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The revolution that didn't arrive: A review of Pleistocene Sahul

Phillip J. Habgood, Natalie R. Franklin*

School of Social Science, University of Queensland, Brisbane QLD 4072, Australia

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ABSTRACT

There is a "package" of cultural innovations that are claimed to reflect modern human behaviour. The introduction of the "package" has been associated with the Middle-to-Upper Palaeolithic transition and the appearance in Europe of modern humans. It has been proposed that modern humans spread from Africa with the "package" and colonised not only Europe but also southern Asia and Australia (McBrearty and Brooks, 2000; Mellars, 2006a). In order to evaluate this proposal, we explore the late Pleistocene archaeological record of Sahul, the combined landmass of Australia and Papua New Guinea, for indications of these cultural innovations at the earliest sites. It was found that following initial occupation of the continent by anatomically and behaviourally modern humans, the components were gradually assembled over a 30,000-year period. We discount the idea that the "package" was lost en route to Sahul and assess the possibility that the "package" was not integrated within the material culture of the initial colonising groups because they may not have been part of a rapid colonisation process from Africa. As the cultural innovations appear at different times and locations within Sahul, the proposed "package" of archaeologically visible traits cannot be used to establish modern human behaviour. Whilst the potential causal role of increasing population densities/pressure in the appearance of the "package" of modern human behaviour in the archaeological record is acknowledged, it is not seen as the sole explanation because the individual components of the "package" appear at sites that are widely separated in space and time.

Introduction

The origin and definition of modern human behaviour is, like modern human origins and the definition of modern human morphology, a much-debated subject (see Henshilwood and Marean, 2003; Shea, 2006). The focus of the archaeological evidence for the appearance of modern human behaviour has been the transition from the Middle to the Upper Palaeolithic in Europe from 50–40,000 years BP. The introduction of the "package" has been directly associated with the appearance in Europe and western Asia of new populations of anatomically modern humans derived from Africa (i.e., the Out of Africa Replacement Model). The assumption has been that behavioural differences between Neanderthals and anatomically modern populations provided an adaptive advantage that facilitated the replacement of the Neanderthals by modern populations throughout Europe. The transition, referred to as a "human or symbolic revolution", has furnished archaeologically visible innovations or traits that are claimed to reflect modern human behaviour (e.g., Chase and Dibble, 1987; Mellars, 1989, 1991, 2005, 2006a,b; Mellars and Stringer, 1989; Harrold, 1992; Klein, 1992, 1995, 1999, 2000; Bar-Yosef, 1998). The group of cultural innovations, which includes art, personal ornaments, blade technology, worked bone, and changes to exchange networks and resource exploitation patterns, is portrayed as a "package" that arrived almost simultaneously in Europe (Mellars, 1991: 63–4, 2005: his Fig. 1; Harrold, 1992: his Table 1; Klein, 1995: his Table 1). Harrold (1992: his Table 1) even compiled the morphological changes evident at the archaic-modern transition, the broad behavioural implications of these changes, and the proposed cultural developments and archaeological correlates. As Bar-Yosef observed, the transition in Eurasia was a "true technological and cultural revolution" (1998: 152). Foley and Lahr (2003) observed that it was difficult to identify a cognitive change associated with the introduction of the Upper Palaeolithic in Europe, especially as it occurred well after the appearance of anatomically modern humans in Africa and western Asia. Alternately, Klein (1992, 1995, 1999, 2000) argued for a strong association between human biological and behavioural evolution and proposed that modern human behaviour, as reflected in the appearance of the "package" of traits at around 50–40,000 years BP, and geographic population expansion were "coproducts of a selectively advantageous genetic mutation" (Klein, 2000: 18). That is, a neurological change that allowed fully

* Corresponding author.
E-mail address: natalie.franklin@epa.qld.gov.au (N.R. Franklin).

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modern humans to innovate and ultimately expand and replace "nonmodern or near modern" populations elsewhere.

The trait list for archaeologically visible modern human behaviour continues to be evaluated and refined. Deacon (1995; Deacon and Deacon, 1999) argued that Middle Stone Age (MSA) African populations were both morphologically and behaviourally modern by at least 100,000 years ago. Deacon (1995; Deacon and Deacon, 1999) based this conclusion not on those traits that separate Neanderthals and anatomically modern groups in Europe, which he felt were inappropriate in an African context, but rather on behaviours that link Middle and Late Stone Age (LSA) and contemporary hunter-gatherers, including family foraging groups, strong kinship ties, active hunting, use of fire for the management of food plants, reciprocal gift exchange of artefacts (backed artefacts made of exotic material), and communication via colour symbols (use of ochre). Whilst Wadley (2001) agreed with Deacon's focus on the behavioural aspects of modernity as opposed to the appearance of items of material culture in the archaeological record, she was not convinced by his recognition of early modern human behaviour during the MSA. Wadley (2001) attempted to refine the list of traits and argued that modern behaviour was only evident in the archaeological record from 40,000 years BP when items of external symbolic storage (art, ornaments, lithics) are used in the definition of individual or group identity (see also Henshilwood and Marean, 2003). Henshilwood and d'Errico (d'Errico et al., 2001, 2005; Henshilwood et al., 2001) demonstrated the MSA appearance of worked and engraved bone, engraved ochre, and shell beads, and concurred with Deacon that behavioural modernity appeared early in Africa, by at least 70,000 years BP and well before the MSA-LSA transition.

In a detailed review of the African MSA, McBrearty and Brooks (2000) found that the "package" of cultural innovations did not suddenly appear in the archaeological record; rather, the traits occurred at sites that are widely separated in space and time (McBrearty and Brooks, 2000: their Fig. 13). This finding that the "package" was gradually assembled over a 200,000-year period challenged the concept of a "human revolution". In doing so, McBrearty and Brooks (2000) dismissed the concept of a time lag between the appearance of anatomical modernity and perceived behavioural modernity in Africa (cf. Klein, 2000).

The "package" of archaeologically visible traces of modern human behaviour investigated by McBrearty and Brooks (2000) included: enlarged geographic range, expanded exchange networks, personal adornments, art and imagery, ritual behaviour, economic intensification reflected in the exploitation of resources that require specialised technology, worked bone and other organic materials, and new lithic technologies.

There is a clear indication that the archaeologically visible "package" of cultural innovations was gradually assembled in the Africa MSA, and by 50–40,000 years BP it had appeared in western Asia and Europe (McBrearty and Brooks, 2000: their Fig. 13; d'Errico, 2003: his Fig. 8). It has also been proposed that the "package" was exported from Africa to other regions of the Old World (Bar-Yosef, 1998: his Fig. 6; McBrearty and Brooks, 2000; Mellars, 2006a: his Fig. 1). As Klein observed, an assessment of Pleistocene Sahul is "crucial for testing the hypothesis that modern humans expanded from Africa following a radical behavioural change 50 to 40 ky ago" (2000: 33). However, Sahul, the combined landmass of Australia and Papua New Guinea, has been a notable omission from most discussions of the "human revolution" or the origins of modern human behaviour. This situation is changing with the growing recognition that anatomically and behaviourally modern humans colonised Sahul at an equivalent time to Europe.

White (1977, 1999; White and O'Connell, 1982) discussed aspects of the late Pleistocene prehistory of Australia, especially lithic material, to question the "creative explosion of the European Upper Palaeolithic". Davidson and Noble placed Pleistocene Australia at the centre of a discussion of archaeologically visible modern human behaviour by arguing the colonisation of Greater Australia was the oldest direct evidence for "the expression of behaviour that is distinctly human" (1992: 135), namely language, because to plan for, construct, and use boats required the use of language. However, this proposal is weakened somewhat by 800,000-year old stone tools recovered on the Indonesian island of Flores that suggest the tool makers were capable of constructing and using water craft (Morwood et al., 1998, 1999). Davidson and Noble (1992) also contend that the earliest inhabitants of Sahul practiced "symbolic behaviour" and list archaeological materials older than 15,000 years BP from Greater Australian sites that they perceived to be "indicative of fully modern human behaviour" (Davidson and Noble, 1992: their Table 1). These materials, including ground axes, bone artefacts, ochre, and ornaments, are encapsulated within the "package" of archaeologically visible modern human behaviour discussed by McBrearty and Brooks (2000). Direct comparisons between aspects of the Australian and European archaeological records have also been undertaken to assess aspects of the "human revolution" model. Holdaway and Cosgrove (1997) compared late Pleistocene southwest Tasmania with Middle Palaeolithic Eurasia to question the unilinear model of an archaeologically visible transition from archaic to modern behaviour. Hiscock and O'Connor (2005, 2006), focusing on lithic material, examined the appearance(s) of backed artefacts in Australia and Africa to assess the validity of these artefacts as an archaeologically visible trait of modern human behaviour proposed by previous researchers (e.g., Deacon and Deacon, 1999; Wadley, 2001; Mellars, 2005). Hiscock and O'Connor (2005, 2006) found that use of backed artefacts to support the appearance of modern human behaviour was limited due to the chronologically and regionally variable nature of their occurrences in both continents. Brumm and Moore (2005), following Wadley (2001), focused on the archaeologically visible manifestations within the Australian archaeological record of "symbolic storage" as evidence for modern human behaviour, namely art, personal ornaments, and style in lithics. Brumm and Moore (2005) found that, whilst there were isolated examples of late Pleistocene "symbolic storage" in Australia, many of the supposed hallmarks of the "creative explosion or symbolic revolution" did not appear until the mid-to-late Holocene. In a broad ranging discussion, O'Connell and Allen (2007) reached a similar conclusion in that they found the appearance of the proposed "markers of modernity" increased within the archaeological record of Sahul from 20,000 years BP onwards, especially during the early Holocene.

As noted by Klein (2000), Australasia needs to be considered in explanations of modern human origins. The starting point for any such assessment is the colonisation of Sahul by anatomically and behaviourally modern peoples. Throughout hominin-human history Sahul has been separated from Sunda by the islands of Wallacea and significant water barriers. Migration to Sahul, therefore, required a number of open sea voyages, some of which may have covered distances of 100 km or more (Birdsell, 1977). Twenty years ago the prevailing view was that the earliest evidence for human occupation of Sahul dated to around 40,000 years BP (Mulvaney, 1975; White and O'Connell, 1982; White and Habgood, 1985; Jones, 1989). This situation has not changed significantly over the intervening years, with most archaeologists agreeing that initial occupation occurred by at least 45,000 years BP, although there have been arguments for earlier occupation in Greater Australia extending beyond 60,000 years BP based on five main sites: Huon Peninsula (44–61,000 years BP), Nauwalabila (53–60,000 years BP), Malakunanja II (45–61,000 years BP), Devil's Lair (48–64,000 years BP), and Lake Mungo (46–62,000 years BP). Roberts et al. provocatively contend that the 50–60,000 years BP thermoluminescence dates from Malakunanja II "…mark the time of initial human arrival on the Australian continent" (1990: 153; see also Chappell et al., 1996). Allen and O'Connell (Allen and O'Connell, 2003; O'Connell and Allen, 2004) have reviewed the evidence at the five earliest sites listed above and concluded that doubts remained with the very early dates due to artefact context and site taphonomy, and that secure dating evidence indicates the earliest human occupation of Greater Australia is around 45,000 years BP. Gillespie (2002) also suggested that there was good dating evidence of early human occupation at $45{,}000 \pm 3{,}000$ years BP in four dispersed regions of Australia (southwest, northwest, north, and southeast) through a combination of radiocarbon, luminescence, and uranium-thorium dating methods. A reasonable estimate for the colonisation of Sahul would be between 45–50,000 years BP (Bowdler, 1993; Bowler and Price, 1998; Gillespie, 1998, 2002; Allen and O'Connell, 2003; Bowler et al., 2003; Fullagar, 2004; O'Connell and Allen, 2004).

To assess if Sahul was one of the other "regions of the Old World" to which the "package" was exported by the earliest colonising groups from Africa as proposed (McBrearty and Brooks, 2000; see also Bar-Yosef, 1998; Klein, 2000; Mellars, 2006a), we examine the late Pleistocene archaeological record of Greater Australia for these cultural innovations.

At the time of the initial colonisation of Sahul the earliest Australians should theoretically have possessed the entire "package" of archaeologically visible modern human behaviour. One exception could be images because even though McBrearty and Brooks (2000, their Fig. 13) postulated a date of at least 40,000 years BP for examples of images in Africa, the earliest well dated example may only be some 27,000 years old: painted slabs with images of quadrupeds from Apollo 11 Rockshelter in Namibia (Bahn and Vertut, 1997). This paper concentrates on assessing whether those traits identified by McBrearty and Brooks (2000) appear at an early period in the archaeological record of Sahul, as would be expected if they were brought from Africa by the initial colonising groups.

As the "human or symbolic revolution" incorporates population movements and colonisation, our paper will also consider inferences that may be drawn about the origin of anatomically modern humans in the region from the assessment of the archaeologically visible "package" of modern human behaviour in Greater Australia.

Enlarged geographic range

As noted earlier, anatomically and behaviourally modern humans colonised an uninhabited continent when they migrated from Sunda and across Wallacea to Sahul. These early colonists adapted to a range of environments within Greater Australia, especially lacustrine and riverine zones, although more arid savannah environments as well as highland regions and the large islands off the northeastern coast of Papua New Guinea also document late Pleistocene occupation (Figs. 1 and 2; White and O'Connell, 1982; Mountain, 1991; Gosden, 1993; Smith and Sharp, 1993; Pavlides and Gosden, 1994; Mulvaney and Kamminga, 1999; Richards et al., 2007). By 35–25,000 years BP the indigenous inhabitants of Sahul had occupied all major environmental zones within Greater Australia, from the tropical equator through to Tasmania (Smith and Sharp, 1993: their Fig. 7; Flood, 1995: her Fig. 2.3). Possible exceptions are the northern Australian rainforests (Cosgrove, 1996), the dunefield deserts (Smith, 1989; Veth, 1989), and small offshore islands (Rowland, 1983; O'Connor, 1992), which generally only show regular or permanent occupation from the mid-to-late Holocene. In the Papua New Guinea Highlands there is also evidence for deliberate and planned landscape modification by 30–35,000 years BP (Mountain, 1991; Fairbairn et al., 2006). Sites include rockshelters, caves, and open sites within a range of environmental and geological contexts (Smith and Sharp, 1993). It should also be remembered that during the late Pleistocene, occupation of sites and whole landscapes would not have been continuous throughout Greater Australia. For example, during the last glacial maximum southwest Tasmania flourished, whereas other areas appear to have been abandoned at this time (Veth, 1989; Habgood, 1991; Cosgrove, 1995; Porch and Allen, 1995; Smith, 1989; Fairbairn et al., 2006; Richards et al., 2007; cf. Smith and Sharp, 1993).

Expanded exchange networks–40,000 years BP (Table 1)

It is difficult to project the existence of the formal long-distance exchange networks evident in the historic period (see Mulvaney, 1976) into the remote past. However, it is clear that evidence from late Pleistocene deposits at sites throughout Sahul indicates long-distance contact and/or wide-ranging mobile groups, and movement and/or exchange of exotic materials for personal adornment, utilitarian, and/or symbolic purposes. The offshore islands of the Bismarck Archipelago at the northeast periphery of Greater Australia also demonstrate the transportation and/or exchange of West New Britain obsidian during the late Pleistocene (Allen et al., 1989a; Summerhayes and Allen, 1993; Gosden, 1995; Fredericksen, 1997; White and Harris, 1997).

Within Pleistocene Sahul, shells, ochre, and stone are the most widely exchanged and/or transported materials (Table 1). In northwestern Australia, there is evidence from the Kimberley Region for long-distance transport and/or exchange of marine shells at a time when the coastline would have been 100–300 km away. For example, Riwi Cave and Carpenter's Gap Rockshelter 1 yielded fragments of *Dentalium* shell beads and baler shell (*Melo amphora*) from deposits dating to 29–42,000 years BP (O'Connor, 1995; Balme, 2000; Balme and Morse, 2006). O'Connor (1999) proposed that baler shell, mangrove clam shell (*Geloina coaxans*), pearl shell (*Pinctada* sp.), and a ground sea urchin spine recovered from late Pleistocene levels at Koolan Shelter 2 and Widgingarri Shelter 1, some dating from possibly 26–28,000 years BP, were imported/transported to these sites from the coast as tools and value goods. Whilst Koolan Shelter 2 would have been only 20 km from the coast, Widgingarri Shelter 1 was some 200 km away. Ethnographically, pearl and baler shell were traded commodities in the Kimberley area, which prompted O'Connor (1999) to propose that the examples of these shells from Pleistocene deposits at Widgingarri Shelter 1, Riwi Cave, and Carpenter's Gap rockshelter may have resulted from indirect "down-the-line" exchange (see also Balme and Morse, 2006).

Some central Western Australian sites, such as Gum Tree Valley Top, Burrup Peninsula, and the Silver Dollar site, also suggest late Pleistocene long-distance transport and/or exchange networks in marine shell (Table 1).

Ochre occurs at many Pleistocene sites within Greater Australia, often without a known local source (Table 1). At Mandu Mandu Creek rockshelter, northwestern Australia, ochre was recovered throughout the deposits, peaking in layers dating between 25–20,000 years BP, but the nearest known sources are on the Hammersley Plateau some 300 km to the northeast or 850 km to the southeast at Wilgie Mia (Morse, 1993b). High quality haematite, often in large nodules including a 1 kg piece, has been recovered from deposits dated between 18–30,000 years BP at the Arnhem Land sites of Nauwalabila I and Malakunanja II, and must have been brought in from some distance (Jones and Johnson, 1985b; Jones and Negerevich, 1985; Chaloupka, 1993). In western New South Wales, ochre is found in small quantities within the Lake Mungo lunette on the eastern lakeshore (Bowler, 1998). The Lake Mungo 3 (LM3) burial, dating to 40,000 years BP, comprises an adult individual who had been covered in red ochre that had stained the

Fig. 1. Sahul indicating the main sites mentioned in the text. The shaded area indicates the extent of the continental shelf exposed at the last glacial maximum (from Franklin and Habgood, 2007: their Fig. 1).

sand of the gravefill a pink colour (Bowler and Thorne, 1976). Ochre does not occur near Lake Mungo, it thus must have been transported there from some distance away for ceremonial and other purposes (Bowler, 1998), with the nearest known sources being possibly the Manfred Ranges 100–200 km to the northwest (Bowler, 1998; Westaway, 2006). At the central Australian site of Puritjarra, Smith (Smith, 1996; Smith et al., 1998; see also Gibbs and Veth, 2002) geochemically sourced red ochres from excavated layers dated between 32–13,000 years as coming from one quarry, Karrku, about 150 km away. There was a significant decrease in the quantity of ochre from Karrku at Puritjarra after 13,000 years BP, with samples of local ochres becoming more frequent. The overall pattern was interpreted as a shift from an open, spatially extensive pattern of long-distance exchange and land use to a more closed system with smaller exchange systems and group territories after 13,000 years BP (Smith, 1996; Smith et al., 1998). This is one of the few instances where a change in the spatial extent of exchange networks can be inferred from the archaeological record in Australia.

There is also evidence for long-distance transport and/or exchange of stone during the late Pleistocene (Table 1). Miriwun in the Kimberley has produced two stone flakes dated to more than 17,980 years BP that Dortch (1977) indicated were made from australites (tektites), which are not found in northern Australia. If the identification is correct, these finds suggest that in the late Pleistocene there was long-distance contact/exchange between northern and southern Australia (Dortch, 1977). In western New South Wales, sandstone used to make grindstones in deposits possibly dating between 35–28,000 years BP at Cuddie Springs (but see later discussion) possibly comes from a quarry at Yambacoona Hill some 120 km northwest of the site. Also, feldspar, porphyry, phyllite, quartz, and quartzite may have come from locations 60–120 km away from the site (Furby et al., 1993; Field and Dodson, 1999). Significant, but more recent, long-distance transport and/or exchange is also evident for grindstones in the Central and Lower Darling Region (Table 1).

At late Pleistocene sites in southwest Tasmania, an impactite referred to as "Darwin glass", was transported from a meteorite crater over distances of up to 100 km. Artefacts in this material are found in levels dated between about 14,000 and 28,000 years BP at several sites (Table 1; Allen et al., 1989b; Jones, 1989b; Stern and Marshall, 1993; Cosgrove, 1995; Flood, 1995; Porch and Allen, 1995; Holdaway, 2004). However, Darwin glass was not recovered from ORS 7, which dates from the late Pleistocene through the Holocene, even though it is only slightly further from the source crater than the southwestern sites listed in Table 1 (Cosgrove, 1995: his Fig. 1). Darwin glass was also absent from Parmerpar Meethaner, only 30 km east of Mackintosh Cave, the most northerly site to contain

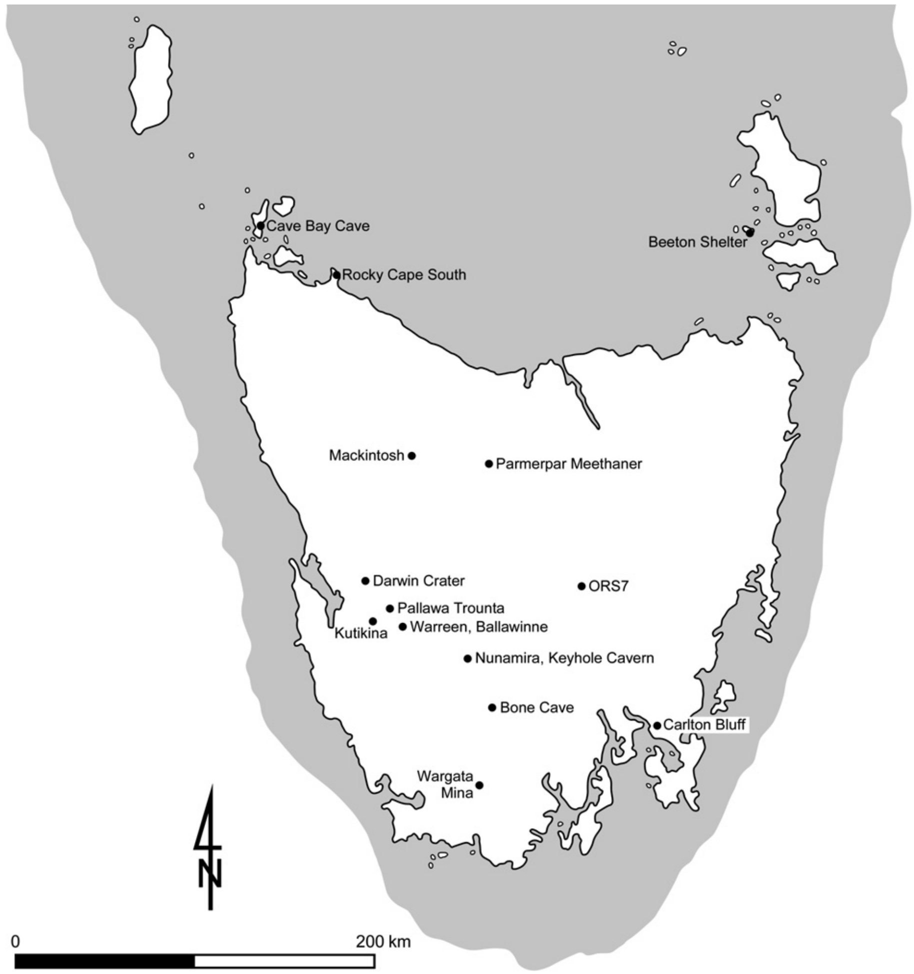

Fig. 2. Tasmania indicating the main sites mentioned in the text. The shaded area shows the continental shelf (from Franklin and Habgood, 2007: their Fig. 1).

this material (Porch and Allen, 1995). At Kutikina Cave in deposits dating from 17–15,000 years BP, not only was Darwin glass transported from some 25 km away, but chert was also sourced from an area in northern Tasmania (Ranson et al., 1983; Flood, 1995). At other sites within the southwest, chert was transported over distances up to 47 km during the late Pleistocene (Sheppard, 1997). Jones initially thought that these southwest Tasmanian sites were "integrated into a single social system" (1989: 769), whereas more recently Cosgrove proposed that "a human behavioural boundary during the ice age" (1995: 93) was suggested by the distribution pattern of Darwin glass during the late Pleistocene.

