Dating the Human Colonization of Australia: Radiocarbon and Luminescence Revolutions

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> If at Cambridge, prehistory sprang from anthropology and classics, it drew also consistently on the natural sciences for many of its methods and procedures. This was particularly true of dating.
>
> (Clark 1989, 79)

THE QUESTION OF THE ORIGINS and antiquity of Australian Aboriginal people goes back to the very beginning of the science of biogeography. Alfred Russel Wallace, in his paper 'On the varieties of man in the Malaya Archipelago' read to the Ethnological Society of London in 1865, rejoiced that one of the implications of the evolutionary theory was that now one had 'the permission . . . to place the origin of man at an indefinitely remote epoch . . . and we can speculate more freely on the parentage of tribes and races' (Wallace 1865, 209–10). Wallace's original 'Line' was an ethnological one (Moore 1997). He described how moving from Ternate to the neighbouring eastern island of Halmahera (Gilolo) 'Here then I had discovered the exact boundary line between the Malay and Papuan races . . . I was very much pleased at this determination, as it gave me a clue to one of the most difficult problems in Ethnology, and enabled me in many other places to separate the two races, and to unravel their intermixtures' (Wallace 1869, 243). He postulated that the Malays had a continental origin with affinities with other Asian peoples, whereas 'the races of Papuan type, including all to the east of the former, as far as the Fiji Islands, are derived not from any existing continent, but from lands which now exist or have recently existed in the Pacific Ocean' (Wallace op. cit., 15). Thomas Huxley took up Wallace's idea of a partly sunken continent on the Australian-Pacific rim, when he tried to explain what he considered to be close physical resemblances between the peoples of New Britain, New Caledonia, and Tasmania as having been due to cohabitation on a once contiguous land mass, most of which

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had since sunk, leaving these peoples as isolated relics of extremely ancient populations. This he felt was as good evidence of the high antiquity of man, as the direct testimony of the hand axes 'in the gravels of Hoxne and Amiens' (Wallace op. cit., 97).

Grahame Clark (1979, 2) considered that part of the reason for the rapid development of archaeology during the latter part of the nineteenth century came from 'the objective support it appeared to give to the idea of progress', that dominant paradigm of the Victorian era. Australian Aborigines were increasingly seen as having been a surviving relic from one of the earliest stages in this historical process, isolated in a remote and hostile land. This was expressed explicitly by W.A. Horn, the leader of a multidisciplinary scientific expedition to central Australia in 1894,

> The central Australian aborigine is the living representative of a stone age, who still fashions his spear-heads and knives from flint or sandstone ... His origin and history are lost in the gloomy mists of the past.
>
> (Horn 1896, ix)

It was this expedition, by bringing together for the first time the Melbourne University biologist Baldwin Spencer and the telegraph postmaster at Alice Springs, Frank Gillen, that was to transform our knowledge of the social life of the Arunta Aborigines with their classic *Native Tribes of Central Australia* in 1899. Here, within the very heart of the desert, were people with minimal material possessions who lived through hunting and gathering for their food, yet who in their kinship relations, their religion, myth, and ceremonial life exhibited a degree of sophistication and complexity that astounded late Victorian scholars, steeped as they were in an assumption of an unilineal association of material and cultural wealth. Yet even Spencer and Gillen considered that through their studies, they were exploring earlier fossilized stages in human development (Mulvaney 1996). The work also profoundly influenced later thinkers such as Freud and Durkheim in their investigations as to the putative origins of human social and psychological phenomena. If, as Wallace put it, the Australian Aborigines were 'the remnant of an ancient and peculiar race' (Wallace 1888, 105), it is strange that this did not stimulate a major programme of archaeological research on the continent to investigate this antiquity. With a few exceptions this did not happen (Horton 1991). There was primarily an intellectual reason that the very archetype itself inhibited enquiry. The past would always resemble the present and peoples of a continuous stone age thus had no history (Jones 1984, 59).

Dubois' publication in 1893, of the *Pithecanthropus erectus* hominid remains from the banks of the Solo River in east Java, raised the expectation that the origins of man might lie in the tropics of south-east Asia. This kindled scientific interest in a long neglected carbonate-encrusted fossil skull with archaic morphological features, which had been discovered by accident in about 1884 at Talgai, on the Darling Downs of south-east Queensland. In 1914, the eminent geologist Edgeworth David presented evidence derived from both stratigraphic and morphological considerations, which indicated a Pleistocene age 'far older than any Aboriginal skulls that have ever been obtained in Australasia, and it proves that in Australia man attained to geological antiquity' (David & Wilson 1915, 531). Unfortunately, the formal anatomical description of the skull made comparisons with the Piltdown jaw, which naturally were not confirmed by subsequent work and so the significance of the Talgai skull became excessively diminished, only being re-established by the anatomist N.W.G. Macintosh (1967; 1969) in the 1960s when radiometric analyses suggested an age of at least 14,000 years.

Despite the efforts of Edgeworth David (1924) to provide further stratigraphic evidence for Pleistocene association of stone tools and middens, such evidence was flimsy or could not be replicated and disillusion set in (Meston 1937). The weight of opinion led by an influential group of stone artefact collectors and typologists based largely in Victoria moved away from a high antiquity for Aborigines in Australia towards a short chronology, to be measured perhaps only in terms of a few thousand years (Mulvaney 1961, 60; Golson 1993, 275; Griffiths 1996). One can make the somewhat ironic observation that it was during this time, the mid-1920s, that Gordon Childe left his native land for Europe to devote himself 'to identify the "primitive culture" of the Indo-Europeans and to locate their *Urheimat*' (Childe 1957 in Green 1981, 167).

In 1929, H.M. Hale and Norman Tindale published their account of an excavation at the limestone rock shelter of Devon Downs on the lower Murray River, where they proposed a sequence of typologically defined 'cultures' which spannned the Holocene. Tindale (1957) later proposed an earlier culture called the Kartan, which he argued was of late Pleistocene age because the distinctive pebble core tools and large scrapers had been found on Kangaroo Island off the coast of South Australia, as well as on the adjacent mainland, which implied that they had been made and left there by people prior to the post-glacial sea level rise. Nevertheless, persuasive though this argument was, it remained the case that up to the late 1950s the prehistory of Australia was confined to a narrow chronological constraint. Glyn Daniel in his *Hundred Years of Archaeology*, mentioned Australia only once, and then as part of a single sentence combining its prehistory within the 'Hoabinhian of south-east Asia, Australia and Japan' (Daniel 1950, 286). Gordon Childe, returning to Australia in 1957, wrote to O.G.S. Crawford in what may have been a somewhat satirical vein that

> Australian archaeology has possibilities though I could not possibly get interested. There are varieties of stone implement types—all horribly boring unless you're a flint fan—some stratified sites, rock drawings and paintings of uncertain age.
>
> (6 August 1957)

Grahame Clark, in the first edition of his *World Prehistory* (1961), devoted an entire chapter to 'Australasia and the Pacific'. His conclusion was that although a great deal of stone artefacts had been collected, 'the scientific pursuit of prehistory is still in its infancy over large areas of the vast Australian territories'; and concerning chronology, his defining phrase was that 'there is no convincing evidence for the immigration of man into Australia before Neothermal times' (Clark 1961, 243). What was to change this came not from archaeologists but from physicists.

