattern have led to the definition of a full cultural complex and it is now known to have been distributed even further afield, as far as Wallis and Futuna and Western Samoa. The only finds of Lapita pottery on the island of New Guinea or adjacent to it are of sherds from a single vessel from Aitape on the central north coast, and a dentate-stamped sherd from Ali Island, just off Aitape (Terrell and Welsch 1997, 558–9).

Three sub-styles of Lapita pottery have been recognized, conventionally called Far Western, Western and Eastern (Anson 1983, 1986), which have geographical and chronological significance. The tendency in Lapita pottery is for simplification through time, as the style spread from west to east.

A link between the west to east spread of the Lapita cultural complex from Island Melanesia to Western Polynesia and the spread of Austronesian languages in this area was first suggested in the 1970s (Shutler and Marck 1975; Bellwood 1978). The idea that this spread was linked to a major dispersal of peoples out of Asia, through Southeast Asia and on into Polynesia was also explicit in these early formulations.

The orthodox view is that the most widespread archaeological phenomenon in the Southeast Asian–Pacific region and the most widespread language group in the same area are intimately linked. It is uncontroversial that the foundations of Polynesian languages and cultures go back to the eastern extension of Lapita in a region previously uninhabited. That the immediate Lapita 'homeland' is further west in the Bismarck Archipelago is now also well accepted. It is also generally agreed that Austronesian languages, whether in Polynesia or the Bismarcks, are derived from even further to the west in Southeast Asia and ultimately in Taiwan. It is hard to imagine a process to get these languages from Taiwan to Island Melanesia and Polynesia that would not leave an archaeological trace, and the obvious trace at the appropriate time period (which has

to be no later than initial settlement of Polynesia about 2900 years ago) is Lapita in Island Melanesia and Polynesia.

The orthodox view of Lapita origins is not without its archaeological critics in Southeast Asia and more so in Melanesia (see for instance Allen and White 1989; Terrell *et al.* 1997). If we list what is new about the Lapita culture, then the evidence for major cultural discontinuity in the Bismarcks — and therefore the likelihood of a population intrusion — is made plain:

1 The most visible attribute is the pottery, its very occurrence and its distinctive decorative system using dentate-stamping, incising and some other minor techniques. There are clear antecedents in terms of vessel form and red-slipping, and possibly decoration, in Island Southeast Asia (Bellwood 1997) and claims for early pottery in New Guinea have not achieved general acceptance (Spriggs 1996b, 329, 334).

2 Lapita represents the first convincing evidence for full-on agriculture in the region, indicated by evidence for accelerated erosion consistent with gardening on hillslopes, the extension of settlement to areas where a non-agricultural subsistence base would be unlikely or impossible, i.e. Remote Oceania (Polynesia in particular), and the very size and nature of Lapita settlements as large settled villages. It has been argued that many of the associated plants are of New Guinea origin, however (Yen 1998).

3 It marks the first appearance of the three Pacific domesticates: pig, dog and chicken, and therefore the beginnings of Pacific animal husbandry. All are of Southeast Asian origin. There is now scepticism concerning claims for early pigs in New Guinea (Spriggs 1996b, 335).

4 The already mentioned settlement pattern is itself new: large villages often consisting of stilt houses over lagoons or on small offshore islands in the Bismarcks and main Solomons, but on the ground and on large islands further out in the Pacific. Lapita sites do not generally re-occupy previously used locations apart from where Lapita deposits occur in rockshelters. The settlement pattern in the Bismarcks and main Solomons suggests a defensive posture or avoidance of mainland situations where malaria could have been rife.

5 There is a distinctive Lapita stone adze kit not paralleled in previous assemblages in the area (Green 1991b). In addition, although edge-ground adzes occur pre-Lapita, there are no examples of fully-ground stone adzes from earlier periods in Island Melanesia.

6 There is a distinctive range of shell ornaments, interpreted by Kirch (1988) as shell valuables, again not paralleled by earlier forms. These include *Conus* shell rectangular units, beads, rings and disks, *Tridacna* rings and *Spondylus* beads and long units.

7 Lapita represents a major extension in the range of New Britain and Manus obsidian. In the pre-Lapita era, Manus obsidian is not found outside that island group. In contrast it is found in Lapita sites throughout the Bismarcks, Solomons and into

Vanuatu. New Britain obsidian was distributed pre-Lapita to the west on the New Guinea mainland as far as the Sepik-Ramu basin (Swadling *et al.* 1988), and to the south and east in New Ireland and on Nissan. In Lapita times its spread encompassed Sabah in Borneo to the west (Bellwood and Koon 1989) and Fiji in the east (Best 1987), a spread of some 7000 km.