These examples demonstrate that during the late Pleistocene within parts of Greater Australia and the islands off the northeast periphery of Sahul there was long distance transport and/or exchange in materials for utilitarian and symbolic purposes and for personal adornment. These early colonists were either utilising the resources of the source areas of the material directly or were in contact or exchange with the inhabitants of these source areas.

Mining and quarrying–24,000 years BP (Table 2)

Major stone mining and quarrying sites do not appear to be common in Greater Australia during the late Pleistocene (Table 2), as raw materials for stone working were generally obtained from the immediate vicinity of sites or from the local area, with procurement often limited to utilisation of naturally fractured rubble from the ground surface or river pebbles (Hiscock, 1996; Hiscock and Allen, 2000). As mentioned earlier, during the late Pleistocene obsidian from west New Britain was being transported around the offshore islands of the Bismarck Archipelago for use in tool manufacture (Allen et al., 1989a; Summerhayes and Allen, 1993; Gosden, 1995; Fredericksen, 1997; White and Harris, 1997).

Hiscock (1996) observed that two-thirds of recorded stone quarries in Australia do not have evidence of prehistoric mining or quarrying. Where stone quarries can be dated, they are generally late Holocene in age and often involve the procurement of material for exchange, such as ground stone hatchets (Hiscock, 1996; Allen, 1997). The oldest dated stone quarry in Sahul is Koonalda Cave, where flint nodules were extracted from the limestone cave walls between 24–14,000 years BP (Wright, 1971a). Karlie-ngoinpool Cave, Mount Gambier Region, may also document silicate mining during the late Pleistocene (Bednarik, 1984). Although this mining activity is not directly dated, significant antiquity has been inferred from the eroded and patinated nature of the scars formed by the removal of chert nodules from the cave walls and from stalagmitic deposits on the chert mining face (Bednarik, 1984; Flood, 1997).

Small-scale excavation activities may account for ochre recovered from late Pleistocene deposits at sites throughout Greater Australia. However, at Puritjarra red ochres recovered from layers dated between 32–13,000 years BP have been geochemically sourced to Karrku quarry, 150 km from the site, indicating larger scale Pleistocene ochre extraction activity (Smith, 1996; Smith et al., 1998; see also Gibbs and Veth, 2002). Extensive ochre mining during the late Holocene is evident at sites like Bookartoo

Table 1
Early occurrences of long-distance transport and/or exchange of material in Greater Australia

Site	Date and associations	Reference
Bismarck Archipelago, Papua New Guinea	Late Pleistocene transport of west New Britain obsidian around the offshore islands of the Bismarck Archipelago at the northeast periphery of Sahul	Allen et al. (1989a); Summerhayes and Allen (1993); Gosden (1995); Fredericksen (1997); White and Harris (1997)
Riwi Cave, the Kimberley	Fragments of marine *Dentalium* sp. shell, possibly beads, dating from at least 29,550 ± 290 BP (Wk7896) to possibly 42,000 BP: 40,700 ± 1260 (ANUA-13006), >40,000 (Wk 7607); coast some 300 km away	Balme (2000); Balme and Morse (2006)
Carpenter's Gap Rockshelter 1, the Kimberley	*Dentalium* sp. shell beads and fragments of baler shell (*Melo amphora*) in Pleistocene levels; coastline some 100 km away	O'Connor (1995)
Koolan Shelter 2, the Kimberley	Mangrove clam shells (*Geloina coaxans*) and pearl shell (*Pinctada* sp.) from late Pleistocene levels; a *Geloina* shell produced a minimum age of 26,500 ± 1,050 BP (Wk 1365); coast some 20 km away	O'Connor (1999)
Widgingarri Shelter 1, the Kimberley	Pearl shell (*Pinctada* sp.) and a ground sea urchin spine from levels dated around 18,900 ± 1,800 BP (ANU/AMS 5-10); a baler shell (*Melo* sp.) dated to 28,060 ± 600 BP (R11795); coast some 200 km away	O'Connor (1999)
Gum Tree Valley Top, Burrup Peninsula	Piece of trumpet shell (*Syrinx aruanus*) dated to 18,510 ± 260 BP (LY3609), possibly a water container; coast some 130 km away	Lorblanchet (1992)
Silver Dollar site, Shark Bay	Baler shell dated to 18,730 ± 600 BP (ANU-7105); coastline some 100 km away	Bowdler (1990a); O'Connor et al. (1993)
Mandu Mandu Creek rockshelter, Cape Range Peninsula	Ochre throughout the archaeological deposits, peaking in layers dating between 20,040 ± 440 BP (SUA-2614) to 25,200 ± 250 BP (SUA-2354); nearest known ochre sources are on the Hammersley Plateau 300 km to the northeast or 850 km to the southeast at Wilgie Mia	Morse (1993b)
Nauwalabila I and Malakunanja II, Arnhem Land	Haematite, often in large pieces including a 1 kg piece, recovered from deposits dated to between 18–30,000 BP; high quality haematite not found in the vicinity of the sites, so must have been brought in from some distance	Jones and Johnson (1985b); Jones and Negerevich (1985); Chaloupka (1993)
Lake Mungo 3, western New South Wales	Extended burial OSL dated at 40,000 ± 2,000 BP, covered in red ochre, which does not occur locally; the nearest known ochre sources such as the Manfred Ranges are 100–200 km to the northwest	Bowler and Thorne (1976); Bowler (1998); Westaway (2006)
Puritjarra, central Australia	An ochre sourcing study identified ochres in layers dated between 32–13,000 BP as coming from Karrku quarry some 150 km away; ochres more recent than 13,000 BP from local sources	Smith (1996); Smith et al. (1998); Gibbs and Veth (2002)
Miriwun, east Kimberley	Two stone flakes dated to more than 17,980 + 1,370/−1,170 BP (ANU-1008) made from australites (tektites), not found in northern Australia; suggests long-distance contact/exchange between northern and southern Australia	Dortch (1977); Flood (1995)
Cuddie Springs, western New South Wales	Deposits dated 28,770 ± 300 BP (Beta 81377), 30,990 ± 360 BP (Beta 81381), 33,660 ± 530 BP (Beta 81379), OSL age of 35,400 ± 2,800 BP; feldspar porphyry from a group of quarries 120 km to the south at Mt. Foster; sandstone used to make grindstones from a quarry at Yambacoona Hill 120 km to the northwest; phyllite, quartz, and quartzite from any one of three locations up to 60 km to the southwest	Furby et al. (1993); Field and Dodson (1999)
Central and Lower Darling River, western New South Wales	Large numbers of grindstones transported for at least 50–300 km from quarries in the Scropes Range and Mootwingee (6–16,000 BP); stone material occurring at sites along the Lower Darling may have been exported from silcrete quarries in the Willandra Region	Balme (1991); Hope (1993)
Kutikina Cave, southwest Tasmania	Stone artefacts made from "Darwin glass" in deposits dating from 17–15,000 BP; "Darwin glass" sourced to a meteorite crater some 25 km away; chert sourced to an area in northern Tasmania	Ranson et al. (1983); Jones (1989)
Nunamira Cave, southwest Tasmania	"Darwin glass" artefacts from 27,700 BP: 27,770 ± 770 BP (Beta-25880)	Allen et al. (1989b); Holdaway and Porch (1996)
Warreen Cave and Pallawa Trounta, southwest Tasmania	"Darwin glass" from at least 19,000 BP, possibly as early as 24–27,000 BP; Warreen Cave: 15,960 ± 310 BP (Beta-42993), 19,460 ± 210 BP (Beta-26958), 27,160 ± 250 BP (Beta-46872), and 34,790 ± 510 BP (Beta-42122B); Pallawa Trounta: 13,410 ± 330 BP (ANU-3982), 18,060 ± 310 BP (Beta-44079), 27,250 ± 530 BP (Beta-62285), and 29,700 ± 860 BP (Beta-44081); chert from Warreen Cave and Pallawa Trounta sourced to an area 37 km and 45 km away, respectively	Allen et al. (1989b); Porch and Allen (1995); Holdaway and Porch (1996); Sheppard (1997)
Bone Cave, southwest Tasmania	"Darwin glass" artefact in levels dating to 16–14,000 BP: 13,700 ± 860 BP (Beta-26509), 15,870 ± 270 BP (Beta-40347), and 16,820 ± 110 BP (Beta-26512); source crater at least 100 km away in a direct line	Jones (1989); Holdaway and Porch (1996); Holdaway (2004)
Mackintosh Cave, southwest Tasmania	"Darwin glass" artefacts in occupation confined to 17–15,000 BP: 15,160 ± 210 BP (Beta-46305) and 17,030 ± 430 BP (Beta-45808); source crater some 70 km away; this is the most northerly occurrence of "Darwin glass" in Tasmania	Stern and Marshall (1993); Cosgrove (1995); Holdaway and Porch (1996)

(Parachilna), South Australia, Wilgie Mia, Western Australia, and in the Campbell Ranges, Northern Territory (Table 2; Hiscock, 1996; Mulvaney and Kamminga, 1999).

Personal adornments (Table 3)

Whilst not common, personal adornments are found in archaeological deposits during the late Pleistocene in Greater Australia, generally in the form of shell or macropod bone beads, but also bone and stone pendants and notational pieces (Tables 3 and 4). By the mid-Holocene, necklaces and headbands are present in burials in southeastern Australia, indicating the well-established use of ornaments for ceremonial and decorative purposes (Table 3).

Beads—42,000 years BP (Table 3)

The Kimberley Region in northwestern Australia has provided evidence of late Pleistocene shell beads. At Riwi Cave and Carpenter's Gap rockshelter 1, fragments of *Dentalium* shell beads have been recovered from levels dating from possibly 29–42,000 years BP (O'Connor, 1995; Balme, 2000; Balme and Morse, 2006). The 10 *Dentalium* shell beads from Riwi Cave range in length from

Table 2
Evidence for mining and quarrying in Australia

Site	Date and associations	Reference
Koonalda Cave, Nullarbor Plain, southern Australia	Between 24–14,000 BP, flint nodules mined from the limestone walls; radiocarbon dates between 13,700 ± 270 (GaK-510) and 23,700 ± 850 BP (ANU-244); radiocarbon date of 19,900 ± 2000 BP (V-92) obtained on charcoal, presumably the remains of a torch	Wright (1971a)
Karlie-ngoinpool Cave, Mount Gambier Region, South Australia	Extensive evidence of silicate mining; undated, but evidence of great antiquity from patinated bulbar scars on the mining impact fractures and formation of substantial stalagmitic deposits on the chert mining face	Bednarik (1984); Flood (1997)
Karrku quarry, Central Australia	Ochre from levels dated 32–13,000 BP at Puritjarra geochemically sourced to Karrku quarry, 150 km from the site	Smith (1996); Smith et al. (1998)
Wilgie Mia, Weld Ranges of northern Western Australia	Extensive evidence of ochre mining, dated to at least 1,000 BP: large, open-cut pit 30 m wide and 20 m deep, excavated shafts follow seams of red and yellow ochre; ochre from the site found throughout Western Australia and possibly as far as Central Australia	Hiscock (1996); Mulvaney and Kamminga (1999)
Bookartoo (Parachilna), South Australia	Extensive evidence of ochre mining indicated, but apparently limited to the late Holocene	Mulvaney and Kamminga (1999)

5.2–17.5 mm and were made from the anterior end of the shell, with some having naturally occurring grooves around their circumference that contain residues that may be ochre (Balme and Morse, 2006). One of the beads retained a fibre fragment, possibly from a string on which the bead could have been threaded (Balme and Morse, 2006).

From Mandu Mandu Creek rockshelter 22, small cone shells and shell fragments (*Conus* sp.) were recovered from the basal occupation horizon (Morse, 1993a,b). Radiocarbon ages of 34,200 ± 1,050 years BP (Wk 1513) and 30,000 ± 850 years BP (Wk 1576) were obtained from samples of baler shell (*Melo* sp.) from just above bedrock (Morse, 1993a,b). Groundwater carbon dioxide contamination resulted in the older sample appearing to be possibly 1,250 years too old. Whilst some uncertainty surrounds the earliest date, due to the groundwater contamination of the dated shell sample, there is no suggestion in any of the published accounts that there is any contamination issue with the second shell sample used. Morse concluded "an uncalibrated determination of c. 32,000 BP is taken as an appropriate age for this occupation horizon" (1993a: 879) and the *Conus* shells. Also, the deposit from which the *Conus* shells were recovered is some 20 cm below a date of 22,100 ± 500 BP (Wk 1575; Morse, 1993a,b). All of the *Conus* material, except for one small shell, appears to have been deliberately modified as beads. Six shells had their apex perforated and their internal structure broken away to form a hollowed out shell with a round hole in the top. The two best-preserved cones have small notches at the posterior end of their apertures consistent with formation from wear from a string on which they could have been threaded (Balme and Morse, 2006). The other beads consist of sections of the spire of each shell with the apex pierced and the last whorls removed. The beads range in size from 2.9 mm to 21.1 mm in length and 7.2 mm to 12.7 mm in diameter. If assembled, the strand of beads is estimated to have been 180 mm in length (Fig. 3; Morse, 1993a). In addition to this material, three other cone shell fragments, one of which may be deliberately modified, were recovered from the site, with an estimated age of about 21,000 years BP (Morse, 1993a). The late Pleistocene deposits at the site also yielded fragments of *Nautilus* or pearl oyster shell (*Pinctada* sp.) and scaphopod shell (*Dentaliidae* sp.), which ethnographically are highly prized and traded commodities in northwestern Australia and are known to have been used as ornaments, such as pendants (Morse, 1988, 1993a; O'Connor, 1999; Balme and Morse, 2006).

A perforated tooth from a tiger shark (*Galeocerdo cuvier*) has been recovered from Buang Merabak, New Ireland, in levels dating to between 39,500–28,000 years BP (Leavesley, 2007). The perforation on the shark tooth is approximately 2 mm in diameter with an apparent lip, suggesting it was formed by drilling (Leavesley, 2007). Four other shark teeth were recovered from these lower units at the site, but these do not display any indication of a perforation. Whilst the dating of the levels from which the perforated shark tooth was recovered seems secure, it should be noted that there remains the possibility that the Pleistocene deposits are disturbed and that artefact movement may have occurred (Leavesley, 2007; Leavesley and Allen, 1998). Other perforated shark teeth from this area date from the Holocene (Wickler, 2001; Leavesley, 2007).

Three beads made on short lengths of macropod long bone were recovered from deposits dated between 12–20,000 years BP at Devil's Lair (Fig. 4; Dortch, 1979, 1984). It is worth noting that the three bone beads were not found together, but were separated in both space and time, and so do not belong to the same personal ornament. The beads range in length from 10.58 mm to 21.06 mm, and in diameter from 3.5 mm to 9 mm (Dortch, 1984). Also recovered at Devil's Lair was a perforated tapering bone splinter dated at 12,000 years BP (Dortch and Merrilees, 1973). The perforation was originally described as rounded and smoothed on one side from friction from a string (Dortch, 1984), but more recently it has been suggested that the bone splinter may be naturally perforated (Dortch and Dortch, 1996). Bednarik (1998) concluded that the perforation was clearly not natural, although he could find no evidence of the wear that would be expected if the piece had been suspended from a string. Similarly, an object of exotic marl (a type of limestone) with a 6.5 mm diameter perforation, which was recovered from a 14,000 BP horizon (Fig. 5; Dortch, 1984), was described as having no indication of being drilled or otherwise modified, and so was probably formed by natural weathering processes (Dortch, 1984). The object weighs 18.65 g and measures at most 55 mm. In a reinterpretation of the piece, Bednarik (1997, 1998) observed that the inner surface of the hole bears four grooves in a form and distribution consistent with the object's suspension from a string (Bednarik, 1998: his Fig. 4). Other finds from Devil's Lair that could be categorised as personal ornaments are detailed in Table 3.

More recent occurrences of beads in Greater Australian sites date to the terminal Pleistocene or early-to-mid Holocene, with necklaces and headbands of items such as kangaroo or Tasmanian Devil teeth appearing in burials in southeastern Australia at sites such as Kow Swamp, Lake Nitchie, and Roonka (Table 3; Macintosh, 1971; Pretty, 1977; Pardoe, 1993, 1995; Flood, 1995; Feary, 1996). A shell pendant was recovered at Liang Nabulei Lisa on the Aru Islands, south of New Guinea, which were part of Sahul during periods of low sea level (Table 3; O'Connor et al., 2006a: their Fig. 7.10). The *Terebra subulate* shell, which has a hole drilled opposite the opercular opening, came from a terminal Pleistocene level, but may be associated with a secondary burial dating to the

Table 3
Beads and pendants in Greater Australia

Site	Date and associations	Reference
Riwi Cave, the Kimberley	Fragments of *Dentalium* sp. shell with smoothed openings suggesting use as beads, some with residues that may be ochre, one with a fibre fragment, possibly from a string; dating from at least 29,550 ± 290 BP (Wk 7896) to possibly 42,000 BP: 40,700 ± 1,260 (ANUA-13006), >40,000 (Wk 7607)	Balme (2000); Balme and Morse (2006)
Carpenter's Gap rockshelter 1, the Kimberley	*Dentalium* sp. shell beads in Pleistocene levels	O'Connor (1995)
Mandu Mandu Creek rockshelter, Cape Range Peninsula, northwestern Australia	22 *Conus* sp. shell beads from the basal occupation horizon at 32,000 BP [between 34,200 ± 1,050 BP (Wk 1513) and 30,000 ± 850 BP (Wk 1576)]; the deposit from which the *Conus* shells were recovered is some 20 cm below a date of 22,100 ± 500 BP (Wk 1575); three cone shell fragments, one of which may be deliberately modified, recovered from deposits with an estimated age of 21,000 BP; fragment of either *Nautilus* or pearl oyster and scaphopod shell (Dentaliidae sp.) from late Pleistocene deposits, known ethnographically to have been used as ornaments, such as pendants	Morse (1993a,b)
Devil's Lair, southwest Western Australia	Three macropod long bone beads in layers dating between 12–20,000 BP; original date 17,370 ± 290 BP (SUA-1248) now rejected and replaced with 19,160 ± 380 BP (SUA 976) and 19,835 ± 75 BP (AA 19691); a small perforated tapering splinter of bone dated at 12,000 BP may be a pendant; short pieces of perforated bone with unrounded ends, may be bead blanks; a 19-mm-long bead-sized oblong bone item covered with scratches could be an ornament intended to be attached with gum adhesive; a possible broken bead blank with a bone sliver inserted, perhaps to clean out the marrow cavity, dated at 12,000 BP; a naturally perforated marl object dating to 14,000 BP, possibly a pendant	Dortch and Merrilees (1973); Dortch (1979, 1984); Dortch and Dortch (1996); Bednarik (1997, 1998); Dortch (2004: his Table 6.3)
Kow Swamp, northern Victoria	A headband of kangaroo incisor teeth with traces of resin indicating that they had been stuck together recovered from a burial said to date to 12,000 BP; burials dated to between 14–9,000 BP	Flood (1995)
Lake Nitchie, western New South Wales	Necklace of 178 pierced Tasmanian Devil teeth from a burial, 6,820 ± 200 BP; each tooth was pierced by a hole that was ground and gouged out	Macintosh (1971); Flood (1995)
Roonka, South Australia	Mid-to-late Holocene elaborate burials found at the Roonka cemetery site; Roonka II Phase, dated 4–8,000 BP; recovered from Grave 89 and dated to 6,910 ± 450 BP (ANU-1408) was a large fossil oyster with closely spaced drilled holes; recovered from Grave 63 were two native cat (*Dasyurid*) mandibles with what have been described as drilled attachment holes; Roonka III Phase postdates 4,000 BP; grave 108 inhumations of a man and child, with a double-stranded band of notched wallaby teeth around the man's forehead, a skin cloak fastened with bone pins and the paws of animal pelts at the shoulder, and another band of wallaby incisors across the left shoulder, a bird skull pendant, and a necklace of reptile vertebrae on the child, whose feet were stained with ochre	Pretty (1977); Flood (1995); Pate et al. (1998)
Allens Cave, Nullarbor Plain, South Australia	Fragment of an abalone (*Haliotis laegivata*) recovered from 13–14,000 year old deposits and proposed to have been transported to the site as a decorative item, such as a pendant	Cane (2001)
Liang Nabulei Lisa, Aru Islands	A *Terebra subulate* shell pendant with a hole drilled opposite the opercular opening, recovered from terminal Pleistocene deposits: 9,630 ± 60 BP (OZD697) and 9,750 ± 60 BP (OZD698); the shell pendant may be associated with a secondary burial dating to the early-to-mid Holocene, although it could be even younger	Bulbeck (2006a); O'Connor et al. (2006a)
Vlaming Head Middens 1 and 2A and North West Cape Midden 1, Cape Range Peninsula, central Western Australia	Three fragments of baler pendant, two of which are pierced, while the third has clearly ground edges on all margins; sites currently undated, but other middens on the Peninsula have been dated, the earliest to 7,810 ± 115 BP (SUA 1735), with most being less than 6,000 years old	Przywolnik (2003)
Nawamoyn, Arnhem Land	One estuarine (*Geloina* sp.) and two marine (*Anadara* sp.) shells with holes drilled in their bases may have been pendants; one of the *Anadara* shells was covered with red ochre; recovered from a shell midden that began accumulating from 7,110 ± 130 BP (ANU-53)	Schrire (1982)
Cooma, New South Wales Southern Tablelands	A collection of 327 pierced kangaroo and wallaby incisors (thought to have been a necklace) scattered throughout the grave deposit of a burial dated to c. 7,000 years old; the teeth were pierced from both sides through the root portions and many are polished, possibly from sliding against each other while strung together	Feary (1996)
David's Dune, Wallpolla Island, Northern Victoria	Burial 20 dated to 7,140 ± 200 BP (ANU-8647); necklace of pierced Tasmanian Devil canines said to be similar to that from Lake Nitchie	Pardoe (1995)

Table 3 (*continued*)

Site	Date and associations	Reference
Matenbek, New Ireland	Small shell bead dated to around 8,000 BP; shells and shell fragments displaying drill holes and other edge modification date to the late Pleistocene and earlier Holocene, but they could be for utilitarian purposes, such as fish hook manufacture	Smith and Allen (1999)
Buang Merabak, New Ireland	A perforated tiger shark tooth from levels dating to between 39,500-28,000 years BP	Leavesley (2007)

early-to-mid Holocene (Bulbeck, 2006a; O'Connor et al., 2006a), or possibly even younger.