Radiocarbon dating

The unstable isotope carbon 14 was first proposed as a theoretical possibility in 1934, during cloud chamber experiments on the fast neutron disintegration of nitrogen. It remained a curiosity until 1946, when Willard Libby, at the Institute for Nuclear Studies at the University of Chicago, theorized that the same process should be happening in nature through the collision of cosmic ray neutrons on nitrogen atoms in the outer atmosphere, and that this isotope as a constituent of carbon dioxide would enter the biosphere through photosynthesis. To test the critical assumption that the cosmic ray flux had remained relatively constant within the recent past, archaeological samples of known age, mostly from the Middle East were tested, the results showing a close fit with the measured C14 ages. Libby and his co-author, the chemist Jim Arnold, published their results in the 23 December 1949 issue of *Science*, in what Grahame Clark called the 'three-page article that was to shake the world' (1989, 84). It seems symbolically appropriate for what is probably the single most influential contribution to prehistoric archaeology in the twentieth century, that it should appear exactly at its mid-point.

Archaeologists now had a universal method to erect absolute chronologies for their sites, without recourse to comparative typologies and the various assumptions of diffusionist theories. Yet Childe also foreshadowed the danger of a loss of disciplinary autonomy and presciently observed in his 'Valediction' written in Australia in October 1957, a few weeks before his death, that 'archaeologists will abandon responsibility for chronology or themselves become nuclear physicists. In any case every prehistorian must master enough mathematics, physics and chemistry to appreciate the limitation of the information the latter can provide' (Green 1981, 167). This issue is the central theme of my paper.

Very quickly radiocarbon dating was applied to a series of key archaeological and palaeo-environmental problems, the bulk of them initially in North America and western Europe. Although there were some surprises, such as extending the antiquity of the earliest British Neolithic back almost a millennium, the impression that one now has from a more distant perspective is that, in general, radiocarbon tended either to confirm the existing chronologies or only change them to a limited extent. It is a credit to the rigour and autonomy of the traditional methods of archaeology that so much of the essential chronological edifice survived the radiocarbon examination.

In Australia and its neighbouring regions of New Guinea and the western Pacific, however, radiocarbon was utterly to transform the field, and probably nowhere else did this new technique have so much immediate impact. Australian archaeologists were quick to see the potential of the method. E.D. Gill sent samples from a midden near Warnambool on the south-west coast of Victoria to be dated by Libby and this result was published in the first corrected list of dates in 1951, alongside ones from the Danish site of Aamosen and Star Carr (Johnson 1951; Clark 1980, 26). In the mid-1950s, Athol Rafter set up the first radiocarbon laboratory in the south Pacific in Lower Hutt, New Zealand, and a series of dating programmes on Australian human fossil sites were initiated. Nevetherless, in his watershed synthesis 'The Stone Age of Australia', published in the *Proceedings of the Prehistoric Society* in 1961, which marked a critical hinge-point in the practice of Australian prehistory, John Mulvaney concluded that there was no firm carbon-dated evidence for any sites in Australia older than Holocene times, the oldest acceptable date being Tindale's date of 8700 BP for stone artefacts in a coastal sand dune at Cape Martin, South Australia. With access to the new technology, Clark (1980, 25–6) felt that 'Australian archaeologists were presented with a challenge almost as urgent as that with which Darwin and Huxley had once confronted the British and French pioneers of prehistory'.

Breakthrough into the Pleistocene

The first dates beyond the 'Pleistocene barrier' were obtained by Mulvaney himelf at Kenniff Cave in the highlands of south-east Queensland in 1962, when an age of 12,900 BP was obtained from a depth of seven feet, extended to 16,000 years BP a year later from lower down the section, and with further artefacts beneath. Within the next decade, this initiated a radical phase of field discovery, much of it carried out by recent graduates of Cambridge archaeology and by their students within newly established teaching and research posts in a few key Australian universities, notably at the Australian National University, which established its influential radiocarbon laboratory in 1965, at Sydney, and at the University of New England, Armidale. Institutional support was given by the Australian Institute of Aboriginal Studies, established by the Commonwealth Government in 1962, and which funded many critical discoveries and was prepared to back independent field projects by junior researchers. The dominant paradigm of this work was derived from an economic prehistory approach, rooted within the traditions and methods of integrated Quaternary research (Mulvaney 1993; Jones 1993, 106–8) and strongly influenced by the teaching and research of Clark (1989, 79–97), Charles McBurney, and Eric Higgs. Most projects involved the cooperation in the field of both archaeologists and Quaternary specialists such as geomorphologists and palynologists, which was reflected in the joint authorship of many of the key papers. The experience of working with indigenous people in northern Australia and New Guinea, together with a growing awareness of the vast ethnographic literature of the region, led to a powerful anthropological dimension (Meehan 1982; Golson 1986). Influences from the USA were strong: in particular the writings on cultural ecology by Julian Steward, work on shell middens by California archaeologists such as Heizer, and the analytical approaches of W.W. Taylor (1948) and Willey and Phillips in their *Method and Theory in American Archaeology* (1958). In many ways these trends echoed a similar integration within New Zealand archaeology, which had developed slightly earlier than in Australia, and much important work done in New Guinea was jointly carried out by Australian and New Zealand based researchers.

By 1967, dates of slightly over 20,000 years had been obtained from a variety of Australian sites, ranging from evidence of underground flint mining at the huge karst

Koonalda Cave on the Nullarbor Plain, or the sandstone shelter site of Burrill Lake on the coast of New South Wales, to several rock shelters in the Kakadu area of the Northern Territory. These latter sites, Malangangerr and Nawamoyn, caused a controversy, since in their basal levels dated to between 20,000 and 23,000 years ago, they contained small, well-made edge-ground hatchet heads made from volcanic or metamorphic rock with lateral hafting grooves on their sides presumably for hafting (C. White 1967; Schrire 1982). Edge-ground axe heads were also found in late Pleistocene contexts in caves in the highlands of New Guinea at Kafiavana and at Nombe (Golson 1971, 127; Mountain 1983, 94). Possibly analagous tools called 'waisted blades', usually made from volcanic rocks, consisting of large, flat, lenticular split-cobbles or flaked core rough-outs, with a pair of opposed notches on their sides or stemmed, and with their edges sharpened by grinding, were also found in Papua New Guinea. At the open Kosipe site they were dated to 26,000 years ago (White *et al.* 1970) and in limestone cave deposits in the highlands were found within terminal Pleistocene stratigraphic contexts, later dated back to about 30,000 years ago (Bulmer 1964; Mountain 1983). Within a remarkable series of tectonically uplifted coral terraces on the Huon Peninsula of north-eastern Papua New Guinea, these tools together with flakes and steep-edged cores were found *in situ* from the walls of a gully cutting the back-lagoon behind the uplifted reef terrace IIIa. This reef was itself dated by uranium series methods to between 45 and 53 ka, and a volcanic tephra covering this gully deposit was dated by thermo-luminescence (TL) to more than 40 ka, giving a minimum age for these artefacts (Groube *et al.* 1986).