8 In Remote Oceania south and east of the main Solomons, Lapita appears to be the founding culture, representing initial human colonization. It is thus evidence that a threshold in voyaging technology and navigation skill was reached at that time (Irwin 1992, 1998). There is at present no evidence of a pre-Lapita extension of voyaging range (and therefore developments in boat technology) in Island Melanesia post-dating 20,000 BP. All of the island groups reached pre-Lapita show evidence of Pleistocene settlement: the Bismarcks, Solomons and the Admiralty Islands (Manus).

9 A process is needed to explain the pattern of genetic markers among populations of the region, particularly the presence of the 9 base-pair deletion found in mitochondrial DNA samples in Polynesia and in coastal and near-coastal populations in Island Melanesia and New Guinea. Its origin is clearly Asian and the spread of the Lapita culture as deriving ultimately from a Southeast Asian source provides the only plausible mechanism for its spread which is visible in the archaeological record. See Merriweather *et al.* (1999, 261–6) for a recent comprehensive discussion of this point.

The recent re-analysis by Summerhayes (1996, 2000) of Lapita pottery decoration and form shows that temporal differences far outweigh regional ones in the division of Lapita decoration into sub-styles by Anson (1983, 1986) and before him Green (1979). Summerhayes (1996, 262, 2000) calls for a re-naming of the sub-styles as Early, Middle and Late Lapita. There are of course no hard and fast breaks between them. The changes are continuous over a span of about 500–600 years, and any divisions we construct are somewhat arbitrary within this continuum, serving mainly to illustrate breaks in the settlement sequence.

1 Early Lapita is what Anson called Far Western or, as I preferred to call it, 'Early Western' (Spriggs 1997a, 70). This sub-style is limited to the Bismarck Archipelago and dates from about 3300 to 3100 BP or slightly later. This sub-style has produced the most complex vessel forms and the most elaborate decorative motifs, often executed using extremely fine dentate stamps.

2 Middle Lapita (Anson's Western Lapita) is found after 3100 BP until about 2900 BP in the Bismarcks and represents the earliest Lapita pottery in the Solomons, Vanuatu and New Caledonia. It consists of less elaborate decoration, fewer vessel forms and generally the use of coarser stamps.

3 Late Lapita (Anson's Eastern Lapita) is found in Fiji and Western Polynesia from first settlement around 2900 BP. Very similar material is identified by Summerhayes (1996, 198–201) from the Arawe Islands assemblages in the Bismarcks and comparable material can be found elsewhere in Island Melanesia. The motifs are simpler still than Middle Lapita and there are fewer vessel forms. A coarse dentate-stamping is often used. The style lasts until the end of dentate-stamped Lapita which may be around 2700 BP throughout the range of its distribution, with some possibility that it continues later in parts of the Bismarcks.

As noted above, Lapita *sensu stricto* may well end in all areas about 2700 BP, the pottery then becoming a plain ware with lip notching until about 2500 BP. There is a usually rare incised component associated with this material. Subsequently, this incised component becomes a common form of decoration, along with fingernail impression. Lasting until about 2300 BP, this goes along with a further decrease in the range of vessel forms produced. After that date pottery goes out of use in several areas, but where it persists there is a change in decoration to incised and applied relief decoration on simple vessel forms, often called the Mangaasi style after a site on Efate in Central Vanuatu. See Sand (1995), Green (1997), Spriggs (1997a), Bedford *et al.* (1998) and Wahome (1998) for discussion of post-Lapita sequences in the region. The material culture that accompanied Lapita pottery continues in these post-Lapita sequences (Spriggs 1984), although over time the range of shell ornament types is reduced.

Given the probable role of shell valuables in Lapita exchange, the changes in the range of ornaments produced are surely as significant as the cessation of dentate-stamped pottery itself in signalling societal changes following the end of the Lapita settlement period.

Once the Lapita expansion had reached its geographical limits and communities had settled into their new homes, the need for displaying whatever Lapita designs symbolized was gone, at least on the non-perishable media where they had been prominently displayed. The spiritual assistance of the ancestors may no longer have been needed (an implication of Kirch 1997, 143–4), or the cult or ritual may have lost its function or meaning (Terrell and Welsch 1997, 568). But this wasn't directly because of isolation. The fact that pottery style change across the entire Lapita range continued in step for at least a further 400–500 years after 2700 BP, and over much of it perhaps for a further 1200 years, testifies to continued social interaction between these far-flung communities.