There appears to be a chronological and geographical pattern to the occurrence of personal ornaments within Sahul. Shell beads and possibly a shell pendant are recovered from late Pleistocene deposits at sites in the northern areas of Greater Australia, bone beads and pendants from Devil's Lair in southwestern Australia from terminal Pleistocene deposits, and during the early Holocene, necklaces of animal teeth become grave goods in burials from southeastern Australia (Table 3).

Notational pieces—25,000 years BP (Table 4)

Examples of archaeologically visible modern human behaviour include items of "external symbolic storage" (see Wadley, 2001), which can incorporate not only personal ornaments and art, but also notational pieces. Notational pieces are here included with personal adornments. Items that are categorised here as notational pieces have been recovered from a number of sites within Greater Australia from late Pleistocene and early Holocene contexts (Table 4).

Devil's Lair has provided two pieces of limestone that were initially identified as "engraved stone plaques" (Dortch, 1976, 2004). One flat surface of each plaque is covered with incisions and scratches. On plaque B3652, which is dated to 25,500 years BP, there is no identifiable motif or clear pattern; rather, there are prominent incised lines and numerous fine striations. However, the engraved face of plaque B3651, which is dated to 13,000 years BP, has a distinct trapezoidal shape formed by adjoining and intersecting incisions and grooves along with other fainter striations (Fig. 6). Dortch suggested that the sides of the trapezoidal shape were "made under control in an attempt to form an angle" and "done with the purpose of producing an enclosed shape" (1976: 38). In a reexamination of these and other similar items from Devil's Lair, Bednarik (1998) dismissed the identification of the incised lines on the two plaques as being deliberate, but rather argued that the markings were animal scratches or other "taphonomic marks". Whilst Bednarik's (1998) conclusions may be correct for plaque B3652, the clear trapezoidal shape on plaque B3651 does appear to be a distinct geometric design or motif (Fig. 6).

Cave Bay Cave on Hunter Island off the northwest Tasmanian coast has yielded a possible notational piece from a level dated between 15,400 years BP and 20,850 years BP (Bowdler, 1984). The object is a macropod femur with the epiphyseal ends broken off and groups of grooves and scratches of varying depths over the shaft, some displaying a gloss over the resulting ridges. Bowdler (1984) observed that a bone from the lower levels of Rocky Cape South, another Tasmanian site, had a similar "use-wear" pattern.

A *Diprotodon* incisor from a collection of megafaunal bones from Spring Creek, southwest Victoria, dated to possibly 19,800 years BP has been identified as a notational piece. Vanderwal and Fullagar (1989) favour a human origin for the 28 incised grooves on the surface of the tooth. They contended that the incisions are not consistent with marks made by rolling within the deposits or with natural processes postdeposition (Vanderwal and Fullagar, 1989). However, a reexamination of the Spring Creek locality by White and Flannery (1995) questioned the stratigraphic integrity of the site and dismissed the proposal that the incisions on the *Diprotodon* tooth were due to deliberate human activity. If deliberately incised, the *Diprotodon* tooth would be the only evidence for human and megafaunal association within the Spring Creek assemblage.

Whilst notational pieces are not common at sites within Greater Australia, examples have been recovered from late Pleistocene contexts across the continent (Table 4). These possible notational pieces are of two types: stone or bone fragments engraved with geometric patterns, and animal bones with incisions that form no

Table 4
Notational pieces in Greater Australia

Site	Date and associations	Reference
Devil's Lair, southwestern Australia	Engraved limestone plaques, one (B3651) with intersecting incisions forming a geometric design of a distinct trapezoidal shape; plaque B3651 from a hearth bracketed by deposits dated to between 12,900–13,200 BP. Original dates 11,960 ± 140 BP (SUA 102) and 12,050 ± 140 BP (SUA 103) now rejected and replaced with 13,050 ± 90 BP (OZD 321); plaque B3652 from a layer dated to between 24,950–26,050 BP; original date 20,400 ± 1,000 BP (SUA 32) now rejected and replaced with 25,500 ± 275 BP (AA 19689)	Dortch (1976, 1984); cf. Bednarik (1998); Dortch (2004: his Table 6.3)
Cave Bay Cave, Hunter Island, Tasmania	A macropod femur with groups of grooves and scratches, dated between 15,400 ± 330 BP (ANU-1613) and 20,850 ± 290 BP (ANU-1612); a broken swan tarsometatarsus with deep incisions and an "embayment" into the bone in which grooves are visible with a gloss over the ridges, from shell midden deposits dating to 6,640 ± 100 BP (ANU-1797) and 3,960 ± 110 BP (ANU-1614)	Bowdler (1984)
Spring Creek, Southwestern Victoria	*Diprotodon* incisor with 28 grooves; from a megafaunal assemblage possibly dated to 19,800 ± 390 BP; stratigraphic integrity of the site may be questionable	Vanderwal and Fullagar (1989); White and Flannery (1995)
Yardie Creek midden, central Western Australia	A weathered bone fragment, possibly dugong, with five lines of parallel incised zig-zags 1.5–2 mm deep along its length; recovered from the surface of a shell midden; undated, but middens from this area date to the early-to-mid Holocene; may be recent	Kendrick and Morse (1982); Bowdler (1990a, b); Morse (1996)

Fig. 3. Cone shell beads from Mandu Mandu Creek rockshelter, central Western Australia (courtesy of the Western Australian Museum).

Fig. 4. Bone bead (DL001) from Devil's Lair, southwestern Australia (courtesy of the Western Australian Museum).

obvious pattern (Table 4). However, the identification of these items as humanly produced remains debated.

Art and imagery

Greater Australia has provided evidence for a range of artistic activities during the late Pleistocene. This includes the presence of pieces of ochre, often with use-wear, as well as implements associated with pigment processing, such as grindstones, through to finger markings, paintings, and engravings on rock surfaces.

Ochre—42,000 years BP (Table 5)

Ochre has a range of utilitarian and ceremonial functions, including the processing of animal skins and hafting of tools, medicinal purposes and in burials, and for the decoration of artefacts, the body, and rock surfaces (Wadley, 2001; Hovers et al., 2003; Wadley et al., 2004). It is often difficult to infer the particular function of ochre within an archaeological context. For example, the sprinkling of ochre in burials may have been ceremonial, but could also have served a more utilitarian purpose, such as neutralising odours and helping to preserve bodies (Bahn and Vertut, 1997). Whilst ochre may have had many uses, it was commonly used as a colouring material in the prehistoric and ethnographic past (Deacon, 1995; Bahn and Vertut, 1997; Barham, 2002; Bednarik, 2003; Hovers et al., 2003). Numerous late Pleistocene archaeological deposits at sites throughout Australia have produced ochre (Table 5).

In the Kimberley, the earliest occurrence of ochre is from Carpenter's Gap, where a pellet of red ochre was found in a level dated between about 42,800 and 33,600 years BP (O'Connor and Fankhauser, 2001). Ochre is also present from an early period in deposits at Riwi Cave, dating from about 31,800 years BP (Balme, 2000), and at Widgingarri Shelter 2, where it is dated between 18,900 and 28,000 years BP (O'Connor, 1999).

At Mandu Mandu Creek, central Western Australia, ochre is most abundant in layers dating to 25–20,000 years BP, but was found throughout the archaeological deposits (Morse, 1993b). In southwestern Australia, one of the few pieces of red ochre recovered from Devil's Lair is dated at about 30,000 years BP (Dortch, 1984, 2004: his Table 6.3; Dortch and Dortch, 1996).

Several sites in Arnhem Land have yielded ochre, sometimes in considerable quantities. At Malangangerr, 447 nodules of white, red, yellow, orange, and purple ochre occur in a sand unit dating to 24–18,000 years BP (Schrire, 1982). Similarly, a large 1 kg piece of haematite was recovered from Malakunanja II, as well as a grindstone stained with red ochre from a level dated to around 18,000 years BP (Jones and Negerevich, 1985), but possibly as old as 50,000 years BP (Roberts et al., 1990; Chaloupka, 1993; but see Allen and O'Connell, 2003). At Nawamoyn and Nauwalabila I, the earliest occurrence of ochre, with many pieces showing use/grinding facets,

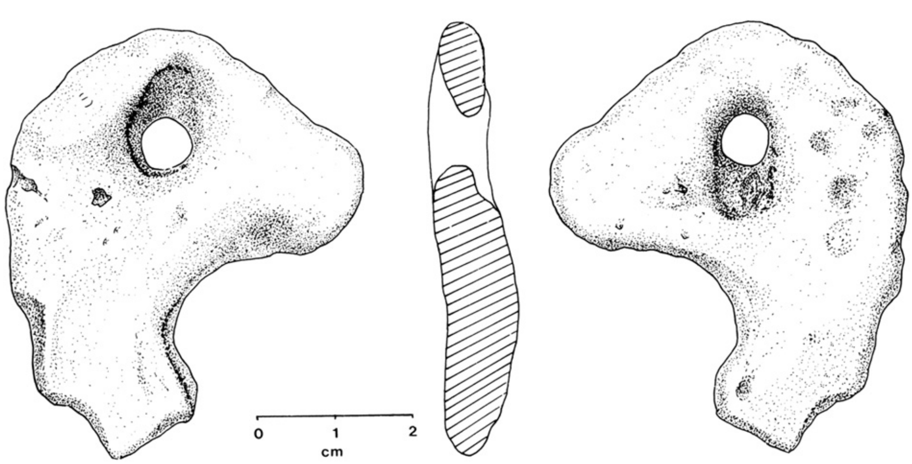

Fig. 5. Perforated object of marl from Devil's Lair, southwestern Australia (courtesy of the Western Australian Museum).

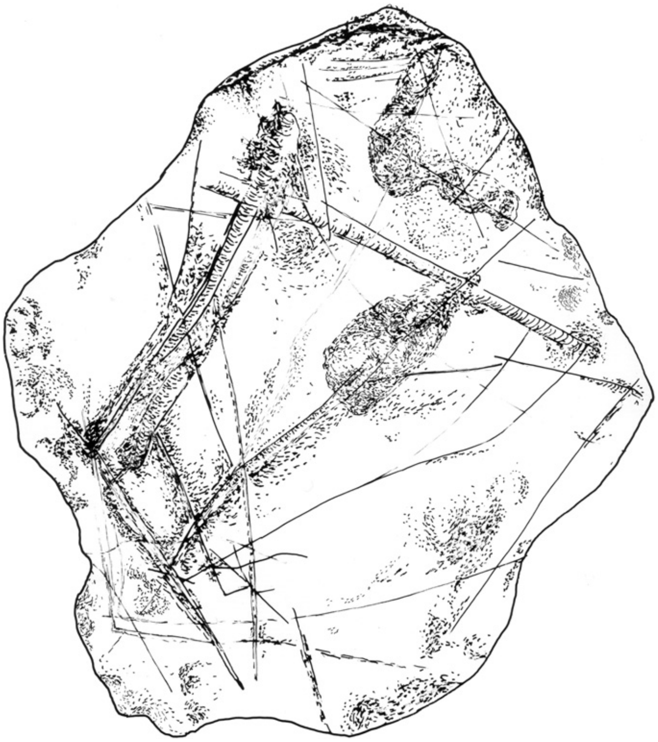

Fig. 6. Limestone plaque (B3651) from Devil's Lair, southwestern Australia (courtesy of the Western Australian Museum).

is from levels dated to 20–30,000 years BP (Schrire, 1982; Jones and Johnson, 1985b: their Plate 9.25).

In the Laura Region, Cape York Peninsula, red and yellow pigment with use-wear striations, dating between about 26,000 and 32,000 years BP, was recovered from Sandy Creek 1 (Cole et al., 1995), while at Early Man, the earliest ochre dates to about 18,200 years BP (Rosenfeld, 1981). Ochre also occurs throughout the archaeological deposits at Fern Cave, where the earliest occupation dates to around 26,000 years BP (David, 1991).

In western New South Wales, powdered red ochre covered almost the entire area of the grave of LM3, including the body, which is dated to about 42–38,000 years BP (Bowler, 1998). At Cuddie Springs, ochre is found in a unit dated to about 33–30,000 years BP (Fullagar and Field, 1997; Field and Dodson, 1999; but see later discussion). Other occurrences of ochre in Greater Australian sites are detailed in Table 5.

Fig. 7. Rock engravings at the Early Man rockshelter, Cape York Peninsula.

Ochre appears in Sahul from an early period, at about 40,000 years BP at Carpenter's Gap and Lake Mungo, and between 18–30,000 years BP in Arnhem Land, Cape York Peninsula, and southwestern Australia. The nonutilitarian use of ochre at some Pleistocene sites is suggested by the variety of colours present (red, yellow, white, purple, and orange). There is also evidence for the early systematic collection and processing of ochre, providing a more robust case for its symbolic use (see Hovers et al., 2003). For example, ochre was transported 150–200 km at Puritjarra and Mandu Mandu Creek rockshelter, and possibly in excess of 300 km at Lake Mungo (Morse, 1993b; Smith, 1996; Bowler, 1998; Smith et al., 1998), while ochre is present within the grave of the Lake Mungo 3 burial (Bowler and Thorne, 1976; Bowler, 1998). The sizeable nodules and large quantities of ochre in a range of colours from at least 18,000 years BP at Puritjarra, Nawamoyn, Malangangerr, and Malakunanja II, plus the grindstone stained with red ochre at Malakunanja II (Schrire, 1982; Jones and Negerevich, 1985; Rosenfeld and Smith, 2002), suggest substantial collection and processing of ochre, as do the ochre nodules with use-wear striations and facets from late Pleistocene deposits at Nauwalabila 1, Laura Region sites, Widgingarri Shelter 1, and Puritjarra (Rosenfeld, 1981; Jones and Johnson, 1985b; Cole et al., 1995; O'Connor, 1999; Rosenfeld and Smith, 2002). *Dentalium* shell beads from Riwi Cave appear to have ochre in grooves around their circumference (Table 3), possibly from direct contact with ochre painted clothing or skin (Balme and Morse, 2006). At Puritjarra in levels dating between 32–18,000 years BP, ochre is restricted to the centre of the rockshelter floor and consists entirely of small crumbs, suggesting its use for body or artefact decoration (Rosenfeld and Smith, 2002). From 13,000 years BP onwards, ochre, often in relatively large quantities, occurs in deposits against the shelter wall and next to a large panel of paintings and stencils (Rosenfeld and Smith, 2002). The use of the ochre for making the art on the shelter walls is suggested by this association and the occurrence of the earliest identifiable paint at the same period (Table 5). At Puritjarra and Lake Mungo (and possibly Riwi Cave) it is therefore possible to infer the particular function of the ochre from the range of possible uses.

Art—40,000 years BP (Table 6)

Rock art has proven difficult to date directly in Greater Australia as it often does not contain the organic material required for radiocarbon dating (see Franklin, 2004, for a discussion of the problems involved). Most attempts at dating have, therefore, been based on the association of rock art with dated archaeological deposits, assumptions about the subject matter of particular depictions, and occasionally on experimental techniques that date the accretions that may cover or underlie rock art.

Recovered at Carpenter's Gap in a layer dated between 42,800 and 33,600 years BP was a fragment of rock covered with a red substance that had fallen from the shelter wall (O'Connor and Fankhauser, 2001). A chemical analysis indicated that the composition of the red substance on the wall fragment was consistent with that of an ochre. Although the walls and ceiling of the shelter are covered with charcoal drawings and red, yellow, brown, and white paintings (O'Connor, 1995; Flood, 1997; O'Connor and Fankhauser, 2001), the nature of any motifs that might be depicted on the wall fragment could not be determined. This is the earliest evidence for rock painting of some form in Sahul (Table 6).

Dates obtained on oxalate skins between pigments in microstratified rock crusts at Laura and in the Chillagoe Region, northern Queensland, have also been argued as evidence for early rock painting in Australia (Watchman, 1993, 2001; Cole et al., 1995;

Table 5
Occurrences of ochre in Greater Australia

Site	Date and associations	Reference
Carpenter's Gap, the Kimberley	Red ochre pellet bracketed by dates of 42,800 ± 1,850 BP (OZD-161) and 33,600 ± 500 BP (ANUA-7626); different composition to that of a red substance on a rock fragment that had fallen from the shelter wall into the same excavation level	O'Connor and Fankhauser (2001)
Riwi Cave, southern Kimberley	Ochre in level dated to 31,860 ± 450 BP (Wk 7606); ochre in much lesser quantities in a lower undated level	Balme (2000)
Widgingarri Shelter 1, the Kimberley	Small nodules of ochre, some with grinding facets, from late Pleistocene and Holocene levels	O'Connor (1999)
Widgingarri Shelter 2, the Kimberley	25 nodules of red, yellow, and orange ochre in levels dated at 18,900 ± 1,800 BP (ANU/AMS 5–10) to 28,060 ± 600 BP (R11795)	O'Connor (1999: her Table 5.17)
Mandu Mandu Creek rockshelter, Cape Range Peninsula, northwestern Australia	Ochre present throughout, peaking in layers dating 25–20,000 BP	Morse (1993b)
Devil's Lair, southwestern Australia	Rare fragments of red ochre, one from a hearth originally dated at 27,700 ± 700 BP (SUA 539); deposit now bracketed by dates of 31,400 ± 1,500 BP (SUA 457) and 30,590 ± 1,810 BP (GX 7255); large ferruginous nodules of ochre (one weighing 13 g) recovered, possibly transported to the site, other smaller pieces could have been washed in to the deposits	Dortch and Merrilees (1973); Dortch (1984); Dortch and Dortch (1996); Dortch (2004: his Table 6.3)
Malangangerr, Arnhem Land	447 nodules of white, red, yellow, orange, and purple ochre with a range of colours matching that within the more recent shell midden at the site, date between 18,000 and 24,000 BP; 201 pieces of ochre and a probable *Geloina* shell "ochre palette" from the shell midden, dating from 6,000 BP to recent times; an additional 115 pieces of ochre from a "transitional zone" between the midden deposits and earlier late Pleistocene sand deposits	Schrire (1982)
Malankunanja II, Arnhem Land	Grindstone stained with red ochre and 1 kg piece of haematite; levels dated to around 18,040 ± 300 BP (SUA-265), possibly 50,000 BP	Jones and Negerevich (1985); Roberts et al. (1990); Chaloupka (1993)
Nawamoyn and Nauwalabila I, Arnhem Land	Ochre pieces, many with use/grinding facets, between 20–30,000 BP	Schrire (1982); Jones and Johnson (1985b)
Sandy Creek 1, Laura Region, Cape York Peninsula	Two striated fragments of red pigment dated at about 32,000 BP; two yellow fragments of ochre dated to 28,000 and 25,900 BP	Cole et al. (1995)
Early Man, Laura Region, Cape York, Peninsula	Small ochre fragments with grinding marks and facets throughout the deposits down to bedrock; earliest ochre from level 8, dated at 18,200 ± 450 BP (ANU-1565)	Rosenfeld (1981)
Fern Cave, Cape York Peninsula	Ochre throughout the archaeological deposits; earliest occupation dated at 26,010 ± 410 BP (Beta 30403), possibly 30,000 BP based on extrapolation from the age-depth curve	David (1991)
Magnificent Gallery, Laura Region, Cape York Peninsula	Single piece of striated red pigment at a level dated to c. 11,500 BP	Cole et al. (1995)
Lake Mungo 3, Willandra Lakes Region, western New South Wales	Grave and body covered with powdered red ochre; dated 42–38,000 yrs BP (OSL dated at 40,000 ± 2,000 BP)	Flood (1995); Bowler (1998); Bowler et al. (2003)
Cuddie Springs, western New South Wales	Ochre in deposit dated between 33,660 ± 530 BP (Beta 81379) and 30,280 ± 450 BP (Beta 44375)	Fullagar and Field (1997); Field and Dodson (1999)
Drual, Grampians-Gariwerd Region, western Victoria	Ochre occurs in the lower levels at the site dated to 22,140 ± 160 BP (AHU-32) and 22,160 ± 150 BP (Beta-98020)	Bird et al. (1998)
Puritjarra rockshelter in the Cleland Hills, Central Australia	Small crumbs of ochre (0.1 g in weight) in the centre of the shelter floor in levels dating 18–32,000 BP; large quantities of ochre from 13,000 BP onwards, in deposits against the shelter wall adjacent to a panel of stencils and paintings; earliest identifiable paint also from this period, sample N5/7-12, a 10 mm diameter piece of very fine-grained pale yellow pigment, possibly "a droplet of thick paint or … pigment incidentally moulded on the end of a small brush" (Rosenfeld and Smith, 2002: 118); c. 30% organic content consistent with a prepared paint	Smith (1989); Rosenfeld and Smith (2002)
Puntutjara rockshelter, Warburton Ranges, Central Australia	Three grindstones with ochre and other residues from levels dated to 7–4,500 BP	Balme et al. (2001)
Cave Bay Cave, off the northwest coast of Tasmania	Three pieces of quartz with ochre adhering in deposit dating to 22,750 ± 420 BP (ANU-1498)	Bowdler (1984)
Mackintosh 90/1, western Tasmania	Ochre in a unit bracketed by dates of 17,030 ± 430 BP (Beta-45808) and 16,010 ± 300 BP (Beta-46306)	Stern and Marshall (1993)
Kenniff Cave, Central Queensland Highlands	Utilised fragments of pigment throughout the deposits, smoothed and scratched, with many striations consisting of longitudinal grooves; "no utilised fragments were found below four feet" (Mulvaney and Joyce, 1965: 202), dated to c. 4,000 BP (4,130 ± 90 BP; GaK 523); earliest date is 16,130 ± 140BP (NPL 68)	Mulvaney and Joyce (1965); Mulvaney (1975)
Batari, Papua New Guinea	Ochre from the site purportedly dates to 16,850 ± 700 BP (ANU-40), but this date may not relate to early occupation at the site; lumps of red ochre found throughout the deposits, which most probably date from 8,230 ± 190 BP (ANU38a)	White (1972) cf. Davidson and Noble (1992: their Table 1)