Golson compared these northern Australian and New Guinean tools with similar ones from late Pleistocene contexts in south-east Asia and Japan and concluded that hafted ground axe/adzes were an integral part of the Pleistocene stone technology of this region, whose importance and antiquity had been long been masked by typological expectations carrying the 'burden of Europe' (Golson 1971, 129). This had led several scholars including Grahame Clark himself (White 1977) to present a somewhat Hobbesian verdict for the region that it was 'one of the most unenterprising parts of the Late Pleistocene world' (1968, 220).

New Guinea horticulture

Groube (1989) has ingeniously suggested that one of the functions for these waisted blades was as hafted axe/adzes to ring-bark trees so as to open up the rain forest canopy, thus allowing light to penetrate to the forest floor, where in the disturbed forest edge many potential food plants are found, such as yams and other vines and the mountain *Pandanus* with its high energy edible nuts. There is direct pollen and geomorphic evidence for landscape modification in the form of firing the higher margins of the forest as far back as about 30,000 years ago (Hope 1982; Haberle *et al.* 1990; Mountain 1991). The early Holocene saw the establishment of water drainage systems in intermontain swamps such as at Kuk in the Wahgi Valley from some 9000 years ago leading to a horticultural system there probably based on taro (Golson 1972, 17–18; 1989). With the land bridge between New Guinea and Australia being finally severed about 8000 years ago, the prehistories of the two land masses continued to diverge due both to physical separation and to the two subsistence trajectories; on the one hand the continuation of hunting and gathering on the savanna to the south with its long dry season and generally nutrient-poor soils of the continental plate, and on the other hand an intensification of horticulture which occurred in the younger upthrust mountain ranges with more continuous seasonal rainfall and volcanically enriched soil (Jones & Bowler 1980, 19–23).

Some implications from Mungo

The discoveries in 1969 at Lake Mungo, a fossil, now dry lake in the arid zone of south-western New South Wales, were important in that a variety of archaeogical evidence could be closely integrated with palaeo-environmental reconstructions of a time period beyond the Last Glacial Maximum, when climatic conditions were much wetter than today (Bowler *et al.* 1970; Jones & Bowler 1980, 10). The cremated and smashed cranium of the Mungo I female dated to between 26,000 and 30,000 years old, indicated a modern sapient and gracile morphology. The Mungo III hominid, found within an older part of the dune more than 32 ka old, was an extended burial of a male in a grave which had been covered with red ochre, and it also exhibited modern morphological features (Bowler & Thorne 1976). There was evidence for a mixed foraging economy with gathering of freshwater unionid mussels and fishing from the lake edge, hunting small marsupial game, and collecting emu eggs from the desert scrub behind. Later research indicated a unionid shell midden in a nearby lake edge lunette dune dated to 35 ka (Bowler 1976, 59), and stone artefacts were excavated close to the base of the Mungo stratigraphic unit, with an assay on an extremely small carbon sample giving a value almost indistinguishable from background, and which was reported at the time as being *c.*40 ka old (Shawcross & Kaye 1980, 123).

At Mungo, flaked stone tools consisted of dome-shaped 'horsehoof' cores or core tools, and scrapers often made from thick flakes with steeply retouched edges, or with noses and deep notches possibly for use as spokeshaves. Their function was probably in the manufacture of wooden tools such as spears, digging sticks, and bowls, which were the primary implements for food production. Typologically, these were similar to assemblages from other late Pleistocene sites such as Kenniff Cave, Capertee in New South Wales, Ingaladdi in the Northern Territory, Mushroom Rock in Cape York, Kafiavana and Nombe in New Guinea, and within the entire Holocene sequence on the island of Tasmania, as many commentators had already noted—including Mulvaney and Joyce in their original Kenniff report (1965) and Grahame Clark in his review of the Australian stone tool sequence (1968, 20–2). In our description of the Mungo material, Harry Allen and I proposed the term 'Australian core tool and scraper tradition' for these industries, following the definition of 'tradition' by Willey and Phillips (1958, 37). Mindful of Childe's strictures that the culturally diagnostic usefulness of a type is proportional to its improbability (1956, 35–7), it might be argued that within this generalized suite of flake scraper types, there is not enough distinctiveness to imply some cultural reality behind it. Yet these kinds of tools are consistently found in Australian Pleistocene and early Holocene sites and so, if they are considered as constituting a distinctive 'technological mode' following Clark (1977) and Foley and Lahr (1997), then there is still predictive utility to the term. A regional exception to this general uniformity occurred in the mountainous region of south-west Tasmania during the Last Glacial Maximum, when the stone industries of people who concentrated their foraging on the hunting of wallabies were dominated by tiny thumbnail-shaped scrapers. This system came to an abrupt end during the early deglaciation at 13 ka when the region became revegetated by dense rainforest (Jones 1984, 52–7; 1989; 1995, 768–71; Allen 1989, 151; McNiven 1994).

Within the few well excavated and dated late Pleistocene sites in south-east Asia, the stone assemblages also bear a similarity to the Australian ones (Jones 1989, 750–4; Bowdler 1993, 65), as was noted as far back as 1970 by Fox in his account of the material from Tabun cave in Palawon Island, the Philippines (Fox 1970). Anderson's analysis of flaked stone tools from the pre-Hoabhinian layers at the limestone cave of Lang Rongrien in south Thailand dated to between 27 ka and greater than 38 ka (1990), and Glover's excavation at Leang Burung 2 on Sulawesi, between 20 ka and 32 ka (1981), have industries consisting of steep-edged and notched scrapers on flakes reminiscent of the Australian material. As Anderson (1990, 67) put it, 'Contrary to expectations built up from nearly a century of archaeological research and speculation, they suggest that flake tool industries and not pebble tool industries characterized the late Paleolithic in the region'. Hoabinhian industries only appeared in south-east Asia during terminal Pleistocene and Holocene times possibly extending down to as recently as 3 ka (Bellwood 1997, 158).

In Australia, typologically distinctive small stone tools such as unifacial and bifacial points, backed microliths, and flake adze pieces only appear within the mid Holocene, in most places at about 5000 years ago. These were probably the armatures of gum-hafted tools which would have included not only spears, but also tools for wood working. The linguist, Nicholas Evans, and I have argued that these technological changes were associated with the rapid spread of the Pama-Nyungan language family over most of the continent at that time, with an origin near south-eastern Arnhem Land (Evans & Jones 1997). These may have reflected a transformational reorganization of Aboriginal ritual and modes of trading relationships at that time, but we believe that they were also rooted within core Aboriginal belief systems which had a much greater antiquity. When considering the evidence from Mungo, while being conscious of the danger of repeating the nineteenth century archetype of an unchanging people, I felt that with the exception of seed grinding, no aspect of the economic nor funerary behaviour of the people there was inconsistent with the ethnographic record. (Jones 1975, 28) The direct evidence from the archaeological record seemed to indicate some trajectory of deep historical continuity.