The causes of the migration associated with the spread of Lapita remain obscure, although as Anthony has argued in a general study of prehistoric migration processes, causes are often extremely complex and in many prehistoric cases can no longer be identified (1990, 898). The migrants' initial success in establishing settlements in the Bismarcks and Solomons may have been due to the demographic advantages imparted by an integrated animal husbandry and agricultural economy in an area previously inhabited by small populations of hunter-gatherer or hunter-horticultural groups. Bellwood (1996, 487) has suggested that the existence of an already in-place agricultural (or at least tree-crop managing) economy on the mainland of New Guinea

may explain why significant Austronesian settlement there appears to have been delayed for over a thousand years after the Bismarcks were settled. He also notes that malaria may have been an added or alternative factor discouraging settlement (cf. Groube 1993). A Lapita trail along the north coast of New Guinea might still await the archaeologist, however.

Conclusions

We have inevitably had to miss out many significant research findings and directions in a contribution of this kind, choosing to concentrate particularly on questions of 'when' rather than 'why'. 'When' remains surely the more basic question and one which inevitably takes priority at an early stage of research. We have identified areas of recent controversy and pointed out the directions we think research should take in considering the chronology of human colonization of the Pacific. For such a vast and comparatively little-studied region, where basic cultural sequences are often lacking, the perhaps somewhat unromantic tasks of cultural sequence building are still the building bricks needed before convincing theory-building and synthesis can occur.

We have avoided discussion of areas such as New Zealand and some other parts of Polynesia where this pioneering stage of research is already over, to highlight areas such as most of the vast island of New Guinea and much of Australia beyond the heavily-populated eastern coastal fringe. Here for the most part, we still do not have detailed cultural sequences, nor many systematic data concerning changing settlement patterns and densities through time, which might allow deeper analysis into cultural process. The basic challenge, even after an energetic half century of research, remains that of gaining fundamental, indeed even first order archaeological knowledge, and of secure sequence building. This is not proposed as some sort of naïve positivist agenda, but is drawn from our direct experiences working in the region.

Within Oceania, we are also actors in a complex political world, where the results of archaeology increasingly 'matter' in nationalist discourse and that of indigenous minorities within larger nations of ultimately settler origins (cf. Spriggs 1999b). It might be considered to be a serious fraud to put our undigested ideas innocently out into such an interested arena, but conversely, the craft of archaeology has some fundamental historical truths which it must tell.

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Note added in proof by M.S.

Rhys Jones passed away on 19 September 2001 after a three-year battle with leukaemia, bravely fought. This paper was originally drafted and sent in at the end of 1999 after his cancer had been diagnosed and initially treated, and Rhys oversaw the correction of the final proofs just a month before his death. The jointly-conceived introduction and conclusions and my section on the Pacific Islands are, bar some updates of referencing, largely as submitted. This is not true of the Australian and early Southeast Asian archaeology sections, which Rhys wrote and which I edited, sometimes savagely, in order to keep them at least close to the word limits we were given. As new discoveries were made and absorbed by the Australian archaeological community, Rhys was continually adding and deleting paragraphs, mainly adding. Every time I went off on fieldwork or to a conference, I would return to find the Australian section again growing like topsy, and in need of judicious pruning. Rhys knew his time might be short and attempted to distill the conclusions of a lifetime of study of the region into what has in fact turned out to be his last word on the subject.

He, of course, had the last word of either of the authors too. I was to be in the field when the final proofs had to be corrected, and Rhys agreed to undertake the task on his own. I realised there was a great risk that another major rewrite would ensue and hoped the editors would be indulgent. By the time I returned to Australia, Rhys was gravely ill but the proofs were in. About 25 lines had been deleted, and he had been careful to add the same amount so as not to disturb the compositors too much. Apart from further gentle editing of my own section, he added lines on the latest discoveries on Flores, which had obviously allayed some of his scepticism of the earlier claims for an early hominid presence there, and also an update on the latest archaeological results from East Timor. He shortened the section on the dating of Mungo 3 as further studies were published and the exegesis required of 'pers. comm.' information was no longer required, but added the latest reference on the DNA analysis of the Mungo skeleton. Finally, he added in the implications of the recent paper by Roberts *et al.* (of which he was a co-author) on the dating of megafaunal extinction in Australia. The proofs were sent off on 13 August. And now silence. Like many other colleagues and friends, I miss him terribly.

ARCHAEOLOGY

The Widening Debate

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