Table 6
Some of the dating evidence currently available for rock art sites in Greater Australia

Site	Date and associations	Reference
Carpenter's Gap, Windjana Gorge National Park, Napier Ranges, western Kimberley	Dates bracketing a rock fragment bearing red pigment detached from the shelter wall; date of 42,800 ± 1,850 BP (OZD-161) from 2 cm below the slab; date of 33,600 ± 500 BP (ANUA-7626) from 5 cm above the slab; minimum age c. 40,000 BP; nature of painting indeterminate	O'Connor (1995); Flood (1997); O'Connor and Fankhauser (2001); Morwood (2002)
Sandy Creek 2, Laura Region	AMS dates on three layers of haematite sandwiched between layers of an oxalate crust; painting events possibly dated at 6,655 ± 80 BP (AA-7723), 15–16,000 BP, and 24,600 ± 220 BP (NZA-2559); no visible motifs	Watchman (1993, 2001); Cole et al. (1995); Flood (1997); Morwood (2002)
Walkunder Arch Cave, Chillagoe	Oxalate AMS dates on mineral crusts covering a "starburst" motif and next to red anthropomorphous figures: 7,085 ± 135 BP (AA-920) and 9,470 ± 120 BP (NZA-2574); AMS dates on haematite and goethite layers in a sequence of gypsum-oxalate laminations on an encrusted boulder: 28,100 ± 400 BP (OZA-391), 25,800 ± 280 BP (OZA-392), 22,800 ± 210 BP (OZA-393), 16,100 ± 130 BP (OZA-395), and 10,400 ± 90 BP (OZA-397); no visible motifs; the early dates indicate artistic activity at the site at an earlier period than the earliest occupation demonstrated by the floor deposits	Campbell and Mardaga-Campbell (1993); Campbell et al (1996); Watchman and Hatte (1996); Campbell (2000); Watchman (2001); Morwood (2002)
Kimberley Region	Series of 18 OSL dates for mudwasp nests overlying paintings; dates range from modern to the three earliest dates of 16,400 ± 1,800 BP, 17,500 ± 1,800 BP, and 23,800 ± 2,400 BP (no sample numbers); series of five AMS dates on mineral encrustations associated with paintings; dates range from 1,430 ± 180 BP (OZB351) to 3,880 ± 110 BP (OZB126); the latter dates conflict with the OSL estimates	Roberts et al. (1997); Watchman et al. (1997); Watchman (2001)
Arnhem Land sites	Age >25,000 BP suggested for a purported painting of the extinct *Palorchestes*; paintings of extinct *Zaglossus*, *Sthenurus*, and *Thylacoleo* also claimed	Chaloupka (1984); Murray and Chaloupka (1984)
Koonalda Cave, South Australia	Finger markings concurrence with flint mining in the cave 14–24,000 BP; 19,900 ± 2000 BP (V-92) from below a concentration of finger markings, a date on charcoal, presumably the remains of a torch used to provide light for execution of the art	Maynard and Edwards (1971); Wright (1971a); Mulvaney (1975)
Malangine Cave, Mount Gambier Region, South Australia	Conflicting uranium-series and radiocarbon dates for the same calcite sample sandwiched between two layers of rock art (finger markings and engraved nonfigurative motifs); uranium-series date: 28,000 ± 2,000 BP (no sample number); radiocarbon date: 5,550 ± 55 BP (Hv-10241)	Bednarik (1999)
New Guinea II, Snowy River, Eastern Victoria	Finger markings similar to Koonalda Cave; occupation deposits at the cave entrance dated 4,660 ± 110 BP (SUA-2217) to 21,000 +900/−800 BP (SUA-2222); rock art not directly dated, but if contemporaneous with the earlier occupation, then potentially of a similar antiquity to Koonalda Cave	Ossa et al. (1995)
Koongine Cave, Mount Gambier Region, South Australia	Finger markings present; occupation dates of 8,270 ± 400 BP (BETA-14859), 9,240 ± 100 BP (BETA-15996), 9,590 ± 140 BP (BETA-14862), and 9,710 ± 180 BP (BETA-14861); no firm association between the occupation and the art, but absence of any material earlier than 10,000 BP suggests art is probably no older than this	Frankel (1986); Rosenfeld (1993)
Gum Tree Valley, Dampier Region, Western Australia	Trumpet shell dated to 18,510 ± 260 BP (LY3609) found in a fissure among deeply patinated figurative engravings	Lorblanchet (1992)
Early Man, Laura Region, Cape York Peninsula	Dates on charcoal covering engraved frieze of circles, grids, mazes, and bird tracks provide minimum date; radiocarbon dates: 12,600 ± 2,800 BP (ANU-1566), 13,200 ± 170 BP (ANU-1441), and 15,450 ± 1,500 BP (ANU-1567); minimum date of 13,200 BP generally cited for the engravings, as the 15,450 date is on a small charcoal sample	Rosenfeld (1981)
Sandy Creek 1, Laura Region, Cape York Peninsula	Date for a sandstone fragment bearing part of an unidentifiable pecked motif that probably fell from the panel of engraved discs, pits, curved lines and bird tracks on the shelter wall, which has evidence of exfoliated sections; 12,620 ± 370 BP (Beta-51089), calibrated age 14,400 BP (minimum age)	Cole et al. (1995); Morwood et al. (1995a); Flood (1997)
Puritjarra, Cleland Hills, Central Australia	Radiocarbon date on *Callitris* charcoal directly under a boulder with pecked weathered circles embedded in the silt floor of the rockshelter; 13,570 ± 100 BP (ANU 7460); maximum age for the engravings on the boulder and the paintings on the resultant shelter wall scar	Smith (1996); Rosenfeld and Smith (2002)
Southwest Tasmanian sites: Wargata Mina, Ballawinne and Keyhole Cavern	Red hand stencils, ochre smears, and a roughly drawn circle; sites occupied between 35,000 and 10,250 years ago, when they were abandoned; paintings covered by a thin layer of calcite, probably formed during a humid phase at the terminal Pleistocene Wargata Mina: AMS dates on "blood residues" in pigments; 10,730 ± 810 BP (RIDDL-1268); 9,240 ± 820 BP (RIDDL-1269); dates no longer accepted by one of the researchers on the original team of dating specialists	Jones et al. (1988); Cosgrove and Jones (1989); Loy et al. (1990); McGowan et al. (1993); Nelson (1993); Gillespie (1997); Porch and Allen (1995); Watchman (2001); Morwood (2002)
Nangalor (Nangaluwurr), Baroalbar Springs, Ngarradj Warde Djobkeng, Snake site, Cannon Hill, Spirit Cave (Angbangbang), Northern Territory	Series of eight AMS dates on oxalates in mineral crusts overlying and underlying rock paintings; range from modern to 8,888 ± 590 BP (ANU-4271) (minimum age); oxalate AMS dates on paint layers in a laminated mineral crust beneath paintings; 3,470 ± 120 BP (AA-9224); 12,250 ± 105 BP (AA-9223); these two dates predate charcoal obtained from the junction between the gravel base of the deposit and the stratigraphic layer above	Watchman (1987, 1990, 2001); Chippindale and Taçon (1993); Watchman and Campbell (1996); Flood (1997)

(*continued on next page*)

Table 6 (*continued*)

Site	Date and associations	Reference
Magnificent Gallery, Laura Region, Cape York Peninsula	Date coinciding with a peak in the rate of pigment discard, assumed to be contemporaneous with rock paintings which are covered by a thin siliceous film and partially superimposed by paintings in Quinkan style: 10,250 ± 90 BP (SUA 2876), calibrated age 11,550 BP	Cole et al. (1995); Morwood and Jung (1995); Morwood and Hobbs (1995)
Sturt's Meadows, western New South Wales	Dates for calcium carbonate covering desert varnish covering engravings (possible minimum age): 10,250 ± 170 BP (Beta-13803); 10,410 ± 170 BP (Beta-13804)	Dragovich (1986)
Mickey Springs 34, North Queensland Highlands	Dates bracketing a series of seven vertical lines on the shelter wall, and sealed by a rock fall layer: 9,920 ± 250 BP (SUA 2248) and 8,080 ± 100 BP (SUA 2252); a vertical line series and a bird track on the shelter wall occur between the following two dates: 8,080 ± 100 BP (SUA 2252) and 3,360 ± 60 BP (Beta 11734)	Morwood (1990, 1992, 2002)
Jinmium, Northern Territory	Series of thermoluminescence dates on quartz deposits, including: 116,000 ± 12,000 and 75,300 ± 7,000 for the earliest ochres (no sample numbers); 58,000 ± 6,900 BP and 75,000 ± 7,000 BP for a buried sandstone slab with pecked cupules (no sample numbers); these dates are very controversial and no longer accepted	Fullagar et al (1996); cf. Roberts et al. (1998); Watchman et al. (2000); Watchman (2001)
Jinmium, Northern Territory	Series of seven AMS dates on charcoal from the upper two thirds of the deposit, ranging from 1,100 ± 60 to 3,330 ± 100 BP (no sample numbers); series of OSL dates on individual quartz grains in the deposit, ranging from 300 ± 30 to 22,700 ± 1,200 BP (no sample numbers)	Roberts et al. (1998)
Jinmium and Granilpi, Northern Territory	Series of 16 AMS date on oxalates in mineral crusts covering cupules, ranging from 1,430 ± 110 BP (CAMS 42877), 5,840 ± 65 BP (OxA-7369) to 11,050 ± 650 bp (OxA-7367: minimum ages; except for the c. 11,000 BP date, these dates are acceptable and consistent with other geomorphic evidence from the site; the c. 11,000 bp date is problematic, as there is a disparity "between the thickness of the crust and its age when compared with the other crusts in the Keep River region" (Watchman et al., 2000: 7)	Watchman et al. (2000); Watchman (2001)
Gnatalia Creek, Sydney Basin	AMS dates on charcoal from a large curvilinear motif: 6,085 ± 60 BP (AA-5850) and 29,795 ± 420 BP (AA-5851); the earlier sample is probably contaminated	McDonald et al. (1990); McDonald (1998, 2000); Watchman (2001)
Laurie Creek, Northern Territory	AMS date on "blood residues" in pigments: 20,320 +3,100/−2,300 BP (RIDDL-1270); date no longer accepted by one of the researchers on the original team of dating specialists	Loy et al. (1990); Nelson (1993); Gillespie (1997); Watchman (2001)
Karolta 1, Yunta Springs, Wharton Hill, Panaramitee North, South Australia	Series of cation ratio dates on desert varnish covering engravings, and AMS dates on organic matter underneath varnish covering engravings; range from 43,140 ± 3,000 BP (AA 6898) to 1,510 ± 50 BP (AA 6906); dates rejected by Dorn and no longer accepted	Dorn et al. (1988); Nobbs and Dorn (1988, 1993); Dorn and Nobbs (1992)
Tari Region, Papua New Guinea	Finger markings at two sites may be of Pleistocene antiquity as there is evidence for a phase of human interference in the vegetation history of the area between 20,000 and 15,000 years ago	Ballard, 1992; Franklin, 1996

Campbell et al., 1996; Watchman and Hatte, 1996; Flood, 1997; Campbell, 2000; Cole, 2000; Tuniz, 2000; Morwood, 2002). The earliest age estimates ranged between 28,000 and 25,000 years BP for painting events at Sandy Creek 2 and Walkunder Arch Cave (Table 6). However, the pigments have only been revealed in cross-section, with no indication as to whether they relate to paintings or stencils, nor to the shapes of any motifs (David, 2002). It is also possible that the haematite may be natural, rather than artefactual (Franklin, 1996).

In terms of rock art with identifiable motifs, conflicting minimum age estimates of 25–17,000 years BP and 4,000 years BP have been obtained in the Kimberley Region for some Bradshaw (Gwion Gwion) paintings using different dating techniques and materials: optically stimulated luminescence (OSL) for mudwasp nests overlying paintings (Roberts et al., 1997; Watchman, 2001) and accelerator mass spectrometry (AMS) for mineral encrustations associated with paintings (Watchman et al., 1997; Watchman, 2001). If the early luminescence dates are accepted, these Bradshaw paintings are the earliest dated figurative motifs in Greater Australia (cf. Brumm and Moore, 2005).

An age of at least 25,000 years has been proposed for rock paintings in western Arnhem Land, where Murray and Chaloupka (1984) identified supposed depictions of extinct fauna, such as *Zaglossus*, *Sthenurus*, *Thylacoleo*, and possibly *Palorchestes*. The minimum date proposed is based on the presence in the region of suitable environments for *Zaglossus* before this period (Chaloupka, 1984). A similar case for a Pleistocene antiquity for rock art was also made in the Laura Region, where an image of a *Diprotodon* has been claimed (Trezise, 1992). However, the identification of this painting and the others in western Arnhem Land as extinct animals has been disputed (Lewis, 1986; Clegg and Fethney, 1988; see also Franklin, 2004).

At Koonalda, finger markings on the soft limestone walls of the cave can be assumed to date some time between 14,000 and 24,000 years BP, as flint mining took place in the cave during this period (see above) and there is no evidence to suggest that the cave was used either before or after this time (Wright, 1971a; see also Rosenfeld, 1993). Although the markings may be as young as 14,000 years or as old as 24,000 years, there is support for an age of about 20,000 years BP derived from a charcoal sample directly below a concentration of the markings, presumed to be the remains of a torch used to provide light for execution of the art (Maynard and Edwards, 1971; Wright, 1971a; Mulvaney, 1975). However, the finger markings cannot be directly related stratigraphically to the charcoal sample (Rosenfeld, 1993).

Bednarik (1999) obtained an even earlier uranium-series (U-series) date of around 28,000 years BP for very similar finger markings at Malangine Cave in South Australia. The date was derived from a calcite sample sandwiched between the finger markings and a layer of deeply carved, nonfigurative motifs, but it conflicted with a radiocarbon date of about 5,550 years BP from the same sample. The latter is also more consistent with another mid-Holocene radiocarbon date obtained from another sample in the same cave (Table 6).

Very similar finger markings to those of Koonalda and Malangine Caves occur in New Guinea II on the Snowy River in eastern Victoria. Although this rock art is undated, occupation deposits at the cave entrance date back to between 4,600 and 21,000 years BP (Ossa et al., 1995). If the finger markings are contemporaneous with the earlier occupation at the site, then they are potentially of a similar antiquity to those at Koonalda Cave. However, an age of less than 10,000 years is suggested for similar finger markings at Koongine Cave in South Australia, based on four radiocarbon dates for occupation of the site (Table 6; Frankel, 1986). Although again a firm association cannot be drawn between the occupation and the art, the absence of any material earlier than 10,000 years in the cave suggests that the art is probably not of Pleistocene antiquity (Frankel, 1986; see also Rosenfeld, 1993). The only relatively firmly dated finger markings in Sahul are therefore about 20,000 years old at Koonalda Cave, with other more recent dates of less than 10,000 years being suggested for similar markings at Malangine and Koongine caves. Other late Pleistocene dates have been obtained for rock art in Greater Australia (Table 6), but some of these are either controversial or no longer widely accepted (Franklin, 2004).

The earliest evidence for rock painting in Sahul is about 40,000 years BP at Carpenter's Gap and about 28–25,000 years BP at Sandy Creek 2 and Walkunder Arch Cave, northern Australia, although the nature of any motifs depicted is unknown. Identifiable rock art dates to possibly 25–17,000 years BP for Gwion paintings in the Kimberley, northern Australia, and to 24–14,000 years BP with the finger markings at Koonalda Cave in southern Australia. Around 14–10,000 years BP there is a series of dates for paintings and engravings, such as at Early Man Rockshelter, Cape York (Fig. 7) but most paintings with identifiable motifs date to the boundary between the Holocene and the Pleistocene, or the mid-Holocene (Franklin, 2004: her Table 1.1).

Burials—40,000 years BP (Table 7)

Elaborate burials that suggest ceremonial and ritual activities are evident in Greater Australia during the late Pleistocene, with cemeteries appearing along the river systems of southeastern Australia from the early-to-mid Holocene (Table 7). Pardoe (1988, 1995) defined cemeteries on the basis of size, density of burials, boundedness, and exclusivity of use, as opposed to isolated individual burials.

The Willandra Lakes area of western New South Wales provides the earliest burials in Sahul, with over 130 individual burials identified (Webb, 1989). A significant number of these burials appear to be older than 10,000 years BP, with possibly ten burials dating to more than 15,000 years BP (Webb, 1989; Pardoe, 1993).

Lake Mungo 1 (LM1) and Lake Mungo 3 (LM3) are the most widely known of the burials from the Willandra Lakes Region. The fragmentary LM1 burial consists of the cremated and smashed remains of a female individual that had been gathered together and deposited in a shallow depression (Bowler et al., 1970, 1972). The LM3 burial is very different to the LM1 cremation burial in that the adult individual was interred in what has been described as a shallow grave in an extended position, slightly rotated to the right with the hands clasped over the pelvis (Bowler and Thorne, 1976). As noted above, powdered red ochre covered much of the grave area and the body of LM3.

The dating of the LM1 and LM3 burials has been much debated (Table 7). Direct radiocarbon dates indicate an age between 16,000–29,000 years BP for LM1 (Bowler et al., 1972; Webb, 1989; Bowler and Price, 1998; Gillespie, 1998). Gillespie (1998) argued for a date between 17–20,000 years BP based on the insoluble residue date of 16,940 ± 635 (NZA-231), as opposed to the older humic acid dates from the LM1 skeleton (Table 7). However, Bowler observed that "cementation by carbonate would suggest an origin before Lower Mungo soil formation, with age implications beyond 40 ka" (1998: 150).

The grave pit of the LM3 burial is estimated to be only 80–100 cm deep (Bowler and Thorne, 1976; Bowler et al., 2003) and would have been dug down from an earlier surface. The actual surface from which the grave for LM3 was dug is difficult to establish. Therefore, the date of the burial could be many thousands of years younger than the dates for the deposit from which LM3 was eroding when found (see Pardoe, 1995; Gillespie, 2002). Initially, the LM3 burial was stratigraphically dated to between 28,000–32,000 years BP (Bowler and Thorne, 1976); however, more recently this estimate has been significantly increased. Bowler (1998) proposed that the deposit into which the LM3 burial was dug was dated between 42,000–45,000 years BP, based on regional correlations, pedogenic analyses, and the results from various dating methods. Thorne et al. (1999) proposed a significantly older age estimate for LM3. Electron spin resonance (ESR) and U-series dating of the LM3 skeleton provided a "best age estimate" of 62,000 ± 6,000 years BP (Thorne et al., 1999). The calcitic matrix on the bones of LM3 provided a U-series age of 82,000 ± 21,000 years, whereas the sediment into which the body was buried produced an OSL age estimation of 61,000 ± 2,000 years (Thorne et al., 1999). These age estimates have not been universally accepted, with criticism based on methodology, interpretation, and the lack of agreement with the radiocarbon and TL dates for the Willandra Lakes area (Bowler and Magee, 2000; Gillespie and Roberts, 2000; Klein, 2000; Gillespie, 2002; Bowler et al., 2003; Habgood, 2003; but see Grün et al., 2000; Grün, 2006). It is worth noting that, whilst acknowledging potential overlap, the results obtained by Thorne et al. (1999) indicate that the calcitic matrix on the bones of LM3 is older than the actual bones and that the bones are older than the deposit into which they were buried. Additional OSL age estimates have been interpreted as indicating that LM3 was buried in sands dated to 42,000 ± 3,000 years BP and the grave sealed by deposits dated to 38,000 ± 2,000 years BP, with Bowler et al. (2003) proposing that both the burials occurred at about 40,000 ± 2,000 years BP.

Whilst some uncertainty remains with establishing the surfaces from which LM1 and LM3 were buried, when all of the dating and stratigraphic data is considered a date for the burials of 40,000 years BP would seem a reasonable estimate, especially for LM3 (see also Allen and O'Connell, 2003; O'Connell and Allen, 2004; but compare Gillespie, 1998, 2002). The WLH 135 burial may be of a similar age to the LM1 and LM3 burials (Webb, 1989; Bowler, 1998).

Individual burials, some with elaborate grave goods, are recorded at sites dating from the late Pleistocene to early-to-mid Holocene, including Keilor, Lake Tandou, Mossgiel, Cossack, Lake Nitchie, and Liang Lemdubu and Liang Nabulei Lisa on the Aru Islands, with cemeteries first appearing at this time at locations which include Kow Swamp, Coobool Creek, Roonka, and Lake Victoria (Table 7; Pardoe, 1988, 1995).

The remains of over 40 individuals were recovered at the Kow Swamp cemetery. The oldest of the Kow Swamp burials are generally dated to 14–9,000 years BP (Thorne and Macumber, 1972; cf. Pardoe, 1995). More recently it has been proposed that the Kow Swamp cemetery dates to 22–19,000 years BP based on OSL dates of the sediments into which the burials were dug (Stone and Cupper, 2003). However, as with the LM3 burial, the relationship between the dated sediments and the surface(s) from which the burials were dug cannot be conclusively established. A terminal Pleistocene age for the Kow Swamp cemetery is supported morphologically by links with individuals buried at Nacurrie and Coobool Creek, which are dated in the range of 15–7,000 years BP (Brown, 1989).