The oldest radiocarbon dates

In a period of research extending just over a decade, from 1962 to about 1975, the radiocarbon chronology for the human occupation of Australia was pushed back from 10,000 to about 37,000 years ago, with successively older results being announced on a regular basis (Mulvaney 1964; 1975; Jones 1973; 1979; Flood 1995). Then a plateau seemed to have been reached with no older dates, but ones of this same order of antiquity began to be obtained from many disparate parts of the continent. A recent systematic review of the data by Smith and Sharp in 1993, indicated that there were some 170 sites with basal occupation dated to more than 10,000 years ago. These sites were distributed across the entire continent including all the major ecological zones, from the highlands of New Guinea at the equator, to the mountains of south-west Tasmania, a span of 42 degrees of latitude, and on an east-to-west traverse from the humid Pacific coast and the tropical savannas through the core of the desert to the isolated temperate region of the extreme south-west of Western Australia. Recently Aru Island, situated on the very north-west edge of the Sahul shelf, and famously associated with A.R. Wallace's travels, has been shown to have occupation extending back to at least 26,000 years (Veth *et al.* in press), completing the documentation of Pleistocene occupation of all of the former parts of the eustatically exposed continental shelf. Of particular interest was the discovery of Pleistocene sites extending back to between 30 and 35 ka on the truly oceanic islands to the east of the New Guinea shelf, on New Britain, New Ireland, and the northern Solomons, indicating that the capacity to make sea crossings in these tropical waters was not confined to the acts that led to the initial colonization of the continent itself (Allen *et al.* 1989; Pavlides & Gosden 1994). The oldest radiocarbon dates within all of of these different regions of the continent ranged back to between about 33 and 37 ka years ago. At present the oldest carbon dates from a secure stratigraphic context in Australia come from Carpenter's Gap, a large open shelter in the side of a Devonian age coral reef called Napier Range which forms a vertical limestone wall, fringing the southern margin of the King Leopold Range on the southern edge of the Kimberley in north-western Australia. Here, two AMS dates of 39,220±870 (AMS NZA 3803) and 39,7000±1000 (AMS NZA 3802), stratigraphically associated with stone artefacts, were obtained by Susan O'Connor (1995) from the base of one of her units. Underneath this was another unit of fine powdery silt without carbon but which also contained stone tools.

The radiocarbon barrier

In a broad-ranging review written in 1989, Jim Allen took this array of radiocarbon dates at their face value, and argued that they represented the real dates which documented the rapid colonization of the continent, which he believed to have been made by about 35,000 years ago, suggesting the first landfall at no older than 40,000 years, a view which he has entrenched in later papers (Allen 1994; Allen & Holdoway 1995; O'Connell & Allen 1998). He was followed by J. Hope (1993) in her assessment of the Willandra lakes situation, and by Bowdler (1989; 1993, 65), who concluded for both the Australian and south-east Asian material that 'there is no evidence that Homo sapiens was present in southeast Asia before 40,000 BP'.

I took a different view: that dates of this order of magnitude were so close to the theoretical limits of the radiocarbon method that maybe the 'plateau' was really an illusion (Jones 1982, 30; 1989, 762). At this order of antiquity, because we are so close to the asymptote of the decay curve, were one to take a 'radiocarbon dead' sample and add only 1 per cent of modern carbon, then the apparent age of the mixed sample would be counted as being about 37,000 years old (Aitken 1990). The question revolves less about the capabilities of the counting technology, which theoretically can extend back to *c*.50 ka or even more, but rather about the fundamental assumption that a prehistoric dating sample has remained closed to all exchanges of carbon from the time of its formation to the time of its measurement (Chappell *et al.* 1996). On Australian materials, while most contamination by mobile organic compounds can be removed by the standard pretreatments, experimentation has shown that further more intensive cleaning can produce a series of different ages on the same sample, indicating the extraordinary persistence of low level contamination (Gillespie *et al.* 1991; Magee *et al.* 1995). Thus the limits of AMS radiocarbon technology at present lie with the capacity to prepare utterly pure elemental carbon targets (Bird & Grocke 1997).

Deep pollen cores such as at Pulbeena Swamp in north-west Tasmania (Colhoun *et al.* 1982) and Lake George in southern New South Wales (Singh & Geissler 1985) follow a coherent relationship with depth up until about 35 ka and then values at this same order of magnitude are maintained below this, even though the real age of the deposits may extend back to quarter of a million years or more. At the critically important Williams Point site, a high bluff of lacustrine and dune deposits fronting the southern edge of Lake Eyre, the base of the sequence is correlated with the Last Interglacial, at oxygen isotope stage 5e some 125 ka ago. The top of the sequence is dated by several methods to 40–50 ka. A combination of amino acid racemization (AAR) on eggshell, thermo-luminescence (TL), optically stimulated luminescence (OSL), and thorium/uranium dating methods on these deposits, showed a steady increase with depth throughout this sequence. In contrast all of the C14 results were less than 45 ka, even though at least five of these had been assayed by AMS, with a state-of-the-art rigorous programme of oxidative pretreatment in an attempt to remove contaminants (Magee *et al.* 1995; Chappell *et al.* 1996).

There were several archaeological sites in Australia-New Guinea where artefacts occurred in stratigraphic situations below the lowest carbon (Jones 1979, 451–3; 1989, 762–4; Bowler 1976, 62–4). Of particular relevance to my own experience was the section at the Nauwalabila rock shelter in Deaf Adder Gorge, Kakadu in the Northern Territory which I had excavated in 1981 (Jones & Johnson 1985). Here was a sequence which had radiocarbon dating back to *c*.25 ka at a depth of 1.7 m; and beneath this there were numerous stone artefacts down to the base of the sand sheet and also within a underlying compacted rubble, to a maximim depth of 3 m. There were independent geomorphological indicators of great age for these basal deposits, including a deep orange colour for the sands, and the fact that the lowest silcrete artefacts showed weathering rinds when split (Jones & Johnson op. cit., 178–83).

Luminescence dating of sands

A solution for this impasse was offered by innovative applications of luminescence techniques to the dating of Quaternary sediments (Wintle & Huntley 1979; Wintle *et al.* 1984). Thermo-luminescence, a phenomenon originally described to the Royal Society of London by Robert Boyle in 1663, consists of the thermally stimulated emission of light from a semiconductor, following the previous absorption of energy from ionizing radiation. In the case of quartz crystals, buried as sand, electrons become steadily displaced into metastable traps within defects in the crystal lattices due to alpha, beta, and gamma rays which are derived from the decay of the primordial radionuclides which occur in the surrounding deposits; together with cosmic rays, if the depth of deposit is shallow. When such a grain is heated or exposed to sunlight, these electrons are evicted from their traps and in a process known as radiative recombination, photons are emitted. The exposed sand is said to have been 'bleached' and the luminescence clock set to zero. One of the critical assumptions of the method is that there remains no 'residual signal' when the grains are later reburied and the process recommenced, otherwise falsely older dates will be obtained. To measure the age of the deposit, the 'palaeodose' which is the total radiation dose which the sand grains had acquired since burial, is divided by the annual dose rate delivered to it from the surrounding soil; the latter being measured in the field with a gamma spectrometer and in the laboratory from soil samples. To measure the palaeodose, TL intensity is plotted against temperature in what is called a 'glow curve', which contains important information about electron traps mainly associated with the 325°C and the 375°C peaks. The latter is bleached slowly and only by ultraviolet wave lengths and is mainly responsible for the residual TL signal discussed above. Red desert sands are covered with a thin film of clay containing iron oxide which tends to shield them from solar radiation and thus they can sometimes carry a residual signal before reburial (Smith *et al.* 1997).