Late Pleistocene to mid-Holocene burials from Greater Australia document a range of mortuary practices, including cremations,

Table 7
Burials from Greater Australia (see also Pardoe, 1995)

Site	Burial, date, and associations	Reference
Lake Mungo, western New South Wales	Over 130 individual burials from the Willandra Lakes Region, with the majority dating to more than 10–15,000 BP; whilst some uncertainty remains, a reasonable estimate for when LM1 and LM3 were buried would be 40,000 ± 2,000 years BP; Lake Mungo 1 is one of the oldest known cremations in the world; dates include: 16,940 ± 635 BP (NZA-231), 19,030 ± 1,410 BP (ANU-618A), 24,710 + 1,270/−1,100 BP (ANU-618B), 24,745 ± 2,400 BP (NZA-246), 25,120 ± 1,380 BP (NZA-230), 26,250 ± 1,120 BP (ANU-375B), and OSL date of 40,000 ± 2,000 BP; Lake Mungo 3 an extended burial in a shallow grave, covered with powdered red ochre; dates include: ESR 31,000 ± 7,000 BP, ESR 30,000 ± 2,000 BP, and OSL 40,000 ± 2,000 BP, with "best age estimate" of 62,000 ± 6,000 BP based on ESR and U-series dating; the WLH 135 burial may be of a similar age to the LM1 and LM3 burials	Bowler et al. (1970, 1972, 2003); Bowler and Thorne (1976); Caddie et al. (1987); Webb (1989); Pardoe (1993, 1995); Bowler (1998); Gillespie (1998); Thorne et al. (1999)
Kow Swamp, northern Victoria	Burials of at least 40 individuals with grave goods including mussel shells, stone artefacts, marsupial teeth and ochre; the Cohuna cranium is from the Kow Swamp site, generally dated to between 14–9,000 BP, possibly as early as 22–19,000 BP; KS1 dated to 10,070 ± 250 BP (ANU-403b); KS5 dated to 13,000 ± 280 BP (ANU-1236); KS9 dated to 9,300 ± 220 BP (ANU-619b); KS9 dated to 9,590 ± 130 BP (ANU-532); KS14 dated 8,700 ± 220 BP (ANU-1038); KS17 dated to 11,350 ± 160 BP (ANU-1235); Kow Sand into which KS9 was buried provided OSL ages of 14,400 ± 800 BP and 19,000 ± 1,100 BP; Cohuna Silt, into which KS1, KS5, KS14, and KS17 were buried, provided an OSL age of 21,600 ± 1,300 BP	Thorne and Macumber (1972); Brown (1987, 1989); Pardoe (1988, 1995); Stone and Cupper (2003)
Coobool Creek, southwest New South Wales	Remains of 33 individuals; CC65 U/Th date of 14,300 ± 1,000 BP (LLO-416); CC65 AMS date of 7,200 ± 60 BP (Beta-90029)	Brown (1987, 1989); Pardoe (1995)
Nacurrie, southwest New South Wales	Remains of two individuals; Nacurrie male dated to 11,440 ± 160 BP (NZA-1069)	Brown (1987, 1989); Pardoe (1995)
Lake Tandou, southwest New South Wales	A kneeling individual dated to 15,210 ± 160 BP (SUA-1805), based on shell from possibly the same stratigraphic unit; cremation dated at 12,530 + 1,630/−1,350 BP (ANU-705)	Freedman and Lofgren (1983); Pardoe (1988, 1995)
Keilor, Victoria	Adult male cranium and fragments of a femur recovered from sand deposits near Maribyrnong River; the associated femur fragment has provided a bone collagen date of 12,900 ± 120 BP (NZ-1327) or 12,000 ± 120 BP (NZ-1327); dates on carbonate crust from the cranium ranged from 5,200 ± 200 (NZ-1320) BP to 6,800 ± 100 (NZ-1321) BP, and from a femur fragment 6,790 ± 50 (NZ-1326) BP	Oakley et al. (1975); Macintosh and Larnach (1976); Brown (1987, 1989)
Lake Victoria, southwest New South Wales	Cemetery estimated to contain at least 10,000 burials; dated sometime after 10,000 BP	Pardoe (1995)
Roonka, towards the mouth of the River Murray, South Australia	Over 100 burials (possibly 120–140 individuals), including multiple burials with ochre and personal ornaments, such as wallaby teeth headbands; dates on associated charcoal and cortical bone collagen range from 7,480 ± 440 (ANU 1428) to 220 ± 80 BP (ANU 3262); Roonka II Phase, dated between 4–8,000 BP, 12 burials including six shaft tombs; Roonka III Phase, postdates 4,000 BP, over 70 burials, most extended or contracted primary interments in shallow pits or shafts; Roonka Grave 107 dated 7,480 ± 440 BP (ANU 1428); Roonka Grave 89 dated 6,910 ± 450 BP (ANU-1408); Roonka Grave 48 dated 3,930 ± 120 BP (ANU-407)	Pretty (1977); Pardoe (1988, 1995); Pate et al. (1998)
Lake Nitchie, western New South Wales	Adult male buried in a small pit in a semi-recumbent position, daubed with red ochre and wearing a necklace of 178 pierced Tasmanian Devil teeth; early evidence for tooth avulsion; bone collagen date of 6,820 ± 200 BP (NZ)	Macintosh (1971); Oakley et al. (1975); Brown (1987, 1989); Pardoe (1993, 1995)
Cossack, Western Australia	Adult male burial dated to 6,500 BP	Freedman and Lofgren (1979); Pardoe (1993)
Mossgiel, western New South Wales	Adult male burial; bone carbonate date of 6,010 ± 125 BP (NZ-814)	Oakley et al. (1975); Brown (1987); Pardoe (1993, 1995)
Aru Islands	Liang Lemdubu: adult female skeleton buried in a small grave partially sealed by a flat stone; secondary burial involving dismemberment of the corpse; dated to 16–18,000 BP on stratigraphic grounds (see Table 10 for dates); direct dating of the skeleton: AMS dating of bone collagen 3,180 BP (OSD577) regarded as minimum age, ESR dating of tooth enamel 15,800 ± 1800 BP (early uranium uptake) or 18,800 ± 2300 BP (linear uranium uptake) Liang Nabulei Lisa: fragmentary remains of an adult female and two young children; comingling of skeletal fragments and indications of burning suggestive of secondary burial; the secondary burials may date to the terminal Pleistocene but are more probably early-to-mid Holocene, although they could be younger	Bulbeck (2006a,b); O'Connor et al. (2006b)

extended and flexed burials, ochre use, and the presence of grave goods (Table 7). Whilst the majority of the burials and the appearance of cemeteries occur from the terminal Pleistocene and into the early-to-mid Holocene, the LM1 and LM3 burials document elaborate burial practices significantly earlier. Further ritual practice may be evident during the late Pleistocene with the LM3 individual having had the lower canine teeth removed, possibly as part of initiation (Webb, 1989). The Lake Nitchie male had avulsion of the central upper incisor, which may also be evidence of ritual initiation practices (Macintosh, 1971). WLH22 also has missing lower central incisors (Webb, 1989). This diverse range of late Pleistocene and early Holocene mortuary practices is suggestive of religious beliefs and established social rules governing burial and ritual.

Economic intensification

In the "human revolution" scenario, specialised technology such as grindstones, harpoons, and/or fish hooks reflect economic intensification (see McBrearty and Brooks, 2000). Additionally, Fullagar (2006) proposed that an important indicator of modern human behaviour was elaborate plant processing (for example, seed grinding and cooking or leaching of unpalatable or toxic plants). However, in an Australian context the discussion is concerned more with resource exploitation, even though it may have required specialised technology, rather than "economic intensification", which is generally a mid-to-late Holocene phenomenon (see Lourandos and Ross, 1994, and references therein).

Freshwater shellfish middens—40,000 years BP (Table 8)

The palaeoriver and lake systems of western New South Wales, southeast Australia, document extensive exploitation of freshwater shellfish and fish from 36,000 years BP and possibly 40,000 years BP, and demonstrate that use of freshwater resources was an important component of the lifeways of the late Pleistocene inhabitants of this region (Hope, 1993; Johnston, 1993; Balme, 1995; Allen, 1998; Gillespie, 1998). The lake systems generally preserve *Velesunio ambiguus* mussel shell middens, while the river systems preserve *Alathyria jacksoni* mussel shell middens (Hope, 1993; Johnston, 1993). These middens form part of a rich late Pleistocene archaeological record from this region. For example, sites on the Lake Mungo lunette include cooking ovens, ash pits, hearths, faunal material, and shell middens incorporating mussel shells, yabbies, and fish remains.

There are late Pleistocene shell middens dating possibly to 35,000 years BP along the Lower Darling River, the Anabranch channel, and the Tandou, Nitchie, and Menindee lake systems (Balme and Hope, 1990; Hope, 1993; Balme, 1995). These middens, often dominated by a single species, have been interpreted as short-term camps representing intensive exploitation of a particular resource—fish, shellfish, or crayfish (Balme, 1995; Allen, 1998). There appears to be two major periods of aquatic exploitation in the Murray-Darling Region—an earlier period between 25–40,000 years BP and a later peak at 15–17,000 years BP (Hope, 1993; Johnston, 1993; Gillespie, 1998). Hope (1993) also identified a late Pleistocene chronological differentiation of dated midden sites around the large lakes (more common earlier, especially 22–15,000 years BP) and river systems and smaller lakes (more recent, especially 12–15,000 years BP). This difference may be related to variations in river flow and lake-full conditions and the associated access to resources, and further demonstrates the adaptability of the local indigenous populations. However, these patterns could also be influenced by differential preservation of shell middens, with many middens either eroded or still covered by deposits (Hope, 1993; Balme, 1995).

The Gulf country in northwest Queensland also has evidence of late Pleistocene shell middens of the freshwater *Alathyria* cf. *pertexta* dating from 40–15,000 BP (Slack et al., 2004).

Did this late Pleistocene exploitation of freshwater resources require specialised technology? The late Pleistocene toolkit in Australia does not seem to have included barbed or multi-pronged fishing spears or fish hooks. However, it has been proposed that the fish remains from western New South Wales lacustrine middens imply the use of fish nets and/or fish traps, as well as the spearing and clubbing of individual fish (Balme, 1995; Allen, 1998). This proposal is based on the assumption that the various sites represent single foraging expeditions and on the consistent size of otoliths at particular midden sites. Further supporting evidence may be Webb's (1989) proposal that the unusual molar wear evident on LM3 may be the result of plant fibre processing for the manufacture of nets or baskets. If the various proposals for the use of nets, traps, and/or spears were correct, the late Pleistocene exploitation of freshwater resources, in western New South Wales at least, could reflect McBrearty and Brooks' (2000) categorisation of economic intensification, as it involved specialised technology. Bowler (1998), however, dismissed the use of "sophisticated fishing gear" in the Willandra Lakes in favour of the scooping of fish from shallow lake waters, but this idea needs to be demonstrated in the archaeological record.

Marine exploitation and shell middens—33,000 years BP (Table 8)

Due to numerous marine transgressions, the coastline of Greater Australia would have varied throughout the Pleistocene and Holocene, with relative sea-level stabilisation at approximately 6,000 years BP (Beaton, 1995: his Fig. 2). Settlement patterns and resource availability would have been significantly impacted by sea-level transgressions. In coastal regions with a gently sloping continental shelf, there would have been a rapid advance of the sea and retreat of the coastline (see Mulvaney, 1975: his Fig. 20). Also, the littoral fringe of Australia currently does not constitute a single ecological zone, and this situation would probably have applied during the late Pleistocene. A coastal colonisation model for Greater Australia proposed early coastal sites with clear evidence of marine exploitation (Bowdler, 1977, 1990c). As with freshwater shellfish, marine shellfish can provide a rich and reliable food resource (Meehan, 1977; Nicholson and Cane, 1994).

Late Pleistocene exploitation of marine resources is evident in the islands off the northeast and northwest coasts of Sahul (Table 8). Marine shellfish middens dating from at least 33,000 years BP are evident at Lene Hara Cave, East Timor, and Buang Merabak, New Ireland, while at Matenkupkum and Matenbek on New Ireland, and Kilu on Buka Island shellfish and fish remains date to 19–30,000 years BP (Table 8; Allen et al., 1988; Wickler and Spriggs, 1988; Allen et al., 1989a; Gosden, 1993; Beaton, 1995; Wickler, 2001; Leavesley et al., 2002; O'Connor et al., 2002). Late Pleistocene marine exploitation and voyaging capabilities are indicated by these sites.

Well-developed coastal economies and the exploitation of marine resources, especially shellfish from the intertidal zone, are evident at sites in Australia from the mid-Holocene (Beaton, 1985; Nicholson and Cane, 1994; Ulm et al., 1995; Hall and McNiven, 1999; Cane, 2001). However, evidence for late Pleistocene marine exploitation is less clear (Table 8). Early sites with evidence of marine exploitation may have been covered by rising sea levels or sand dune movement, or destroyed by weathering and erosion. Beaton (1985) challenged this concept when he found that within Princess Charlotte Bay on the east coast of Cape York Peninsula, environmental stasis was required for coastal economies to become established. Beaton proposed that coastal resources would have been exploited "in a tentative manner" and that the Holocene record was the "nearly complete archaeological expression of coastal foraging in the past" (1985: 18).

However, there are some sites with reported late Pleistocene evidence of limited marine shellfish exploitation dating from 20–30,000 years BP (Table 8). The Montebello Islands are currently off the northwest coast of Australia, but during periods of low sea levels were joined to the mainland. Noala Cave establishes the presence of indigenous Australians on the continental shelf coastline at 30,000 years BP when the sea would have been approximately 8 km from the site and prior to the continental shelf's inundation by rising sea levels, which stabilised at approximately 6,000 years BP (Veth, 1993). The fauna from this early phase of occupation is predominantly terrestrial, although a single valve of *Polymesoda coaxans* shell was recovered and dated to 27,220 ± 640 years BP (Wk-2905; Veth, 1993). Mandu Mandu Creek rockshelter has shellfish remains dating to 25–22,000 years BP, with well-established utilisation of marine resources after 5,500 years BP (Morse, 1988, 1993b). Beaton (1995) suggested that the early evidence for marine exploitation at Mandu Mandu Creek is negligible and may have been introduced into the late Pleistocene deposits from the mid-late Holocene levels by bioturbation. The nearby site

Table 8
Examples of shell middens in Greater Australia (see also Cane, 2001)

Site	Date	Reference
Willandra Lakes and Lower Darling River system, western New South Wales	Willandra Lakes system from 36,000 BP, possibly 40,000 BP; Lower Darling River system from 27,000 BP, possibly 35,000 BP, to 5,000 BP	Balme and Hope (1990); Hope (1993); Johnston (1993); Balme (1995); Allen (1998); Gillespie (1998)
Murray River, southwestern Australia	Freshwater shell middens at Karadoc Swamp, Merbein Common, and Monak dating from 20–26,000 BP	Richards et al. (2007)
Gulf Country, northwest Queensland	Freshwater *Alathyria* cf. *pertexta* shell middens at rockshelter GRE8 dating to 16,249 ± 120 BP (Wk-12229), 28,360 ± 340 BP (Beta-18431), and 37,110 ± 2,945 BP (Wk-11429), and at site OLH to 12,886 ± 83 BP (Wk-1222), 13,061 ± 81 BP (Wk-12226), and 13,092 ± 85 BP (Wk-11430)	Slack et al. (2004)
Box Gully site, Lake Tyrrell, western Victoria	Limited freshwater mussel shell remains dating to 22,015 ± 125 BP (Wk-166)	Richards et al. (2007)
Lene Hare Cave, East Timor	Shell midden material, consisting of mostly rocky platform species, throughout the deposit from 34,850 ± 630 BP (ANU-11418) to 30,110 ± 320 BP (ANU-11398)	O'Connor et al. (2002)
New Ireland, Papua New Guinea	Buang Merabak: shell midden dating to 32–40,000 BP: 40,090 ± 570 BP (ANUA-15809), 39,090 ± 550 BP (ANUA-15808), 33,270 ± 560 BP (ANUA-16302), and 32,440 ± 570 BP (ANUA-16303) Matenkupkum: shell midden material from 33–21,000 BP, more intensive marine exploitation at 10,000 BP: 33,300 ± 950 BP (shell degraded; ANU-5070), 32,700 ± 1550 BP (shell undegraded; ANU-5070), 32,500 ± 800 BP (ANU-5065), 31,350 ± 550 BP (ANU-5469), 21,280 ± 280 BP (ANU-5953), and 10,890 ± 90 BP (ANU-5467) Matenbek: shell midden material from 19–20,000 BP: 18,560 ± 360 BP (Beta-29009), 19,540 ± 250 BP (Beta-29008), and 20,430 ± 180 BP (Beta-29007)	Allen et al. (1989a); Gosden (1993); Beaton (1995); Leavesley et al. (2002)
Kilu, Buka Island, Solomon Islands	Shell midden material from 28,000 BP – 20,140 ± 300 BP (Beta-26149), 23,200 ± 290 BP (Beta-26150) and 28,740 ± 280 BP (ANU-5990)	Wickler and Spriggs (1988); Wickler (2001)
Lachitu shelter, northern coast of Papua New Guinea	Shell midden material dating to 14-12,000 BP: 12,300 ± 110 BP (ANU-7699), 13,570 ± 200 BP (ANU-7700), and 13,940 ± 160 BP (ANU-7603)	Gorecki et al. (1991)
Montebello Islands, off the central West Australian coast	Noala Cave: a single valve of *Polymesoda coaxans* shell dated to 27,220 ± 640 BP (Wk-2905); sea approximately 8 km from site and prior to the continental shelf's inundation by rising sea levels; clear evidence for exploitation of marine resources from terminal Pleistocene and early Holocene, 8,730 ± 80 BP (Wk-2912) Hayne's Cave: evidence of marine and terrestrial exploitation during the early Holocene 8,240 ± 90 BP (Wk-2911) to 7,460 ± 70 BP (Wk-2914); sea within 4 km of the sites; after c. 7,500 BP, the Montebello Islands appear to have been abandoned, possibly as a consequence of rising sea levels	Veth (1993, 1995)
Mandu Mandu Creek, central Western Australia	Limited evidence of marine exploitation from 25–22,000 BP, with well-established utilisation after 5,500 BP; dates on marine shell: 34,200 ± 1,050 BP (Wk 1513), 30,000 ± 850 BP (Wk 1576), 25,200 ± 250 BP (SUA-2354), 22,100 ± 500 BP (Wk 1575), 20,040 ± 440 BP (SAU-2614), and 5,490 ± 80 BP (Wk 1511)	Morse (1988, 1993a, b); cf. Beaton (1995)
Koolan Shelter 2, West Kimberley	Possibly 24,000 BP, with limited shellfish remains, well established marine economy from 10,850 ± 160 BP (Wk-1099)	O'Connor (1999)
Devil's Lair, southwestern Australia	Isolated remains of estuarine bivalves and marine shell fragments recorded in Pleistocene levels when the coast would have been 10–30 km from the site	Dortch et al. (1984)
Nawamoyn, Arnhem Land	Estuarine and marine shell midden began accumulating from 7,110 ± 130 BP (ANU-53)	Schrire (1982); cf. Beaton (1985)
Aru Islands	Limited estuarine/marine shell preserved in levels dating back to 13,130 ± 80 BP (OZF518) at Liang Nabulei Lisa and 17,750 ± 450 BP (OZC776) at Liang Lemdubu; *Geloina coaxans*, *Terebralia* sp., *Nerita* sp., and *Ellobium* sp. material preserved in late Pleistocene levels; focused marine exploitation is only evident in the late Holocene	O'Connor et al. (2006a,b)
Malangangerr, Arnhem Land	Estuarine and marine shell midden from 5,980 ± 140 BP (GaK-627) to 370 ± 80 BP (GaK-626)	Schrire (1982); cf. Beaton (1985)
Malakunanija II, Arnhem Land	Estuarine midden dating from 6,360 ± 100 BP (SUA-264)	Jones and Negerevich (1985)
Widgingarri Shelters 1 and 2, West Kimberley	Single marine shell dated at 7,780 ± 390 BP (Wk-1101); well-established utilisation of marine shellfish from 4,660 ± 60 BP (Wk-1398)	O'Connor (1999)
Central coast of Western Australia	Wadjuru Rockpool from 8,520 BP; a *Turbo intercostalis* shell collected from an erosion channel on a shell midden at Warroora dated to 7,810 ± 110 BP (SUA-1735); Warroora midden deposit produced shells from a range of mollusk and gastropod species, as well as crab, sea urchin, and fish remains dating from 7,360 ± 115 BP; Silver Dollar shell midden deposits (fish and marine shellfish: mostly *Terebralia* sp.) date to 6,640 ± 260 BP (ANU-7457), 6,950 ± 70 BP (ANU-7456), 7,290 ± 140 BP (Wk 2436), and 7,360 ± 190 BP (Wk 2435); Skew Valley middens on the Burrup Peninsula date to 7,000–2,200 BP; Tulki Well consists almost exclusively of turban shell (*Turbo* sp.) and is dated to 5,660 ± 115 BP (AR-L245); Coral Bay midden dated to 6,270 BP; Mulanda Bluff midden dated to 7,210 BP; marine shell samples from Pilgonaman Creek rockshelter, Cape Range, provided dates of 9,990 ± 270 BP (Wk 1520), 10,150 ± 66 BP (R16098/2), 17,410 ± 66 BP (R11879/1), and 31,770 ± 390 BP (R16098/1); Yardie Well rockshelter, Cape Range, early shell remains and midden deposits dated to 10,490 ± 100 BP (R11879/2) and 7,290 ± 110 BP (Wk 1477)	Kendrick and Morse (1982, 1993); Bowdler (1990a, 1999); Lorblanchet (1992); Bradshaw (1995)

Table 8 (*continued*)

Site	Date	Reference
Nara Inlet 1, Hook Island, Central Queensland	Marine exploitation from at least 8,150 ± 80 BP (Beta 27835) with more intensive marine exploitation from 3,000 BP: between 3,990 ± 60 BP (Beta 31742) and 2,090 ± 50 BP (Beta 28188)	Barker (1989, 1991); cf. Beaton (1995)
Currarong Shelters, south coast of New South Wales	Evidence for exploitation of a range of marine resources by at least 5,540 ± 90 BP (SUA-224) and possibly as early as 7,000 BP	Lampert (1971); White and O'Connell (1982)
Discovery Bay area, southeastern South Australia and southwestern Victoria coasts	Sporadic exploitation of marine resources from 12,000 BP at: Bridgewater South Cave, 11,390 ± 310 BP (Beta-3923), and Koongine, 9,240 ± 100 BP (Beta-15996), 9,590 ± 140 BP (Beta-14862), and 9,710 ± 180 BP (Beta-14861) Discovery Bay middens dating from 9,000 BP, such as: Cape Martin, 8,700 ± 120 BP (NZ 69); Noble's Rock, 8,490 ± 70 BP (Wk-1262), 8,390 ± 80 BP (Wk-605), and 8,340 ± 110 BP (Wk-410); Bevilaqua Cliffs, 8,250 ± 60 BP (GaK 397); Suttons Rocks, 8,230 ± 60 BP (Wk-1263); and East Monbong, 7,960 ± 90 BP (Wk-1105)	Lourandos (1983); Frankel (1986); Godfrey (1989)
Cape du Couedic, Kangaroo Island, South Australia	Shellfish remains, mostly rocky shore species of limpets and periwinkles, dating from 7,320 ± 100 BP (CS 495)	Draper (1987)
Carlton Bluff, southeastern Tasmania	Midden dating from 8,700 ± 200 BP	Porch and Allen (1995)
Point Hibbs, southwestern coast of Tasmania	Midden dating from 5,300 BP	Porch and Allen (1995)
Rocky Cape, northwest coast of Tasmania	Rocky Cape South midden dating from 8,120 ± 165 BP (GXO-266) to 3,700 BP; Rocky Cape North midden dating from 5,425 ± 135 BP (V-89) to at least 450 BP	White and O'Connell (1982); Bowdler (1984); Flood (1995)
Cave Bay Cave, off the northwest coast of Tasmania	Midden deposits from 6,640 ± 100 BP (ANU-1797) and 3,960 ± 110 BP (ANU-1614); later shell midden dating from 2,580 ± 70 BP (ANU-1362) to 990 ± 90 BP (ANU-1616)	Bowdler (1984)
Beeton Shelter, Badger Island, off the northeast coast of Tasmania	Midden deposits from at least 8,700 ± 125 BP (ANU-8752), possibly to 21,890 BP	Flood (1995); Porch and Allen (1995)
Palana Beach, Flinders Island, off the northeast coast of Tasmania	Earliest shell midden dating from at least 7,150 ± 135 BP (SUA-641)	Orchiston and Glenie (1978); Porch and Allen (1995)
Flinders Island off the northeast coast of Tasmania	Five shell middens date within the range of 7–5,000 BP	Porch and Allen (1995)

of Pilgonaman Creek rockshelter also has shellfish, crab, and sea urchin remains in deposits dating from 17,400 to 31,700 years BP, with increasing evidence of marine exploitation from 10,000 years BP (Morse, 1993b, 1999). The late Pleistocene levels at Koolan Shelter 2 reflect a terrestrial economy, but there are limited shellfish remains that may be some 24,000 years old, although intermixing from the shell-rich early Holocene levels cannot be excluded, especially considering the sea may have been over 200 km away from the site (Beaton, 1995; O'Connor, 1999). Sites on the Aru Islands preserve limited estuarine/marine shell in levels dating back to 13,130 years BP at Liang Nabulei Lisa and 16,850 years BP at Liang Lemdubu, although focused marine exploitation is only evident in the late Holocene (O'Connor et al., 2006a,b).

The majority of midden sites along the Australian mainland coast date from after sea-level stabilisation at approximately 6,000 years BP, although terminal Pleistocene-early Holocene sites with estuarine and marine resource exploitation are evident (Table 8; see also Hall and McNiven, 1999; Cane, 2001), including: the Arnhem Land sites of Nawamoyn, Malangangerr, and Malakunanja II, Koolan Shelter 2, Noala Cave, Nara Inlet 1 on Hook Island, Queensland, and Bridgewater South Cave and Koongine, Discovery Bay area of southeastern South Australia/southwestern Victoria (Table 8; Schrire, 1982; Lourandos, 1983; Jones and Negerevich, 1985; Frankel, 1986; Godfrey, 1989; Barker, 1991; Bird and Frankel, 1991; Veth, 1993; O'Connor, 1999). On the northern coast of Papua New Guinea at Lachitu shelter shell midden material dates to 14–12,000 years BP (Gorecki et al., 1991). Tasmania, which became an island some 10,500 year ago, presents a different picture to other parts of Greater Australia in that marine based economies appear to be well-established in the early Holocene from at least 8,000 years BP at sites like Carlton Bluff, Rocky Cape South, and Beeton Shelter (Table 8; Nicholson and Cane, 1994; Porch and Allen, 1995; Cane, 2001). It has also been suggested that bone points from some coastal Tasmanian sites may have been used as spear points for spearing and gutting fish or for the manufacture of fishing nets (Bowdler, 1984; Flood, 1995).

Pleistocene sites on islands off the northern Sahul coast document marine shellfish and fish exploitation from 20,000–40,000 years BP (Table 8). The evidence for this from Greater Australia is equivocal, with late Pleistocene sites suggesting that marine resources were only exploited "in a tentative manner" and were secondary to exploitation of terrestrial resources (see discussions in White and O'Connell, 1982; Nicholson and Cane, 1994). As noted by Beaton (1985), there is a difference between coastal use and coastal economies, with the latter being a significantly more focused exploitation regime, which only appears in Australia during the Holocene. Also, Nicholson and Cane observed that in Greater Australia there was "an ancient marine tradition which intensified, diversified, and became more sophisticated over the last few thousand years" (1994: 114). Some marine shellfish, including baler (*Melo* sp.), pearl shell (*Pinctada* sp.), and clam (*Tridacna* sp.), would also have been resources for tools, water carriers, adornments and traded commodities more than food resources (O'Connor, 1995, 1999; Morse, 1996; Smith and Allen, 1999; Balme, 2000).

For Greater Australia suggestions of specialised technology for the exploitation of marine resources remain speculative, with the best evidence coming from the islands off the northern Sahul coast. At Kilu and Matenkupkum the presence of pelagic fish remains in late Pleistocene deposits suggest offshore angling, netting, and/or fish traps (compare Allen et al., 1989a, and Wickler, 2001). Lene

Hara Cave, East Timor, provides the earliest shell fish hook from the region, which dates to the early Holocene (O'Connor and Veth, 2005). However, a worked piece of *Trochus* shell was recovered from late Pleistocene deposits at Matenbek, New Ireland, and is similar to later Holocene shell fish hook blanks from the Bismarck Archipelago, so the antiquity of shell fish hooks may extend back into the Pleistocene (Smith and Allen, 1999).

Macropods—30,000 years BP

The intensive exploitation of a particular species, the red-necked or Bennett's wallaby (*Macropus rufogriseus*), is evident at late Pleistocene sites in southwest Tasmania from 30,000 years BP. At sites including Kutikina, Nunamira Cave, and Bone Cave, Bennett's wallaby accounts for some 85% of the faunal material recovered (Ranson et al., 1983; McNiven et al., 1993; Cosgrove and Allen, 2001). The data from these late Pleistocene southwest Tasmanian sites have been interpreted as indicating seasonal hunting (autumn, late winter/early spring) and prey age selection by indigenous groups targeting macropods that were "ecologically tethered" to open grassland areas (Cosgrove et al., 1990; Holdaway and Cosgrove, 1997; Cosgrove and Allen, 2001; Cosgrove and Pike-Tay, 2004). Pleistocene bone points from some of these sites have use-wear indicative of hafting for spear points (Webb and Allen, 1990; but see Cosgrove and Pike-Tay, 2004).

Although it remains speculative and we are dealing with simple unipoints and bipoints, late Pleistocene bone artefacts from Tasmanian sites could equate with McBrearty and Brooks' (2000) categorisation of economic intensification involving specialised technology, as these artefacts may have been developed to facilitate the intensive exploitation of particular terrestrial and marine resources.

Grindstones—30,000 years BP (Table 9)

Another example that may fit McBrearty and Brooks' (2000) scenario of intensive resource exploitation requiring specialised technology was the apparent appearance of grass seed grindstones, initially thought to have been established at 12–15,000 years BP and linked to the habitation of arid zones within Greater Australia (Smith, 1986; Balme, 1991). This pattern, however, has changed with earlier late Pleistocene grindstones having now been recovered in Greater Australia (Table 9). Australian grindstone morphology has been categorised into various types (Smith, 1986), although it has been suggested that the "formal grindstone types" may be the end product of use over a prolonged or intensive period (Gorecki et al., 1997). For this discussion, the term "grindstone" will be used to cover all proposed types.

At Cuddie Springs, western New South Wales, 26 grindstone fragments have been recovered from "stratified contexts" along with bones of megafauna and stone tools from levels proposed to span the period from 35–28,000 years BP (Dodson et al., 1993; Fullagar and Field, 1997; Field and Dodson, 1999). The first appearance of grindstones is said to coincide with a change in the pollen record, which is interpreted as indicating a local vegetational change to grassland (Field and Dodson, 1999). Use-wear and residue analyses revealed starchy and siliceous plant residues, animal residues, and use-polish suggesting wet milling of seeds. Fullagar and Field concluded that the Cuddie Springs grindstones provided "strong evidence for a seed-grinding economy around 30,000 BP" (1997: 305). However, issues with the stratigraphic integrity of the Cuddie Springs deposits remain, especially with a 5 cm deposit described as a "deflation pavement" that is argued to have sealed the late Pleistocene deposits (David, 2002; Gillespie and Brook, 2006; but see Trueman et al., 2005; Field, 2006). Also, some of the other finds from Cuddie Springs do not equate with chronological placements elsewhere in mainland Australia. In mainland Australia thumbnail scrapers and tulas appear in the mid-to-late Holocene (Flood, 1995; Mulvaney and Kamminga, 1999), whereas at Cuddie Springs they were recovered from levels older than 19,000 years BP. Similarly, a ground cylindrical stone artefact recovered from Cuddie Springs is similar to ritually significant cylcons that are surface finds elsewhere in western New South Wales (Dodson et al., 1993; Bednarik, 1998).

Residue from a potentially toxic fern—nardoo (*Marsilea drummondii*)—possibly identified on some Cuddie Springs grindstones has been interpreted as indicating the grinding and leaching of toxic plants at 30,000 years BP (Fullagar, 2006), whereas elsewhere in Australia this practice appears to be limited to the last 5,000 years, although it may have occurred during the terminal Pleistocene (Cosgrove, 1996; Mulvaney and Kamminga, 1999). The ongoing debate over the stratigraphic integrity of Cuddie Springs, grindstones that are similar to late Holocene and ethnographic examples, as well as the "unique discoveries" detailed above, could be suggestive of mixed deposits (but see Fullagar, 2004; Trueman et al., 2005; Field, 2006).

In Arnhem Land at Nauwalabila I, what have been referred to as grinding slabs are possibly 22,000 years old (Jones and Johnson, 1985b). Also, at Malakunanja II, three grindstones, including one stained with ochre, were recovered from levels that are at least 18,000 years old (Jones and Negerevich, 1985). Bowler (1998) has

Table 9
Grindstones in Greater Australia

Site	Date and associations	Reference
Cuddie Springs, western New South Wales	Over 30 grindstone fragments recovered, 26 from "stratified contexts", from levels proposed to date from 35,000–28,000 BP; AMS dates of 28,770 ± 300 BP (Beta 81377), 30,990 ± 360 BP (Beta 81381), and 33,660 ± 530BP (Beta 81379); OSL age of 35,400 ± 2,800 BP	Dodson et al. (1993); Fullagar and Field (1997); Field and Dodson (1999); cf. David (2002); Gillespie and Brook (2006)
Arnhem Land	Nauwalabila I: grinding slabs throughout Pleistocene and Holocene levels; the earliest possibly 22,000 years old: 21,450 ± 380 BP (ANU-51); ochre pieces with grinding facets from 20,000–30,000 BP levels Malakunanja II: three grindstones found in levels dated to at least 18,000 BP, one stained with ochre: 18,040 ± 300 BP (SUA-265) Blue Paintings site: grindstone fragment dated at 7,900 ± 200 BP (ANU 3210) Nawamoyn and Malangangerr: stone pounders recovered from the late Pleistocene and Holocene	Schrire (1982); Jones and Johnson (1985a,b); Jones and Negerevich (1985)
Lake Mungo, Willandra Lakes, western New South Wales	Possible evidence for late Pleistocene grinding activity	Bowler (1998)
Miriwun, East Kimberley	Quartzite fragments which may be parts of grindstones or anvils in levels bracketed by dates of 17,980 + 1,370-1,170 BP (ANU-1008) and 2,980 ± 95 BP (SUA-142)	Dortch (1977)

also argued for grinding activity (not grindstones) at Lake Mungo older than 15,000 years BP, but this needs to be confirmed.

Whilst the Cuddie Springs site may indicate a seed-grinding economy around 30,000 years ago, elsewhere in Greater Australia grindstones only appear at 22–18,000 years BP at the earliest, if not closer to 15,000 years BP. If the Cuddie Springs grindstones were actually Holocene in age, the earliest grindstones would be multi-functional grinding tools from northern Australia (Table 9), with seed grinding tools a later, possibly Holocene introduction (Smith, 1986, 1989; Balme, 1991).

The exploitation of freshwater and, to a lesser extent marine, shellfish, macropods in southwest Tasmania, and possibly the use of grindstones indicate that intensive resource exploitation (economic intensification?) was an important component of the late Pleistocene foraging strategies of the indigenous inhabitants of Sahul and the larger offshore islands. As Balme observed, "two regional sources of data, the lower Darling and southwest Tasmania, evidence efficient and highly developed exploitation of two environmentally distinct areas" (1995: 20).

Worked bone and other organic materials—22,000 years BP (Table 10)

Artefacts made from organic materials in Greater Australia include a few instances of wooden tools—which, as expected, are rarely preserved—and tools made of bone. Wyrie Swamp, South Australia, has produced 25 wooden artefacts made from sheoak (*Casuarina stricta*) dated to 10,200 years BP (Luebbers, 1975), but is the only prehistoric site known to contain such implements. They include digging sticks, boomerangs, and one-piece spears. Within this context it is interesting to note that the LM3 individual had severe osteoarthritis of the right elbow caused in part by repetitive stress from use of an implement such as a spear thrower (Webb, 1989). Furthermore, stone tools most probably used for woodworking also occur throughout Greater Australia during the late Pleistocene and Holocene.

The bone artefacts comprise mostly simple bone points (Table 10), a term used to cover a variety of forms (cf. Lampert, 1971; Bowdler, 1984; Webb and Allen, 1990; Pasveer, 2006). Late Pleistocene bone points can broadly be categorised as sharp unipoints, small bipoints, or rounded spatulate-ended bone tools. They are generally made from macropod fibulae and often display use-wear.

Thirteen bone points were recovered from Devil's Lair, with the oldest dating to possibly 26,000 years BP, although the majority are dated to less than 20,000 years BP (Table 10; Fig. 8; Dortch and Merrilees, 1973; Dortch, 1984, 2004). Several sites in Tasmania have yielded bone tools from late Pleistocene contexts. In southwest Tasmania, bone points date from about 14,000–29,000 years BP at Bone, Warreen, and Kutikina caves (Table 10; Ranson et al., 1983; Allen et al., 1989b; Webb and Allen, 1990). Cave Bay Cave in northern Tasmania produced a spatulate tool form and a point dated to 20,800–22,800 years BP, a spatulate-ended tool dated to 19,520 years BP, and a ground bone point dated to 18,550 years BP (Bowdler, 1984). Bone artefacts recovered from sites in the southern highlands of Victoria include a sharp, highly polished bone point from levels bracketed by dates of 13,690 and 17,720 years BP at Clogg's Cave, and four bone points dating between 4,600 years BP and 21,000 years BP from New Guinea II rockshelter (Flood, 1980; Ossa et al., 1995). At the South Australian site of Seton on Kangaroo Island, two bone points are dated to 10,940 years BP (Lampert, 1981).

Davidson and Noble (1992: their Table 1) indicated there was ground bone from the Papua New Guinea site of Batari dating to 16,850 years BP, but this date may not relate to early occupation at the site. Furthermore, a complete bone unipoint from the site is unstratified, while smaller bone points—including a bipoint—are either unstratified or from deposits dating to less than 8,230 ± 190 years BP (ANU-38a; White, 1972). Bone points that may date to the terminal Pleistocene have been recovered from the Aru Islands (Table 10). At Liang Lemdubu 3, bone points are dated between 9,000 and 18,000 years BP (O'Connor et al., 2006b; Pasveer, 2006). Eleven bone tools, mostly unipoints and spatulae, were found in levels dated to 9–13,000 years BP at Liang Nabulei Lisa (O'Connor et al., 2006a; Pasveer, 2006). Both sites also provide mid-to-late Holocene bone points. Whilst the dating of the levels from which the bone points were recovered seems secure, it should be noted that the dating sequences at both sites display age depth reversals, which may infer some sediment disturbance (O'Connor et al., 2006a,b).

The majority of sites with late Pleistocene bone points are in southern Greater Australia (Table 10), where they may have been used in skin working and cloak making in these colder southern regions. Analyses of use-wear evident on bone points from Tasmanian sites indicate that the tools were used in clothing manufacture [what Gilligan (2007) would call "simple clothes"]. That is, fine bone points were used for piercing skins, flat-tipped points for scraping skins, and spatulae as cloak fasteners or toggles (Webb and Allen, 1990). Thumbnail scrapers found at southwest Tasmanian sites (see below) may also have been used for scraping animal skins as part of clothing manufacture. The bone points from the Aru Islands may have been used for drilling, piercing, or engraving activities (Pasveer, 2006). Some Pleistocene bone points from Tasmania may also have been used for pressure flaking stone tools, as a pressure-flaked denticulate flake with 12 "teeth" along a 15-mm edge was recovered from Bone Cave and dated to 23,000 years BP (Allen, 1989; Cosgrove et al., 1990: their Fig. 7). Bone points from sites in northern Greater Australia may also have been used for pressure flaking in the manufacture of stone points, but these only date to the Holocene epoch (O'Connor, 1996, 1999). As noted earlier, it was also proposed that bone points from some coastal Tasmanian sites may have been used as fishing spear points or in the manufacture of fishing nets, but this remains speculative.

New lithic technologies

The introduction of new lithic technologies, such as ground stone artefacts and blade technology, is a key component of the "package" of archaeologically visible evidence for modern human behaviour and the proposed "human revolution".

Late Pleistocene assemblages

Within Greater Australia, late Pleistocene stone tool assemblages are flake-based with few formal types, mostly scraper forms, and are dominated by retouched and unretouched flakes (Mulvaney, 1975; White and O'Connell, 1982; Mulvaney and Kamminga, 1999). They have been viewed as typologically amorphous and technologically homogeneous and were encompassed within the broad label of the "Australian Core Tool and Scraper Tradition/Phase", although this concept has been challenged (Allen, 1998; Shawcross, 1998; Mulvaney and Kamminga, 1999; Hiscock and Allen, 2000; McNiven, 2000; Hiscock and Attenbrow, 2003). Foley and Lahr (1997) suggested that Pleistocene stone tool assemblages in Greater Australia could be encompassed within Clark's (1977) Mode 3 lithic technologies—flake tools from prepared cores, but they lack the formal secondary shaping found elsewhere, resulting in a strong retention of Mode 1 elements. Bowdler (1993) described the early assemblages as a travelling survival kit with a flexible and opportunistic repertoire. These late Pleistocene assemblages display regional and temporal variation but do not generally include those components that McBrearty and Brooks (2000: their Table 3) identified as signals for modern human

Table 10
Examples of bone and wooden tools in Greater Australia

Site	Date and associations	Reference
Tasmania	Bone tools from a number of southwest Tasmanian sites: 13 bone tools recovered from deposits dated 14–29,000 BP at Bone Cave: 13,700 ± 860 BP (Beta-26509) and 29,000 ± 520 BP (Beta-29987); six bone tools recovered from deposits dated 18–22,000 BP at Warreen Cave: 17,880 ± 135 BP (Beta-42066) and 21,980 ± 310 BP (Beta-26960); stout bone unipoint at Kutikina Cave, dated 20–15,000 BP Several bone points and other bone artefacts from Cave Bay Cave, including: a spatulate bone tool form and a bone point from contexts dated to between 20,850 ± 290 BP (ANU-1612) and 22,750 ± 420 (ANU-1498) BP; a spatulate-ended bone tool from a level dated to 19,520 ± 300 BP (ANU-1774); a 90-mm-long ground bone point made from a macropod fibula associated with charcoal dated to 18,550 ± 600 (ANU-1361) BP; four bone points from the mid-Holocene shell midden deposits dating from 6,640 ± 100 (ANU-1797) and 3,960 ± 110 (ANU-1614) BP Thirty-seven bone points from the Rocky Cape sites, especially Rocky Cape South: from deposits dating 3,500–8,000 BP with the majority dating 5–8,000 BP	Bowdler (1977, 1984); White and O'Connell (1982); Ranson et al. (1983); Allen et al. (1989b); Webb and Allen (1990); Flood (1995); Holdaway and Porch (1996)
Devil's Lair, southwestern Australia	13 bone points, the oldest may be 26,000 BP; most date to less than 20,000 BP; one specimen is a 149.42-mm-long unipoint made on a whole macropod fibula directly associated with charcoal; original date 19,250 ± 900 BP (SUA-33) now rejected and replaced with 24,930 ± 335 BP (AA 19690); others are small 20-mm-long bipoints made on macropod long bone segments; a small bone object, described as a bone awl, 14 mm long and made on the proximal end of a bird fibula with a highly polished and pointed distal end	Dortch and Merrilees (1973); Dortch (1984, 2004: his Table 6.3)
Clogg's Cave, southern highlands of Victoria	Bone point recovered from levels bracketed by dates of 13,690 ± 350 BP (ANU-1182) and 17,720 ± 840 BP (ANU-1044); "burnishing pebbles" from late Pleistocene levels, which are used for rendering skins soft and pliable	Flood (1980)
New Guinea II, southern highlands of Victoria	Four bone points on macropod fibulae dating between 4,660 ± 110 BP (SUA-2217) to 21,000 + 900/−800 BP (SUA-2222)	Ossa et al. (1995)
Seton, Kangaroo Island, South Australia	Two bone points with use-wear from deposits dated to 10,940 ± 60 BP (ANU-925)	Lampert (1981)
Roonka, South Australia	Bone points recovered from elaborate burials, including a large 29-cm-long piece possibly used as a "pointed bone dagger" from Grave 106, dated 8–4,000 BP; numerous bone pins used to fasten an animal skin cloak recovered from Grave 108, which postdates 4,000 BP	Pretty (1977); Flood (1995); Pate et al. (1998)
Arnhem Land	Variety of bone points throughout the midden deposits at Nawamoyn and Malangangerr, which accumulated from 7,110 ± 130 BP (ANU-53); no bone points from the Pleistocene sand layers below the midden deposits	Schrire (1982)
Batari, Papua New Guinea	Ground bone from the site dates to 16,850 ± 700 BP (ANU-40); early date may not relate to early occupation at the site; small bone points, including a bipoint, either unstratified or from deposits dating to <8,230 ± 190 BP (ANU-38a); complete but unstratified bone unipoint	White (1972); Davidson and Noble (1992: their Table 1)
Koongine Cave, South Australia	A bone point po ssibly dating to between 9–10,000 BP: 9,240 ± 100 BP (Beta-15996) and 9,710 ± 180 BP (Beta-14861)	Frankel (1986)
Aru Islands	Liang Lemdubu: three bone points dated to 9–18,000 BP: one between 9,250 ± 60 BP (OZF357) and 16,570 ± 510 BP (OZD460) and two around 16,770 ± 110 BP (AA-32848), 16,850 ± 120 BP (OZF248), 17,750 ± 450 BP (OZC776), and 13,300 ± 300 BP (OZC777) Liang Nabulei Lisa: 11 bone tools, mostly unipoints and spatulae, recovered from levels dated 9–13,000 BP: 8,420 ± 50 BP (OZF030), 9,320 ± 60 BP (OZD696), 9,630 ± 60 BP (OZD697), 9,750 ± 60 BP (OZD698), 9,870 ± 70 BP (OZD699), 9,450 ± 60 BP (OZD700), and 9,850 ± 60 BP (OZD702)	O'Connor et al. (2006a,b); Pasveer (2006)
Widgingarri Shelters 1 and 2, West Kimberley	Ground bone points and bone "indenters" in late Holocene levels in conjunction with the appearance of stone points with pressure flaking; bone points may be pressure-flakers	O'Connor (1996, 1999)
Wyrie Swamp, South Australia	25 wooden sheoak (*Casuarina stricta*) artefacts, including digging sticks, boomerangs and one piece spears with simple sharp points or with barbs; date between 8–10,200 BP: 10,200 ± 159 BP (ANU-1292) and 8,990 ± 120 BP (ANU-1293)	Luebbers (1975)

behaviour, namely: increasing artefact diversity; standardisation within formal tool categories; new lithic technologies (blade technology, backing); special purpose tools (projectiles, geometrics); and hafting and composite tools.