The more sophisticated, optically stimulated luminescence method developed in the late 1980s (Huntley *et al.* 1985) uses light to evict the traps and the OSL signal has been shown to correspond to the 325°C peak, which is extremely light sensitive; being emptied by a brief exposure of less than a minute to direct sunlight (Spooner 1994; Roberts & Jones 1994). There are also internal checks to see whether or not the sample had been fully bleached prior to burial. In TL this is called the 'plateau test' where a palaeodose plateau which extends from 270°C to 450°C indicates that the sample was well bleached in antiquity (Roberts & Jones 1994, 7), and there is an analagous 'shine down' test with OSL (Huntley *et al.* 1985). There are other assumptions concerning possible leaching of some of the daughter radionucleides in the deposit, so that detailed measurements of the decay isotopes have to be made and compared with the predicted values (Roberts & Jones 1994, 7–8). Luminescence methods in typical Australian conditions can be used to date an age range of a few hundred years back to about 200,000 years and thus provide the critical new tool to explore the time period beyond the radiocarbon barrier.

TL was first used to date Australian Quaternary deposits by Readhead (1982) on sands at the Mungo site. In the late 1980s Richard Roberts was engaged in a research programme using TL to date sand aprons situated at the base of cliffs in the Kakadu area of Western Arnhem Land. Within his auger columns, from which he obtained a series of consistent TL dates extending back in time to about 120,000 years, he was not able to obtain charcoal samples below a few centimetres from the ground for corroborative C14 dating, because carbon in this environment is rapidly recycled by biogenic agents. However, within the deposits of archaeological sites of the region, because so much firewood had been concentrated there by Aborigines in the past, there was enough charcoal to buffer some of these decomposing processes, so that although density of charcoal decayed rapidly with depth, there was still enough surviving to give dates that extended back to about 25,000 years ago (Jones & Johnson 1985). In 1988, a project was planned to pair TL dates against the known C14 chronology within these archaeological sequences, and if they matched, then to use TL to attempt to date the lowest artefact-bearing deposits beyond the limits of charcoal.

Malakunanja

Malakunanja II, first investigated by Kamminga and Allen (1973), is sheltered under the high sloping cliff of a quartzite outlier, detached a few kilometres from the main Arnhem Land escarpment. A sand apron with a low angled slope has accumulated at its foot, and excavations in 1988–9 revealed a total depth of 4.6 m of sand capped by a small shell midden. Within every excavation unit of the upper 2.6 m of deposit, there were numerous flaked stone artefacts, in total numbering several thousand. Yet within the entire bottom 2.0 m of the deposit there were none. The break was sharp, extending over only a single spit of 5 cm depth. A TL sample just below the surface gave a value of only 200 years, indicating that the assumption of total bleaching in the sand sample had been attained. At a depth of 1.5 m, a TL date of 15 ka was stratigraphically bracketed between two calibrated C14 dates of 15 ka and 18 ka; and at 2.0 m depth, a TL date of 24 ka corresponded reasonably well with a calibrated C14 value of between 20 and 22 ka (Roberts *et al.* 1990a, 153; Roberts & Jones 1994, 14). Beneath these, where charcoal was no longer preserved, there were three further TL dates associated with artefacts; the zone of first occupation of this site being bracketed between 53 ka and 60 ka ago. Underneath this within the culturally sterile deposits, were four further TL dates extending from 65 ka back to 107 ka at the base. The error estimate for each individual TL date was large, being some 15 per cent of the mean; but all the dates were in the correct chronological order as compared to their stratigraphic positions (Roberts *et al.* 1990a; Roberts & Jones 1994). A linear least-squares regression with the assumption of a uniform rate of accumulation of the sand deposit, showed that all samples lay within one random uncertainty of the 95 per cent confidence limit for this best fit curve. A conservative interpretation would indicate that the zone of first human occupation at this site would be around 50,000 years old (Roberts *et al.* 1990b, 127–8), with a possible extension back to *c.*60 ka.

We put forward two propositions: not only that humans were present in Australia at this time, but also that the Malakunanja II sequence indicated that there was nobody here before *c.*60 ka, since we regarded the total absence of any artefacts at this site over the previous 50,000 years as being highly significant (Roberts *et al.* op. cit., 128). This was because of the strategic location of the site at the first line of high terrain facing the then eustatically exposed Arafura Plain. With its gullies and gorges containing deepwater pools and rain forest pockets, this landscape constitutes one of the most biodiverse and stable landscapes on the entire Australian continent, which once found would never be relinquished.

Adding as they did, potentially a 50 per cent increase to the antiquity of humans on the Australian continent, these results were subject to fierce criticism (Bowdler 1990; Frankel 1990), only some of which was scientifically informed. Hiscock (1990) made the reasonable suggestion that although the TL dating of the sands themselves might be correct, the first artefacts might have been pushed or trodden into lower and much older stratigraphic contexts by the human activities of living on a sandy camp surface. We tried to answer this by pointing out that the luminescence method dates the time since the last exposure of sand to sunlight. Thus in a scuff zone which is normal in an occupation site, any sand kicked up by people's domestic activities would instantly be zeroed of its TL signal. In this taphonomic context, the method is paradoxically a more reliable indicator of the last time that the deposit finally bedded down than is the dating of charcoal, which can move up or down a stratigraphic column due to disturbance, while its C14 value is unaffected (Roberts *et al.* 1990b).

Nauwalabila

In order to try and replicate these results, in 1992 we returned to the Nauwalabila site, 60 km south, which previously we could not sample due to access restrictions following the burial nearby of two senior Badmardi men who had worked with me on the original excavation (Jones & Johnson 1985, 167). By this time, the OSL methodology was available at Martin Aitken's Oxford laboratory and five OSL samples were dated from this site. One from just below the surface gave a value of 300 years, indicating that the conditions of total bleaching had been achieved. At a depth of 1.1 m, an OSL date of 13.5 ka, consistent both with a TL date of 14.6 ka and a set of three radiocarbon samples dated to between 11 ka and 13 ka indicated a close chronological fit between the two methods. At 1.7 m, the lowest level where charcoal survived, there was a calibrated C14 date of *c.*27 ka, which was reasonably consistent with a TL date of 28 ka and an OSL one of 30 ka. Below that, where no charcoal existed at the base of the sand column at a depth of 2.4 m, there was an OSL date of 53 ka. Underneath this sand was a tightly packed rubble which also contained some 300 stone artefacts, and beneath the rubble was a small sand lens. An OSL sample from this at a depth of 3.0 m gave a date of 60 ka, and another OSL sample from an auger at the same general depth on the sand sheet outside the rock shelter gave a value of 58 ka. The lowest occupation at this site therefore was bracketed between dates of 53 and 60 ka, and here, there was no possibility of artefacts being worked down to lower levels due to any conceivable taphonomic process (Roberts *et al.* 1994b; Roberts & Jones 1994).

Comparison of OSL and carbon 14 methods: Allen's Cave and Ngarrabullgan

Work at other sites around the continent to try and replicate these results is proceeding, and a major effort has been put into trying to compare OSL with reliable C14 chronologies, especially those based on adequate pretreatment to produce pure elemental carbon. At the karst Allen's Cave on the Nullarbor Plain, a single well-defined hearth at the top of the basal red unit had three C14 dates (two being liquid scintillation and one AMS determination) with calibrated mean ages between 10.0 and 10.5 ka. An OSL sample from unburnt deposit immediately beneath this feature gave a value of 10.1±0.6 ka, indicating close correspondence of the two methods (Roberts *et al.* 1996, 14).

A detailed study has been made at Ngarrabullgan Cave, situated at the top of the Mount Mulligan sandstone plateau massif in north Queensland. Here, the shelter situated at the very highest point of the watershed has a depositional regime where the only accumulation of sand has come from the roof itself, with no other component washed in. As a consequence, there was an intensely compressed and highly coherent stratigraphy at this site. From within a single well-defined stratigraphic unit towards its base, a series consisting of 20 separate pieces of charcoal were dated individually using AMS, and their means showed a Gaussian distribution with a weighted mean age of 32,540±110 years BP. From this same level, an OSL date of 34,700±2,000 was obtained, which at 2 ka greater than the C14 mean, was the same difference that Bard *et al.* (1993) also obtained when they compared C14 and Ur/Th ages from Barbados coral at this 30–40 ka age period (David *et al.* 1997, 187). Where the appropriate methods are used, and where the various assumptions of the methods are met, there is a close correlation of C14 and OSL dating methods.

The rubble problem

A potentially serious problem concerning the application of luminescence dating at certain kinds of sandstone sites, was indicated during investigations at the Mushroom Rock shelter in Cape York, northern Queensland. As its name implies, this is a small undercut outlier off a main plateau of coarse-grained sandstone of Cretaceous age, and it overlooks a low angled sloping sand sheet. This site had originally been excavated by Richard Wright in 1962–3, when he found numerous stone artefacts within all excavation units in this sand down to a depth of 4.5 m, where they abruptly stopped. A further 1.3 m of sand in the excavation contained no artefacts (Wright 1964; Clark 1989, 117). In 1991, this site was re-excavated by Mike Morwood; and with a series of TL dates done by D. Price, extending back to 29 ka at a depth of 3.8 m, suggested, on an age-depth correlation, that the age for initial occupation at the site might have been prior to some 40 ka (Morwood *et al.* 1995, 137). Because this situation was analagous to that at Malakunanja II, Roberts and I joined Morwood in a further excavation at Mushroom Rock in 1994, where we excavated down to a total depth of 6 m making it one of the deepest archaeological sites in Australia. An OSL sample near the lowest artefacts gave unexpectedly old apparent age. Further research indicated that this was due to the inclusion in the sample of sand grains which had been derived from friable *in situ* weathered bedrock or *saprolite*. Never having been exposed to sunlight, these carried a saturated signal, and gave a falsely old age. Since it was difficult to distinguish these by microscopic methods this presented a formidable problem to the luminescence dating method at this type of site.

A similar problem was identified at the Puritjarra rock shelter in central Australia some 350 km west of Alice Springs (Smith *et al.* 1997). Here the TL and OSL dates done by John Prescott, with exemplary precautions as to possible errors, were persistently a small amount older than the C14 dates, except in the deepest part of the site, where both seemed to converge on a basal date of some 35 ka. These discrepancies were possibly explained by incorporation of *in situ* disintegration of old material from the bedrock.

The solution to this problem lay in miniaturization, which was analagous to the trend of research in radiocarbon. In luminescence dating, normally a value is obtained from an array of some 2000 grains of sand. However, if, say, 20 separate equal samples or 'aliquots' of a hundred or less sand grains are individually dated, then there is a reasonable statistical chance that in many of these the unbleached saprolite grains will be missing, and thus the contaminated samples easily identified. The ultimate is to be able to obtain luminescence dates from individual grains of sand, and this was technically achieved at the ANU in late 1995 (Murray & Roberts 1997).

The Jinmium controversy

In 1996, Fullagar, Price, and Head published TL dating results from a small sandstone rock shelter of Jinmium, situated a short distance from the north Australian coast at the border between the Northern Territory and Western Australia. They claimed that this site indicated stone tools stratified between TL dates of 116 ka and 176 ka; ochre between 75 ka and 116 ka; and a piece of rock with two pecked depressions buried between levels dated to 58 ka and 75 ka (Fullarger *et al.* 1996, 764–5, 771). On the shelter wall, there is a large panel of such features called 'cupules', believed by some to be the oldest expression of art in Australia. These results gained widespread international coverage (Bahn 1996; Holden 1996; Dayton & Woodford 1996; Gore 1997, 107–8), and John Noble Wilford in the science pages of the *New York Times*, headlined his extensive piece as 'In Australia, signs of artists who predate *Homo sapiens*' (1996).

Because of our scepticism as to the validity of these dates, Richard Fullagar invited Roberts and me to reinvestigate the chronology of the site, which we did in the field in July 1995, when samples were collected for OSL dating. Our doubts concerned the fact that the apparent compressed rate of deposition within the shelter, where there was much friable rubble, was only a tenth of that within the general sand sheet outside. The one published dose response curve for sample W 1752 with a TL age of 50 ka (Fullagar *et al.* 1996, 767), does not pass the plateau test, indicating that the sample had been incompletely reset on deposition (Spooner 1998). Geomorphologically, there were no marked stratigraphic breaks, despite dating indications of great time differences over a narrow depth of deposit, and it showed none of the pedogenic staining which is characteristic of Pleistocene deposits, both in the vicinity of the site itself and elsewhere in tropical Australia.

The new samples have been subjected to an intensive multi-method dating regime, involving OSL dating of single grains, and, in a parallel study, AMS dates from specially prepared elemental carbon samples designed to eliminate any organic carbon contamination. These results indicate that all of the deposit within the shelter is less than 10 ka years old, and that the levels in which the engraved rock was buried are also less than 4 ka (Roberts *et al.* 1998a). The single-grain OSL results agreed closely with the AMS dates within the error margins of both systems. The erroneous old ages at this site had been due to two factors: firstly that the TL signal had been incompletely reset at the time of sediment deposition, and secondly there had been contamination by unbleached grains derived from weathered bedrock.

Whereas the Jinmium example shows that luminescence dating of some sandstone rock shelters must be proceeded with due care, on the other hand, appropriate high-precision techniques have now been developed which can isolate the problems identified. A further programme of research has been initiated at both Malakunanja and Nauwalabila using single-grain OSL techniques to test the integrity of the previous results. At Malakunanja, where the initial work had involved TL dating, internal evidence such as confirmation of the behaviour of samples to the plateau test, and comparison with radiocarbon dates in the upper levels, had given confidence that the sediments at this site had been adequately bleached at the time of their deposition. A new set of OSL dates carried out at this site confirm the previous results (Roberts *et al.* 1998b). The oldest stone artefacts in the site had been bracketed between samples KTL 164 which gave a conventional TL date of 45±9 ka, and sample KTL 162 associated stratigraphically with the lowest artefacts with a TL date of 61±13 ka. Optical dates have since been measured for these samples. Multi-grained *c.*800 grains) OSL dates gave values of 46±4 ka for KTL 164, and 61±8 ka for KTL 162. Finally, individual sand grains were assayed from both samples; the results from the highest precision grains being 43±5 ka from KTL 164 and 56±8 ka from KTL 162. These multi-method results are within statistical accord of each other and despite the somewhat carping comments of O'Connell and Allen (1998, 135) on our previous work, confirm our claim that people were present in this region of north tropical Australia by about 50–60 ka.