As noted above, there is a degree of regional and temporal variation, with assemblages that have a small component of backed artefacts being found at a number of mainland sites by the terminal Pleistocene and earlier in Tasmania (Hiscock and Attenbrow, 1996, 1998; McNiven, 2000; Slack et al., 2004). Southwest Tasmanian sites have also produced small and relatively standardised thumbnail scrapers dating from 24,000 years BP (Ranson et al., 1983; Cosgrove, 1995; Porch and Allen, 1995; Holdaway, 2004). These possibly special-purpose thumbnail scrapers could have been used as hand-held multi-purpose scraping/cutting tools (clothing manufacture?) or specialised blades on multi-component tools (Mulvaney and Kamminga, 1999).

Edge-ground and waisted hatchets—40,000 years BP (Table 11)

In northern Sahul (New Guinea, the Kimberleys, Arnhem Land, and Cape York Peninsula), a "new lithic technology" that is evident in late Pleistocene stone-tool assemblages is edge-ground and/or waisted adzes/hatchets (Table 11). Waisted adzes/hatchets (hatchets) incorporate what have been referred to in this region as notched, grooved, shouldered, tanged, or stemmed adzes/hatchets/blades or butt-modified artefacts (Groube, 1986; Golson, 2001).

Fig. 8. A selection of bone points from Devil's Lair, southwestern Australia (courtesy of the Western Australian Museum).

These artefacts seem to have been waisted or grooved to facilitate hafting (Bulmer, 1977; Golson, 2001). Edge-ground and/or waisted hatchets could have been used for a range of adzing and axing activities, including ring-barking and clearing trees and undergrowth; modifying and working wood; making watercraft; and chopping holes in trees to hunt possums and collect honey.

At the Bobongara site on the Huon Peninsula, Papua New Guinea, three large waisted hatchets were recovered from a stream gully running into a palaeolagoon on reef terrace IIIa, which is one of a series of raised coral terraces covered by volcanic tephras (Groube et al., 1986; Golson, 2001). These excavated waisted hatchets can be dated to between 40,000 and 61,000 years BP (Allen and O'Connell, 2003; O'Connell and Allen, 2004). More than 100 other waisted hatchets were collected from the general area (Groube et al., 1986). Other Papua New Guinea sites have produced similar waisted artefacts. At Kosipe and Nombe they are dated to approximately 25,000–26,000 years BP, at Kuk to about 20,000 years BP, and at Yuku to older than 12,000 years BP (Bulmer, 1977; White and O'Connell, 1982; Mountain, 1991; Golson, 2001).

Waisted hatchets are not commonly found in Australia, but a number have been recovered on Kangaroo Island, some of which could possibly be late Pleistocene in age (Lampert, 1981; Morwood and Trezise, 1989: their Fig. 1; Golson, 2001).

Although Nombe has some Pleistocene examples, edge-ground hatchets generally appear at sites in Papua New Guinea during the Holocene (Mountain, 1991; Holdaway, 1995; Hope and Golson, 1995; Golson, 2001). An interesting variation is found at Pamwak rockshelter on Manus Island, Admiralty Islands, where 16 edge-ground *Tridacna* shell artefacts were found along with five edge-ground stone hatchets/adzes in levels dated from 5,500 to 12,000 years BP (Fredericksen et al., 1993; see also Smith and Allen, 1999).

Late Pleistocene edge-ground hatchets are more commonly found in northern Australia (Table 11). At Sandy Creek 1 rockshelter, an edge-ground, waisted, and grooved hatchet was recovered and dated to possibly 32,000 years BP (Morwood and Trezise, 1989). Two other southeast Cape York Peninsula sites have provided evidence of early edge-ground artefacts—Early Man rockshelter and Mushroom Rock (Table 11). Evidence of Pleistocene edge-ground artefacts also comes from the Kimberley sites of Miriwun and Widgingarri Shelters 1 and 2, with the earliest examples being from the latter site where volcanic stone flakes were possibly detached from the edges of ground stone hatchets and date to about 28,000 years BP (Table 11; Dortch, 1977; O'Connor, 1996, 1999). Fourteen edge-ground hatchets were recovered at the Arnhem Land sites of Malangangerr and Nawamoyn, some dating between 18,000 and 24,000 years BP (Schrire, 1982; but see Golson, 2001). Schrire (1982) has interpreted four hatchets found together beneath an overhang at Nawamoyn as a Pleistocene edge-ground hatchet cache.

Late Holocene assemblages <5,000 years BP

Backed artefacts (geometric microliths, Bondi points), bifacial and unifacial points, thumbnail scrapers, and tulas (adzes), which could be proposed as signals for modern human behaviour (McBrearty and Brooks, 2000; Wadley, 2001), generally appear in the mainland Australian archaeological record during the mid-to-late Holocene (Mulvaney, 1975; White and O'Connell, 1982; Jones and Johnson, 1985a,b; Flood, 1995; Mulvaney and Kamminga, 1999; cf. Bird et al., 1998). These new or more commonly occurring stone tool types have more standard shapes than earlier forms and are suitable for hafting and incorporation into composite tools. The chronological and geographical distributions of these new elements are "individual", in that they do not appear as a "set" in the archaeological record or as a single chronological event (Mulvaney, 1975; Schrire, 1982; White and O'Connell, 1982; Jones and Johnson, 1985a,b; Flood, 1995; Mulvaney and Kamminga, 1999). They also do not replace the earlier assemblages, but either become more prevalent over time, as with backed artefacts, or they are added to the assemblages.

Scenarios that account for this late Holocene pattern of stone assemblage innovation have included simple functional explanations, such as the development of more task-specific and extractively-efficient tool forms, through to complex discussions of intensification involving demographic and socioeconomic change, increasing intergroup exchange networks, risk reduction strategies during periods of environmental change, and stylistic phenomena (White and O'Connell, 1982; Hiscock, 1994; Lourandos and Ross, 1994; Mulvaney and Kamminga, 1999).

Discussion

As detailed earlier, McBrearty and Brooks (2000) challenged the concept of a "human revolution" at approximately 50,000 years BP by documenting in MSA Africa the gradual assembling of the "package" of archaeologically visible traits for modern human behaviour over a 200,000-year period and proposed that the "package" was then exported to other regions of the Old World by colonising groups of anatomically modern humans. By examining the late Pleistocene archaeological record of Sahul, it has been possible to assess if this region was one of the other regions of the

Table 11
Edge-ground and waisted hatchets in Greater Australia

Site	Date and associations	Reference
Papua New Guinea sites	*Huon Peninsula*: Bobongara: over 100 waisted hatchets, three from excavations, dated at possibly greater than 40,000 BP Kosipe: 20 waisted and edge-ground hatchets, the earliest dating to possibly 26,000 BP (26,870 ± 590 BP; 26,450 ± 880 BP) Nombe: two waisted and stemmed hatchets dating to possibly 25,000 BP Kuk: a waisted hatchet dating to around 20,000 BP Yuku: two waisted hatchets older than 12,100 ± 350 BP (GX-3112B), with up to 18 in more recent levels	Bulmer (1977); White and O'Connell (1982); Groube et al. (1986); Golson (2001); Allen and O'Connell (2003, 2004)
Kangaroo Island sites, South Australia	Waisted hatchets, possibly late Pleistocene or early Holocene in age	Lampert (1981); Golson (2001)
Mackay, Central Queensland	Waisted hatchets, but surface finds	Groube (1986)
Pamwak rockshelter, Manus Island, Admiralty Islands	Five edge-ground stone hatchets/adzes; 16 edge-ground *Tridacna* shell artefacts; levels dated to 5,500–11,000 BP: 11,730 ± 280 BP (ANU-7124) and 12,400 ± 80 BP (ANU-6980)	Fredericksen et al. (1993)
Southeast Cape York sites	Sandy Creek 1: edge-ground, waisted, and grooved pink quartzite hatchet found on bedrock stratigraphically equated with 31,900 + 700/−600 BP (SUA 2870); a flake with a ground surface from early Holocene levels Sandy Creek 2: an edge-ground hatchet fragment from basal rubble dating in excess of 10,300 ± 1,700BP (TL date-sample W1209) Early Man rockshelter: flakes with grinding marks, probably from edge-ground hatchets, dated to the terminal Pleistocene Mushroom Rock: fragments of edge-ground hatchets recovered from base of deposits and well below a date of 6,870 ± 150 BP, so possibly late Pleistocene in age	Wright (1971b); Rosenfeld (1981); Morwood and Trezise (1989); Morwood et al. (1995b); Morwood (2002)
Kimberley sites	Widgingarri Shelters 1 and 2: flakes of volcanic stone possibly detached from the working edges of ground stone hatchets from levels dated to 28,060 ± 600 BP (R11795); ground stone artefacts also recovered from Holocene levels at these sites	O'Connor (1996, 1999)
	Miriwun: single flake possibly detached from the working edge of a ground stone hatchet dating to 17,980 + 1,370/−1,170 BP (ANU-1008); edge-ground hatchet dated to between 1,675 ± 185 BP (SUA-141) to 2,980 ± 95 BP (SUA-142)	Dortch (1977)
Arnhem Land sites	Malangangerr: five edge-ground hatchets, one described as "waisted", from lower sand deposits dating between 18,000 ± 400 BP (ANU-19) to 22,900 ± 1,000 BP (ANU-77b); a large flake that may be an incomplete edge-ground hatchet; ground schist "rod" that may have been part of a larger ground tool from the lower sand deposits; ground sandstone "rod" from the lower unit within the midden dated from 5,980 ± 140 BP (GaK-627)	Schrire (1982)
	Nawamoyn: nine edge-ground hatchets from Holocene and late Pleistocene levels; rock with small depression ground into its surface; 22 pebbles showing signs of pounding; some dating to at least 21,450 ± 380 BP (ANU-51) others older than 7,110 ± 130 BP (ANU-53)	Schrire (1982)
	Anbangbang 1: ground hatchet from levels older than 5,770 ± 100 BP (ANU-3206)	Jones and Johnson (1985a)
	Nauwalabila I: weathered pieces of exotic dolerite have the general shape of hatchet blanks or actual hatchets, but due to weathering and erosion cannot be determined if the edges were ground from levels that date in excess of 19,975 ± 365 BP (SUA 237) and are possibly 25–30,000 years old; small flakes possibly from the cutting edges of edge-ground hatchets, the lowest example possibly dating between 13,195 ± 175 BP (SUA 236) and 19,975 ± 365 BP (SUA 237)	Jones and Johnson (1985b)
	Jimeri I: two small edge-ground hatchets of porphyritic dolerite dating from 3,820 ± 100 BP (ANU-52) and possibly to 10,790 ± 100 BP (GaK-632)	Schrire (1982)
	Jimeri II: eleven small edge-ground hatchets of porphyritic dolerite and possible waist flakes from manufacture and/or use from deposits dating from 6,650 ± 500 BP (ANU-18) to 4,779 ± 150 BP (ANU-50)	Schrire (1982)

Old World where the "package" was exported. If this proposal were correct, at the time of the colonisation of Sahul at around 50,000 years BP, the earliest Australians should have possessed the "package" of modern human behaviour. McBrearty and Brooks' (2000) proposal is not supported by our review in that the "package" is not evident at the earliest sites in Sahul. However, it needs to be emphasised that the earliest inhabitants of Sahul **were** anatomically and behaviourally fully modern. These indigenous peoples used boats to cross open ocean to colonise Sahul, adapted to a diverse range of environments as they moved throughout the continent, and developed a unique material culture.

The late Pleistocene archaeological record of Sahul illustrates a gradual assembling of the "package" over a 30,000-year period following initial occupation of the continent (Fig. 9). This is a similar pattern to that observed by McBrearty and Brooks (2000) in Africa over a 200,000-year period. Also, the components of the "package" appear at sites that are separated in space and time and so do not suddenly occur together. From their more limited review, Brumm and Moore (2005) argued that there were only isolated examples of "symbolic storage" in the late Pleistocene archaeological record of Australia, whereas there was a "symbolic/human revolution" within the mid-to-late Holocene. Similarly, O'Connell and Allen (2007) downplay the appearance of "indicators of modernity" prior to the LGM, and contend that the increasing occurrence of the traits following this period was causally linked to population increase.

Rather than a poor representation or patchy distribution, our detailed review has identified that the presence of the individual traits reveals both chronological and geographical patterning in the archaeological record of Greater Australia, although not every site has all of the traits during the same period (Franklin and Habgood,

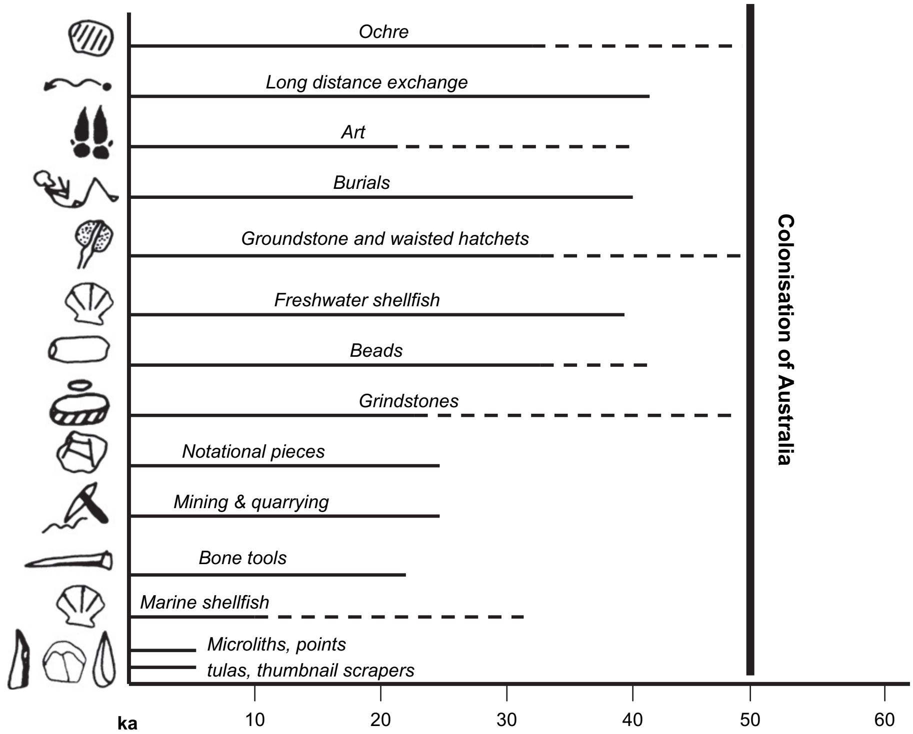

Fig. 9. Diagram showing behavioural innovations in Pleistocene Sahul.

2007). Following initial colonisation of the continent, terrestrial fauna are the dominant resources exploited, but freshwater shell middens are apparent around the palaeoriver and lake systems of southeast Australia. Long-distance transport and/or exchange networks are evident, as is collection and use of ochre for ritual behaviour (burial) and rock painting. Stone assemblages are dominated by retouched and unretouched flakes, but waisted hatchets are found in Papua New Guinea at this time. By 30,000 years BP, an expansion in resource exploitation may be signified by evidence of marine exploitation on islands off the northern coast of Sahul, the (possible) appearance of grindstones, and the intensive exploitation of macropods in southwest Tasmania. Flake-based stone tool assemblages are augmented by the introduction of ground stone hatchets in northern Australia and small thumbnail scrapers in southwest Tasmania. Personal ornaments in the form of shell beads are also present in northwestern Australia at this time. By 20–18,000 years BP the variety of personal ornaments has expanded to include bone beads, pendants, and notational pieces. Although there is evidence of painting of some form by 40,000 years BP, identifiable art does not appear until around 20,000 years BP. Flint mining is evident at this time, and the flake-based stone tool assemblages are supplemented with bone points made on macropod long bones in the southeast of the continent.

Inferences

Mellars (2006a) reaffirmed the position that modern humans left Africa with the "package" and colonised Europe, southern Asia and, ultimately, Australia. Whilst there is evidence from chronological data, skeletal morphology, and the archaeological record for a movement of anatomically modern humans into and across Europe from 40,000 years BP and the replacement (with or without direct interaction and/or hybridisation) of the indigenous Neanderthals, a movement of modern humans into eastern and southern Asia at this time is less clear-cut (see Mellars and Stringer, 1989; Bräuer and Smith, 1992; Foley and Lahr, 1997; Churchill and Smith, 2000; Klein, 2000; Stringer, 2002; Habgood, 2003).

As we have demonstrated, the entire "package" of traits is not evident in the late Pleistocene archaeological record of Sahul (Fig. 9). There is however, a pattern and/or tradition of symbolic behaviour within Sahul following initial colonisation with the manufacture of personal ornaments, use of ochre as a colourant, and burial of the dead. Some of the archaeologically visible traits, such as bone tools, personal ornaments, and rock art, remain uncommon within the archaeological record of Greater Australia until the terminal Pleistocene and are more commonly found during the mid-to-late Holocene.

Henshilwood and Marean (2003) highlighted how taphonomy can complicate the evaluation of the presence/absence of these "archaeologically visible" traits. Bednarik (2003) also argued that the archaeological record is biased due to taphonomic processes. Hiscock (Hiscock and Allen, 2000; Hiscock, 2001) proposed that the presence or absence of rare artefact types can be related to the size of an assemblage, and that some types of implements may only be present in large assemblages and not in small ones. The inference from these cautionary statements is that much of the variation found in late Pleistocene assemblages may simply be a consequence of archaeological sampling. Multiple factors would impact on site assemblages, including site type and location, intensity and regularity of use, sampling strategies, and taphonomic processes, as well as material culture differences. However, the presence of components of the "package" of traits at late Pleistocene sites in Greater Australia is not necessarily linked to the size of the excavation, amount of artefacts recovered, or the intensity of site usage in prehistoric times. Some sites with small assemblages have produced unique finds, while others with large assemblages produced few components of the "package"—compare Riwi Cave, Carpenter's Gap, Devil's Lair, Mandu Mandu Creek rockshelter, and southwest Tasmanian sites, such as Kutikina, Nunamira, and Bone caves (Ranson et al., 1983; Dortch, 1984; Cosgrove et al., 1990; Morse, 1993a,b; O'Connor, 1995; Balme, 2000; Holdaway, 2004).

Finally, in this review it has been the occurrence of components of the "package" within the entire late Pleistocene archaeological record that has been important, not the presence or absence of individual traits at particular sites. As the late Pleistocene patterning we have identified in the archaeologically visible traces of the "package" of modern human behaviour does not appear to be the result of taphonomic processes alone, how can it be explained? Three possible scenarios will be reviewed.

The earliest indigenous Australians lost the "package" on the way to Australia

Mellars (2006a) argued that biologically and behaviourally modern humans rapidly dispersed from Africa across southern Asia via the coast and into Australia between 60–40,000 years BP. He also argued sites from India and Sri Lanka revealed archaeological assemblages that resembled material from MSA sites in Africa (geometric microliths, ostrich eggshell beads, marine shell bead, incised ostrich eggshell). In a review of the later Pleistocene archaeological record of south Asia, James and Petraglia (2005) demonstrated that although some elements of the "package", such as ochre and possibly art, appear early (see also Bednarik, 2003); other components (bone tools, microliths, beads, notational pieces) date to only 28,500 years BP (see also Kennedy et al., 1987; Kennedy and Deraniyagala, 1989). Mellars (2006a) inferred that similar assemblages may extend further back in time in south Asia and provide a direct link with modern humans in Africa. Batadomba lena and Kitulgala Beli lena caves, southern Sri Lanka, may have geometric microliths, ochre, a marine shell bead, and human burials possibly associated with ochre, dating to 30–40,000 years BP (Kennedy et al., 1987; Kennedy and Deraniyagala, 1989; Nimal Perera, pers. comm. 2007). If there is an archaeologically visible "package" of modern human behaviour that was assembled in Africa during the MSA, it seems to have been exported from Africa into western Asia and Europe by at least 40,000 years BP (but see Hayden, 1993; d'Errico, 2003; d'Errico et al., 2003; Zilhão, 2006) and into southern Asia by 30–35,000 years BP.

Mellars (2006a) acknowledged that late Pleistocene flake-based stone assemblages from Sahul do not match the industries from Africa, but argued by the time modern humans reached Sahul they had lost the blade- and microlith-based industries they had exported from Africa due to a lack of high-quality, fine-grained stone for their production. He also raised the proposition, first put forward by Pope (1985), that bamboo and other nonlithic materials, not stone, were used to produce most tools. Research on Flores indicates that 800,000-year-old artefacts were made on fine-grained chert and are similar to 95–12,000 year old artefacts from Liang Bua (Brumm et al., 2006). The Flores material demonstrates that fine-grained stone for tool production was available in parts of southern Asia and that there is a very long tradition of using it for tool production. Obsidian from west New Britain was also being used for tool manufacture during the late Pleistocene, and large obsidian blade cores were produced, but only in the Holocene (Allen et al., 1989a; Gosden, 1995; Fredericksen, 1997; White and Harris, 1997; White, 1999). In Australia, late Pleistocene sites reflect individual raw material utilisation patterns for stone tool manufacture. For example:

- the earliest occupation levels at Puritjarra rockshelter, dating from 22,000 years BP, have small flakes made predominantly on high grade silcrete, whereas layers dating to around 13,000 years BP are dominated by larger flakes made on a lesser quality raw material—local silicified sandstone (Smith, 1989);
- the mid-Holocene introduction of points at Widgingarri Shelter 2 coincides with a change in raw material use from predominantly fine-grained quartzite to coarse-grained quartzite (O'Connor, 1996); and
- at Mandu Mandu Creek rockshelter there is a preference for finer quality raw material during the late Holocene compared to the Pleistocene levels (Morse, 1988).

Clearly, high-quality, fine-grained stone was available in parts of southern Asia and Sahul, and was being used for tool production during the late Pleistocene.