Crossing Wallacea

With the presence of *erectus* populations in Java on the Sunda shelf back to about a million years ago (de Vos 1994), there has always been the issue of whether or not these people had the capacity to cross any of the water barriers to or even through Wallacea. Some elements of the large Asian mammalian fauna such as elephants and the related extinct Stegodontidae managed some of these crossings. On Luzon in the Philippines, with one water crossing, there were two species of stegodon, one extinct elephant, and an extinct rhino; on Sulawesi, also with a single crossing, there were two stegodons, one elephant, and some suids. Finally on both Flores and Timor, with several narrow water crossings along the Lesser Sunda Chain, there were a pigmy *S. sompoensis* and a large *S. trigonocephalus* (Hooijer 1972; Sondaar *et al.* 1994). In the early 1970s, claims were made for stone artefacts being associated with Middle Pleistocene fauna at the Cagayan Valley in northern Luzon, but these have not as yet been confirmed by further work.

A much better case is the one recently being reinvestigated on Flores. At Mata Menge in the west central part of the island, in the shadow of a large volcano, Maringer and Verhoeven (1970) reported finding stone artefacts in association with stegodon fossils in a water-lain tuffaceous sandstone. New excavations by Sondaar *et al.* (1994) found further stone tools of basalt flakes and fractured pebbles in the same Ola Bula Formation, stratigraphically associated with the large *S. trigonocephalus* located in the sequence immediately above the Bruhnes-Matuyama magnetic reversal, indicating an age for these artefacts of *c.*700 ka. Further analysis of stone artefacts within this formation was carried out by M. Morwood *et al.* (1997), and dating work is proceeding with a paper reporting fission track dates for this deposit dated to *c.*800 ka which was consistent with previous age estimates (Morwood *et al.* 1998). There is no doubt as to the authenticity of the stone artefacts, nor the general order of age for the stegodon fossils. It remains to be seen whether or not the ongoing geomorphological and taphonomic research can confirm the genuine association of tools and fossils in this tectonically dynamic region. If it does, then it will set an important claim for the capacity of *erectus* humans to cross limited stretches of tropical sea in Middle Pleistocene times.

Occupying the continent

My view is that it was only modern *Homo sapiens* who made the final journey to the Sahul shore, and that this was done at the order of 60 ka ago. This corresponds to the end of the isotope stage 4 (Linsley 1996, 236), and the palaeoenvironmental record from Lake Eyre indicates that this was close to the end of a far wetter period, when lake-full phases held as much as a hundred times the present flood events, implying a long-term average rainfall some four to five times greater than the present value (Magee *et al.* 1995). During the next 10 ka, there was a deterioration in the rainfall regime, leading eventually to slow desiccation of the Centre which reached its maximum at the Last Glacial Maximum. As Mulvaney (1961, 62) pointed out, there is a natural road into the heart of the Australian continent, south from the Gulf of Carpentaria, where there is only an imperceptible watershed on a wide plain separating the northerly rivers from those that flow south-west through western Queensland to feed Lake Eyre, whose basin encompasses a seventh of the area of the entire continent; or via the Paroo into the headwaters of the Darling-Murray basin. During rare but huge flood events fed by tropical monsoons, even in today's climate, rivers such as the Diamantina within the appropriately named Channel Country, form a network of braided streams and floodsheets of slowly moving water hundreds of kilometres wide, with an explosion of fish and aquatic bird life. During a wetter period, this would have been even more dramatic, allowing the probing colonization of core areas of the eastern half of Australia to be effected in a very short time, even within the timescale of a few generations and certainly to be measured as an instantaneous event given the errors of our dating methods (Webb & Rindos 1997).

There remains the question of the potential impact of the human arrival on the process of megafaunal extinction, when about a third of the marsupial species of Australia and New Guinea became extinct; almost all of these genera being much larger than existing forms. A similar process was also seen with some birds and reptiles. The central problem in investigating this issue has been that the extinction events may have occurred during a time period beyond the range of C14 dating, so that it has been impossible to erect a firm chronology for these events. The best record that we have so far, using new dating methods of any extinction event, is that concerning the giant flightless *Genyornis*, a bird about twice the weight of an emu. In the Lake Eyre sequence, both *Genyornis* and emu eggshells have been dated by amino acid racemization, and whereas emus continue through all of the vicissitudes of climatic change, including the deeply arid phase of the Last Glacial Maximum, *Genyornis* suddenly collapses about 45–50 ka, at about the time of human arrival (Miller *et al.* 1997; J. Magee pers. comm.).

In the swamp site of Cuddie Springs in western New South Wales, in a low energy riverine environment, hundreds of stone tools have been found in close stratigraphic association with bones of *Genyornis* and the marsupial Diprotodon (Furby *et al.* 1993; Pain 1997). This deposit has been dated by both C14 and OSL to about 34 ka ago, and fascinating though this site is, it remains to be entirely proven that there has been no slumping of older bone beds within this periodically saturated context. ESR dates on the teeth of the extinct fauna should be a critical test. I remain convinced that the megafauna which had existed and radiated over a period of more than five million years and survived at least 20 ice age events during the Pleistocene was somehow fatally affected by the arrival of the new human superpredator, either through direct hunting, or more likely through landscape modification by imposing a new firing regime (Jones 1975; Diamond 1997, 43–4).

Among the first modern humans out of Africa?

Genetic evidence over the past 15 years has accumulated a powerful case for a recent single origin for modern humans dated back to about 150 ka in sub-Saharan Africa (Klein 1995; Foley & Lahr 1997, 4). In the spread out of Africa, there were several genetic bottlenecks, notably in north-east Africa (Tishkoff *et al.* 1996), and the human spread out of this region may date to only some 80 ka ago. The Australian archaeological data are critical to this debate, since they provide some of the best chronometric evidence for the spread of modern humans out of an African bottleneck. Recently reported results from M. Stoneking presented to the Human Evolution Meeting, October 1997 at the Cold Spring Harbor Laboratory, suggested from a study of DNA sequences recognized by the restriction enzyme *Alu,* that the major split between African and non-African populations occurred about 140 ka ago. In addition, population samples from Sahul, both New Guineans and Australian Aborigines, are as close to the presumed ancestral state of the human Alu family as are samples from African populations, suggesting that 'a migration to Southeast Asia must have been one of the first "out of Africa" excursions of modern humans' (Wood 1997, 120). The route along the Parallel of the tropical savanna, from west to east was the obvious new terrain to people adapted to closely similar conditions in east Africa. The savannas of northern Australia only required short sea crossings to get into them.

There exist some fossil skulls in Australia which exhibit remarkable archaic characteristics. This is perhaps most exemplified by the Willandra Lakes (WLH) 50 skull, which has a vase shape to the top of the cranium, prominent post-orbital constriction and a broad flat occipital shape inviting anatomical comparison of some of these features with those of the Ngandong hominids (Frayer *et al.* 1994, 427–8). Whether or not these characteristics in the Australian fossil material indicate some direct genetic input from late Solo populations in Indonesia, as Weidenreich originally suggested, and as has been argued consistently by Thorne as a central element of his 'Multi-regional hypothesis' (Thorne & Wolpoff 1992; Frayer *et al.* 1994; Wolpoff *et al.* 1984), or whether they represent the retention within the isolated Australian region of generalized archaic characteristics of the first modern humans (Stringer & Brauer 1994), is an issue of contemporary debate (see Klein 1995, 179–83; Foley & Lahr 1997, 4). New dating programmes now underway on some of the Mungo hominid sites (Oyston 1996; Grün & Thorne pers. comm.), may help to clarify some of these issues, at least to place the various fossils into a firm chronological framework.

Dating rock art

Rock shelters, whose stone tool assemblages may carry little specific cultural information, often have walls and ceilings covered with fragmentary superimpositions of different styles of paintings, containing potentially the greatest information as to how the people conceptualized their world view. The problem has been to date these and thus to fix them into a historical context. Detailed superimposition studies over the past three decades in northern Australia, notably in Cape York, Kakadu, and the Kimberley have resulted in broadly accepted comparative sequences of the major styles (Chaloupka 1985; 1993; Chippindale & Taçon 1993; Cole *et al.* 1995; Walsh 1994) The question now is to be able to pin critical points within these floating sequences into an absolute timeframe. The solution also lies in the miniaturization of the dating techniques. AMS has been used to date beeswax forming parts of pictures back to 4 ka (Nelson *et al.* 1995). These oldest dates from a large rock shelter near Kakadu came from a representation of a turtle, conforming stylistically to Chaloupka's most recent 'Estuarine' phase, estimated on other grounds to extend back to some five thousand years (Chaloupka 1985). One of these dated figures overlays at least five further sets of weathered paintings. Chaloupka's oldest phase in his Kakadu sequence is argued to extend back to the late Pleiostocene and includes depictions of extinct animals such as *Thylacine*.

In Cape York mineral skins covering walls of caves have been shown to have layers of paint within them, dated by AMS on calcium oxalate back to 25 ka and 28 ka ago at different sites, but of course the details of the motifs themselves have also been obscured (Watchman 1993; 1997, 32), and the technology in this research field is difficult (Gillespie 1997). Plant fibres incorporated into the pigment as binders have been directly dated, and in this case the identity of the picture itself can be recognized (Watchman & Cole 1993). A new technique is the dating of fossilized mud-wasp nests, which when old, have the look and texture of small blobs of cement. Sand grains within these nests, absorbing radiation from the rock on which they had been stuck, can be dated by OSL, using small sample and single-grain techniques (Roberts *et al.* 1997). In the Kimberley an early phase representation of a Wandjina stylized human face, associated with cults still actively being practised in the area during the 1930s, has been dated to more than 600 years old. An extremely faded, deep purple coloured, small human figure with a head-dress, had a cemented nest on it dated to 17 ka (ibid., 697). Field observations suggest that the faded figure may be considerably older than the nest, and in turn, there is an even more faded pale violet coloured hand stencil under the human figure.

Distributed widely across the continent are panels of pecked rocks, typically depicting tracks of bird, macropod, and sometimes human, together with geometric designs. Sometimes referred to as the Panaramittee style, from a site in South Australia, these panels are often covered with mineral skins. In northern Australia at least, these skins contain calcium oxalate, and can potentially be dated (Watchman 1997). At the Early Man Site in Cape York, a panel of such engravings was found stratified beneath deposit dated to 13 ka, indicating a minimum age for such art (Rosenfeld *et al.* 1981). High quality haematite, often with striations indicating their having been ground to produce pigment, are ubiquitous within Australian sites down to the very basal levels. One such piece was directly associated with a 50 ka OSL date from Nauwalabila (Jones & Johnson 1985; Roberts *et al.* 1994b). Now that the initial techniques have been developed, they need to be applied systematically on key sites. These manifestations of art, part of the cultural inheritance of the first Australians, were, to paraphrase Clark, 'symbols of excellence', the surviving evidence of the conceptual worlds of ancient Aboriginal societies.

Concluding remarks

Grahame Clark's inspiration for the concept of world prehistory sprang from despair in the depth of the Second World War, as a response to the racialist thinking of the time. He wrote then that

> To the peoples of the world generally, the peoples who willy nilly must in future co-operate and build, or fall out and destroy, I venture to think that palaeolithic man has more meaning than the Greeks. (There must be) an over-riding sense of human solidarity such as can come only from a consciousness of common origins.
>
> (Clark 1943, 410, 416)

And in another essay, written towards the end of his life, he returned to this universalist theme:

> In the final resort, archaeology—and prehistoric archaeology in particular—is concerned with nothing less than the identity of man.
>
> (Clark 1979, 3)

The past 40 years of archaeological research in Australia has placed the continent and the deep prehistory of its indigenous peoples into the forefront of knowledge about the global spread of modern sapient people and of the unique economic and symbolic adaptation that they made to the new continent. Amongst Aboriginal people themselves, there is a special interest and a sense of pride at the demonstrated fact of an antiquity of occupation that is recognized and celebrated by the wider community. This has become a potent symbol for cultural autonomy and emancipation. A key Aboriginal response to the bicentenary celebrations in 1988 of the first British settlement at Port Jackson, was a slogan saying 'You have been here for 200 years, we for 40,000'. Australia is at present in the throes of a profound analysis of itself and of its past as a 'settler nation' and of the possibilities of an equable reconciliation between the descendants of the indigines and colonists. To the extent that the archaeological discoveries of Australia's deep past can serve to induce a 'convergent' identity in the nation, to quote the poet Les Murray, it will be a vindication of the universalist message of Grahame Clark's world prehistory.

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Our conclusion is that the boundaries of *Homo* should be reset so that it includes early African *Homo erectus*, or *Homo ergaster*, and excludes *H. habilis sensu stricto* and *H. rudolfensis*. This would mean that the manufacture of stone tools would no longer be restricted to members of the genus *Homo*. However, we would contend that this has been an untenable association ever since the realization that synchronic taxa have existed in East Africa for much of the early phases of hominin evolution for which there is also evidence of stone artefact manufacture.

JOHN PARKINGTON

Western Cape Landscapes

The Atlantic coast of the western Cape is host to a vast quantity of archaeological sites of the past 100,000 years. Ecological studies of Middle and Late Stone Age sites provide opportunities to explore the development of behavioural patterns. The multitude of painted shelters and caves in the western Cape allow us to glimpse the systems of belief that structured early societies.

RHYS JONES

Dating the Human Colonization of Australia: Radiocarbon and Luminescence Revolutions

Dating the early colonization of Australia has for long been at the forefront of prehistoric archaeological enquiries. This paper reviews the historical progression from conjecture to fact, amplified by increasingly sophisticated methods of dating, and identifies those sites now acknowledged to be of paramount importance to a greater understanding of human colonization of the continent.

BRIAN FAGAN

Grahame Clark and American Archaeology

Grahame Clark exercised a seminal influence on American archaeology at a critical stage in its development. His ecological and subsistence researches in the Cambridgeshire Fenland and interest in settlement archaeology were known to but a few American scholars of the 1940s and 1950s. However, the publication of *Prehistoric Europe: The Economic Basis* (1952) and *Star Carr* (1954) came at a time when Americanists were turning from culture history to processual archaeology. Clark's analyses of environment and subsistence played a vital role in the formulation of some of the basic tenets of the so-called 'new archaeology' of the 1960s. His field researches provided a practical component to the influ-