Mellars (2006a) further argued that the coastal adaptation of the colonising modern humans removed the emphasis on hunting, meat processing, and skin clothing or tent manufacturing tools. However, the early inhabitants of Sahul seem to have exploited coastal resources in a "tentative manner", as marine exploitation at late Pleistocene sites generally appears to have been limited in extent and duration, and was secondary to terrestrial exploitation (White and O'Connell, 1982; Beaton, 1995). This situation also seems to be the case at late Pleistocene sites on the islands off the northern periphery of Sahul. As Beaton observed, "the sites on the precipitous coastline of Melanesian islands show that breadth of diet in the Pleistocene went well beyond coastal foraging, suggesting a generalized complex foraging pattern over all local ecozones, excepting the open ocean" (1995: 804).

The exploitation of terrestrial resources was a key component of late Pleistocene lifeways within Greater Australia, as demonstrated in southwest Tasmania with the intensive exploitation of Bennett's wallaby. Also, late Pleistocene bone points from southern Australia may have been used for skin-working and cloak-making (see earlier discussion; Webb and Allen, 1990). There was not, therefore, a lack of emphasis on hunting and meat processing or skin clothing manufacturing in Pleistocene Sahul, as advocated by Mellars (2006a).

Mellars (2006a) also proposed that cultural drift caused by multiple founder events during colonisation of southern Asia and Australia led to a progressive loss in the complexity and diversity of technological patterns. Whilst it is difficult to assess this proposition, it is apparent that there were limited changes to the material culture evident in the archaeological record in Australia following the last glacial maximum (LGM), centred around 18,000 years BP, when there would have been depopulation of large areas of the continent and movement of people to refuges (Veth, 1989; Habgood, 1991, 2003). During this colder and drier period, there is evidence of changes to discard rates, intensity of occupation of sites, and site abandonment (O'Connell and Allen, 1995). If complexity and diversity of technological patterns are reduced as a result of founder events, one could expect changes in the early Holocene archaeological record in Australia following climatic amelioration and recolonisation of large areas of the continent. The periods both prior and just subsequent to the LGM reveal the addition of archaeologically visible traits of "symbolic behaviour" (Fig. 9; Franklin and Habgood, 2007), not the loss of these components as proposed by Mellars (2006a). Also, the majority of the changes to subsistence economy, lithic technologies, and social organisation in Australia appear to occur from the mid-Holocene, a considerable time after the climatic amelioration following the LGM, and not as a component of a recolonisation process (White and O'Connell, 1982; Lourandos and Ross, 1994; Flood, 1995; Mulvaney and Kamminga, 1999).

In summary, the late Pleistocene archaeological record in Greater Australia does not indicate a scarcity of high-quality, fine-grained stone for tool production or a lack of focus on exploitation of terrestrial resources, and postglacial recolonisation processes do not provide support for a loss of complexity and diversity of technological patterns by small founder groups. Ongoing innovation is clearly documented in the late Pleistocene archaeological record, with the appearance of personal ornaments, art and images, ritual behaviour, worked bone, and new lithic technologies, such as ground stone artefacts, grindstones, and thumbnail scrapers. There does not, therefore, appear to be a loss of the "package" of traits said to be indicative of modern human behaviour en route from Africa to Sahul.

The earliest indigenous Australians never had the entire "package" because they did not come from Africa

The "human or symbolic revolution" incorporates population movements and colonisation within and beyond Africa, throughout the Old World and into Sahul by modern humans who possessed the "package" of archaeologically visible modern human behaviour. Therefore, the lack of the entire "package" in the late Pleistocene archaeological record of Sahul could indicate that the earliest indigenous Australians did not come from Africa, but rather originated in an area where the "package" was not evident prior to the date of the colonisation of Sahul. In such a scenario, Southeast Asia, where the "package" is not found, could have been a dispersal centre or homeland for the expansion of groups into Greater Australia (Bulbeck et al., 2003).

Mellars (2006a) cited DNA studies to support the rapid dispersal of genetically and behaviourally modern humans from Africa along the Indian Ocean coast via southern and southeastern Asia to Australia (see also Forster and Matsumura, 2005). Macaulay et al. (2005) proposed that mtDNA studies indicated that modern humans arrived in India about 66,000 years ago and in Australia by about 63,000 years ago, some 15,000 years earlier than the archaeological record of Sahul suggests (cf. van Holst Pellekaan et al., 1998, 2006; Redd and Stoneking, 1999; Redd et al., 2002; Ingman and Gyllensten, 2003; Hudjashov et al., 2007). Much of the genetic data does support a relatively recent African origin for modern humans (about 200,000 years ago), subsequent migration(s) within and out of Africa, and replacement of local indigenous populations throughout the world with little or no admixture/hybridisation (see Stoneking, 1993; Eswaran et al., 2005; Forster, 2004)—the "African Eve model" (Cann et al., 1987) or "Weak Garden of Eden model" (Harpending et al., 1993). However, LM3 is claimed to be the oldest modern human skeleton from which mitochondrial DNA (mtDNA) has been extracted (Adcock et al., 2001a). When compared with modern Aboriginal Australians and modern populations from other regions of the world, the LM3 sequence, unlike other late Pleistocene Australian sequences, diverged before the most recent common ancestor of contemporary human mtDNA sequences (Adcock et al., 2001a: their Fig. 1). These results have been criticised on the grounds of methodology, interpretation, and whether uncontaminated mtDNA was actually sequenced from LM3 (Colgan, 2001; Cooper et al., 2001; Groves, 2001; Trueman, 2001; but see Adcock et al., 2001b,c). If the analyses and results are correct, it would imply that the most divergent mtDNA for anatomically modern humans is from Australia, not Africa.

As Pearson (2004) highlighted, analyses of genetic data has not settled the debate over the origin of anatomically modern humans (for southern Asia and Australia, cf. Cordaux and Stoneking, 2003; Endicott et al., 2003; Hudjashov et al., 2007). Other proposals based on analyses of genetic data, including Templeton's (2002) "Out of Africa again and again model" and Eswaran's (2002) "diffusion-wave model", allow for local admixture/hybridisation (see discussion in Eswaran et al., 2005). Differing factors can influence within-group genetic variation, including differences in population size, variation in gene flow, and patterns of population expansion and migration (Templeton, 1993). Late Pleistocene population history in southern and southeastern Asia and Sahul would have involved population stress, contractions and extinctions, growth and expansion, and replacements and admixture, making the interpretation of genetic data complex.

A consideration of the late Pleistocene skeletal sample from Australia may provide further insight into this issue. The initial colonisation of Sahul was not an example of a rapid replacement of one population by another because the continent was uninhabited at the time of initial colonisation. However, this does not mean that other migrations could not have followed the initial colonisation. Studies of genetic, archaeological, and skeletal data have been interpreted as indicating multiple migrations to Greater Australia (e.g., Birdsell, 1967, 1977; Thorne and Wolpoff, 1981; Lahr and Foley, 1994; Foley and Lahr, 1997; Redd and Stoneking, 1999; Redd et al., 2002).

With regard to the skeletal material, it has been proposed that Australia was colonised by morphologically distinct groups of anatomically modern humans (Thorne, 1977; Thorne and Wolpoff, 1981; Wolpoff et al., 1984; Webb, 1989; see also Birdsell, 1967, 1977) based on proposed "regional features": a "robust" group that was morphologically linked with Southeast Asia (Indonesia) and a "gracile" group that inferred a morphological link with East Asia. Curnoe and Thorne (2006a,b) recently reaffirmed the separate "gracile" and "robust" morphologies based on anatomy, metrics, and multivariate analyses. However, Curnoe and Thorne's (2006a,b) own data seems to document a morphological continuum. For example, their multivariate analyses (their Fig. 12) demonstrate that the "robust" and "gracile" samples are more similar to each other than to other modern samples in the analyses, confirming Habgood's (1985, 1986) earlier results. A more parsimonious explanation involves a single but morphologically diverse colonising group of anatomically modern humans (Brown, 1981, 1987; Habgood, 1986, 1989, 1991, 2003; Pardoe, 1991, 2006). Small groups may have colonised Sahul from a single geographical source and, due to isolation during continental colonisation and demographic variations, were acted upon by genetic processes including founder effect, selection, mutation, genetic drift, and varying amounts of gene flow, causing the development of a large range of morphological and genetic variation. As Brown (1987, 1989) found, although there is variation, there is a consistent Australian Pleistocene skeletal morphology. Pardoe (1991, 2006) also demonstrated a "gracile-female" and "robust-male" link, and identified that LM1 and LM3 seem typical of modern desert people (taller, leaner, with smaller teeth), while the Kow Swamp and Coobool Creek material is consistent with modern Murray River people (relatively shorter and stockier, with larger teeth). Whilst the interpretation of Australian Pleistocene skeletal material remains difficult because of chronological uncertainties with respect to key finds and the continuing possibility that some of the "robust" material reflects cranial modification and pathology (Brown, 1981, 1989, 2000; Webb, 1989, 1990; Antón and Weinstein, 1999; cf. Thorne and Curnoe, 2000; Curnoe and Thorne, 2006a,b), the initial occupation of Sahul appears to reflect a single colonisation event by fully modern groups.

As has been alluded to, the "human or symbolic revolution" has been directly associated with Stringer and Andrews' (1988) Out of Africa Replacement Hypothesis (e.g., Mellars, 2005, 2006a). The other of the two polarised explanations for the global origin of anatomically modern humans is the Regional Continuity or Multiregional Hypothesis. This explanation emphasises regional morphological continuity and argues that there was not a total replacement of local populations, but rather an integration of the gene pools of the local populations and anatomically modern humans from Africa (Wolpoff et al., 1984). Southeast Asia and Australia have figured prominently in discussions of the Multiregional Hypothesis (see Habgood, 2003, for a summary).

In a review of the morphological features proposed to link Pleistocene Australians with southern Asia as proposed by the Multiregional Hypothesis, Habgood (1989, 2003) demonstrated that, on an individual basis, none of the proposed "regional features" can be justifiably assessed as documenting "regional continuity", as they are primitive retentions and are consistently found on crania from outside this region (see also Groves, 1989; Lahr, 1994, 1996; Lahr and Wright, 1996). However, there was a group of five morphological features that, when found in combination, appeared to document a degree of continuity between Pleistocene Southeast Asian and Australian populations. These features, which may constitute a functionally related frontofacial complex, are a long and sagittally flat frontal bone with a posterior position of minimum frontal breadth, prognathic faces and malars with everted lower margins, and prominent malar tuberosities. Bulbeck et al. (2003) described a similar pattern in late Pleistocene and early Holocene crania from South Asia—long narrow vaults, sloping frontals, and marked prognathism. However, the earliest crania from the region (Niah Cave, LM1, LM3, Liang Lemdubu, and Keilor) lack the combination of "regional features" (Habgood, 1989, 2003; Bulbeck, 2006b; cf. Lahr, 1994, 1996; Lahr and Wright, 1996). There are, therefore, indications of both morphological continuity and discontinuity in the cranial material from the region, thus precluding a clear choice between the two competing explanations for the origins of modern humans in the region. However, the argument for a total replacement of successfully adapted indigenous inhabitants in Australasia is contradicted by the discovery of *Homo floresiensis* at Liang Bua on Flores (Brown et al., 2004; Morwood et al., 2004; Falk et al., 2005 ; Morwood et al., 2005; Argue et al., 2006; cf. Henneberg and Thorne, 2004, and Jacob et al., 2006, who challenged the attribution of the Flores material to a new species), and the divergent mtDNA from LM3, if the analyses and results are correct (Adcock et al., 2001a).

Alternative explanations for the world-wide origin of anatomically modern humans that incorporate replacement, continuity, and assimilation have also been proposed (Bräuer, 1984; Smith et al., 1989; Habgood, 2003). These "assimilation and replacement" models accept an early African origin for anatomically modern humans and their migration from Africa, but combine, to differing degrees, local continuity, population replacement, and multidirectional gene flow, the pattern of which varied from region to region. An "assimilation and replacement" scenario for the origin of modern humans would be consistent with the skeletal and genetic data from Greater Australia. The 40,000-year-old Tianyuan 1 skeleton from China may also reflect an assimilation process for the origin of modern humans in eastern Asia (Habgood, 2003; Shang et al., 2007). At present, it is not possible to conclusively establish the relative importance of replacement and continuity for the origin of modern humans in Southeast Asia and Australia. However, there remains the possibility that the earliest anatomically and behaviourally modern indigenous Australians did not possess the complete "package" of archaeologically visible traits because they were not part of a rapid colonisation process from Africa.

The "package" of archaeologically visible traits does not reflect modern human behaviour

The concept of a trait list for archaeologically visible modern human behaviour has been challenged (e.g., Chase and Dibble, 1987; Straus, 1989; Lindly and Clark, 1990; Harrold, 1992; Hayden, 1993; White, 1999; Wadley, 2001; d'Errico, 2003; Henshilwood and Marean, 2003; Brumm and Moore, 2005; James and Petraglia, 2005; Zilhão, 2006; O'Connell and Allen, 2007). Marshack (1989: 1) argued for an early appearance of symbolling in the archaeological record that may represent "incipient and preparatory innovations" for the later European "creative explosion" (see also Bednarik, 2003). D'Errico (2003) went further, detailing the gradual development of the individual traits within Europe by the Neanderthals and arguing that behavioural modernity as expressed by the archaeologically visible "package" cannot be a species-specific consequence of biological modernity, as the "package" is also evident within the material culture of the Neanderthals (cf. Chase and Dibble, 1987; Lindley and Clark, 1990). Zilhão (2006) also supported the appearance of "fully symbolic *sapiens* behavior" within Neanderthal populations in Europe and even proposed that early anatomically modern groups in Europe may have "borrowed" symbolic items, such as bone, ivory, and pierced and grooved animal teeth pendants, from indigenous Neanderthal groups. Zilhão contended there is no "Neanderthal behaviour" or "modern human behaviour", as Neanderthals and anatomically modern humans had "similar levels of cognitive development and behavioral modernity" (2006: 192). However, Mellars (2005, 2006a,b) continues to dismiss an in situ development of the behavioural changes evident within the "package" in Europe in favour of a migrationist approach, where the introduction is directly associated with the appearance of anatomically and behaviourally modern humans derived from Africa. Lindly and Clark (1990: 234) recommended the establishment of more sophisticated ways of analysing the archaeological record of symbolism than simply documenting the presence or absence of art, style, and other ritual activities. Henshilwood and Marean (2003) also suggested the use of the "package" of traits was "inherently flawed" because their appearance in the archaeological record could be explained in other ways, and so they are not "unambiguous indicators" of modern human behaviour. Whilst much behaviour by early modern humans would be archaeologically invisible and so not necessarily reflected in trait lists, the concept of a "package" of traits continues to be used and refined (e.g., Mellars, 2005, 2006a).

As McBrearty and Brooks (2000) and Wadley (2001) found in southern Africa and James and Petraglia (2005) in South Asia, our review indicates that the individual traits do not occur suddenly together as a package in Sahul, but appear at sites that are widely separated in space and time. There is chronological and geographical patterning of the individual traits within the archaeological record of Sahul (see also Brumm and Moore, 2005; Franklin and Habgood, 2007; O'Connell and Allen, 2007). The earliest indigenous inhabitants of Sahul were behaviourally and anatomically fully modern, yet the full "package" of traits is not present at the earliest sites. This pattern indicates that modern human behaviour cannot be automatically inferred from inventories of archaeologically recovered material.

Conclusions

The late Pleistocene archaeological record of Greater Australia does not support the proposal by McBrearty and Brooks' (2000) that the complete "package" of modern human behaviour was exported from Africa to other regions of the Old World, as all of the components of the "package" are not evident at the earliest sites in Sahul. Following the initial occupation of the continent, the "package" is gradually assembled over a 30,000-year period (Fig. 9). In addition, the individual components of the "package" appear at sites that are widely separated in space and time, and do not occur suddenly together as a "package". This review further supports the view that there is no "package" of archaeologically visible traits that can be used to establish modern human behaviour, as the components used currently not only appear in different continents at different times, but also at different times and locations within continents (compare Fig. 9; McBrearty and Brooks, 2000: their Fig. 13; d'Errico, 2003: his Fig. 8). This pattern does not support an export of the "package" from Africa.

We have shown that it is unlikely that the "package" was lost en route to Sahul. Innovation is evident in the late Pleistocene archaeological record, with the appearance of personal ornaments, art and images, ritual behaviour, worked bone, and new lithic technologies, such as ground stone artefacts, grindstones, and thumbnail scrapers. Whilst it is not currently possible to conclusively establish the relative importance of replacement and continuity for the origin of modern humans in Southeast Asia and Australia, there remains the possibility that the initial colonising groups did not possess the "package" because they may not have been part of a rapid colonisation process from Africa. As the earliest indigenous inhabitants of Sahul were anatomically and behaviourally fully modern, possessing the ability to cross the open ocean in boats, adapt to a range of diverse environments, and develop a unique material culture, the absence of the "package" at the earliest sites suggests that the "package" of traits may not reflect modern human behaviour. As O'Connell and Allen point out, whilst the presence of the "package" indicates modern behaviour, its absence "does not necessarily mean those capabilities were lacking" (2007: 405). Could there be a simpler explanation for the patterning in the appearance of these traits within the archaeological record of Sahul?

Population growth, demographic expansion, increasing contact between populations, and population pressure have been seen as possible causal factors for the appearance in the archaeological record of the "package" of modern human behaviour (Lindly and Clark, 1990; Hayden, 1993; McBrearty and Brooks, 2000; Kuhn et al., 2001; Shennan, 2001; Foley and Lahr, 2003; Henshilwood and Marean, 2003; James and Petraglia, 2005; O'Connell and Allen, 2007; cf. Clark, 1999). The general assumption is that the appearance of the "package" may be a consequence of population growth and the resulting increase in contact between groups, and/or the behavioural traits were needed to facilitate access to limited resources. McBrearty and Brooks (2000) were of the view that intensification evident at the MSA-LSA transition in Africa was partly the result of population increase and greater competition for resources. Lindly and Clark suggested that not only does the appearance of symbolic behaviour in the archaeological record reflect "increased social complexity, population density, and/or subsistence uncertainty" (1990: 252), but the lack of that evidence in newly colonised areas may reflect low population densities and, therefore, a reduced need for such symbolic behaviour even when groups had the capacity for such behaviour. James and Petraglia (2005) expressed a similar view with respect to the late appearance of the "package" in South Asia. Brumm and Moore (2005) concluded that the "package" appears in Australia from the mid-to-late Holocene as a result of social or demographic changes, such as regional populations reaching a threshold necessitating new information transmission channels (see also Lourandos, 1983; Hiscock, 1994; Lourandos and Ross, 1994). O'Connell and Allen (2007: 404) went further and proposed that population growth was the "driving force" behind the increasing appearance of components of the "package" following the LGM.

The number of sites and intensity of site usage (discard and sedimentation rates) suggest relatively low population densities throughout the late Pleistocene in Sahul, although this would vary between regions depending on resource availability (compare southwest Tasmania and northwest Australia). The mode of population increase within Greater Australia (rapid, gradual, stasis, or a combination) has been a much-debated subject (see Birdsell, 1977; White and O'Connell, 1982; Beaton, 1983, 1985; Lourandos, 1983; O'Connor et al., 1993; Smith and Sharp, 1993; Mulvaney and Kamminga, 1999). Nevertheless, can the proposed link between the appearance/nonappearance of the "package" and population increase/density/pressure account for the chronological and geographical pattern we have identified for the appearance of the individual components of the "package" of archaeologically visible modern human behaviour in late Pleistocene Sahul?

As mentioned earlier, Wadley (2001) argued that modern behaviour was evident in the archaeological record when items of external symbolic storage (art, ornaments, lithics) are used in the definition of individual or group identity. Hayden proposed it was the "need to display status and economic success" (1993: 139) that prompted symbolic behaviour. Kuhn et al. (2001) observed that Palaeolithic beads and pendants from Africa, Europe, and the Levant may have been used to communicate social identity. The distribution of ornaments within Australia may reflect such use—shell beads in northwestern Australia, bone beads and pendants in southwestern Australia, and necklaces of animal teeth in burials from southeastern Australia (Table 3)—Pleistocene groups in different parts of Australia using different forms of ornaments for group or individual identity or as displays of individual status. Rock art may also have served a similar identity and territorial marker function from an early period, with some degree of regionality apparent in the Australia-wide, more homogeneous, and less figurative corpus of rock engravings, such as those at Early Man (Fig. 7) dating from at least 13–14,000 years BP (Franklin, 2007: her Fig. 3). Increasing levels of regionality are evident through time, with the proliferation of distinct and more figurative styles occupying spatially restricted areas from the terminal Pleistocene through the Holocene (Franklin, 2004, 2007). Also, Pardoe (1988) argued that the appearance of cemeteries throughout the Murray River corridor following the LGM may reflect the need to legitimise control and ownership over the restricted riverine resources in an area of high population pressure and demand for resources. Cranial modification as possibly practiced at Coobool Creek and Kow Swamp may be another example of a system to enforce group identity and distinguish one group from another in a region experiencing population pressure (Brown, 1989; Pardoe, 1993).

The occurrence of some components of the "package" may, therefore, reflect increasing population densities/pressure in parts of Greater Australia during the late Pleistocene/early Holocene. However, this cannot be the only explanation as the individual components of the "package" appear in the archaeological record at sites that are widely separated in space and time, and at sites such as Riwi Cave and Mandu Mandu Creek rockshelter that reflect low level or intermittent occupation at this time (Morse, 1993a: her Fig. 2; Balme, 2000: her Fig. 6). The chronological and geographical pattern is not consistent with the concept that the sudden appearance of the "package" was the direct result of continent-wide or regional population increase, and the reaching of thresholds requiring new information transmission channels, symbolic behaviour, or the definition of individual and/or group identity. What can be said is that late Pleistocene population history within Greater Australia would have involved population growth, expansion, replacement, contraction, and differing amounts of population stress and pressure, all of which would have had an impact on the archaeological record (see O'Connell and Allen, 1995). As Klein stated, "the essential issue is cause and effect—whether population growth drove human behavioral change or behavioral change drove population growth" (2000: 29).

We hope that our review of the appearance of the proposed "package" of archaeologically visible traits of modern behaviour and the inferences we have drawn from the chronological pattern we identified will stimulate further consideration of Sahul in discussions of the origin of anatomically and behaviourally modern humans. This detailed review demonstrates that late Pleistocene Sahul is different to Middle Stone Age Africa, and Middle and Upper Palaeolithic Europe. It should also dispel the view that the earliest Australians possessed a "simplicity" of material culture (see White, 1977; Mellars, 2006a). The preceding discussion illustrates that in addition to the exploitation of a range of diverse environments and the presence of long-distance transport and/or exchange networks, the material culture of late Pleistocene Sahul includes shell and bone beads, notational pieces, pigment processing and early use of ochre, rock art, ritual cremation and burials, bone points, mining and extraction of flint and ochre, wooden tools, edge-ground stone hatchets, and grindstones.

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