Pre-LGM Sahul (Australia-New Guinea) and the archaeology of early modern humans

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Discussions of the origins of modern humans and their distinctive behavioural capabilities often refer to material traits thought to mark those capabilities archaeologically. Traits most commonly nominated include complex lithic and organic technologies, evidence of broad-based subsistence economies (possibly involving habitat management), indicators of symbolism in the form of art, ornament or "style," and burial of the dead. Recent treatments typically focus on the dates at which these proposed markers first appear in the material record, the implications for the rate at which modern human capabilities might have developed, and (less consistently) the processes that might have been involved (e.g. Klein 2000; McBrearty & Brooks 2000; Mellars 2005).

An important problem with this approach lies in the assumption of a 1:1 relationship between behavioural capabilities and material evidence of their presence. The archaeological record of Pleistocene Australia-New Guinea, the continent sometimes called Sahul, illustrates the point. Though it is generally agreed that this region was colonized by fully modern humans about 42-45 ka BP, the record they left behind includes few of the conventionally identified markers of modern behaviour until after peak of the Last Glacial Maximum (LGM, here pegged at 20 ka BP), more than 20 millennia later. Most do not appear widely until the mid-Holocene. This observation raises important questions about the determinants of those markers and the significance of their absence.

Here we provide an overview of the pre-LGM Sahul record, with special attention to evidence of modern human behavioural capabilities and to the absence or limited presence of many conventionally defined markers thereof. We then briefly consider the factors that might account the patterning observed, especially those involving climate change and human population density. We conclude with some comments on the implications of these findings for future research on modern human origins.

Humans in pre-LGM Sahul: an overview

Geographic setting

Pleistocene Sahul was a large continent (Fig. 1). When sea levels were at their lowest (20-22 ka BP), it covered nearly 11 million square kilometres, roughly the same area as sub-Saharan Africa or Eurasia west of the Ural Mountains. Relief was moderate: more than 90% of its surface was less than 500 metres above maximum low sea level. Significant uplands included only the New Guinea Highlands on the north and the Great Dividing Ranges on the east (maximum elevations ~5200 m and ~2400 m above maximum low sea level, respectively).

Major biomes in modern Australia-New Guinea include tropical forest, sub-tropical savanna, and low temperate desert. Small but important patches of temperate forest are found in the southeastern and southwestern corners of mainland Australia and in Tasmania. During the last glacial cycle (75-10 ka BP), cooler, drier climates and lower CO^2 levels generally reduced the distribution of tree cover, increased the size of the arid zone, and favored the development of glacial and peri-glacial habitats in both the northern highlands and far southeast.

Arrival date

Sahul was first occupied 42-45 ka BP and widely colonized by 35 ka BP (Fig. 2; O'Connell & Allen 2004)). Though claims have sometimes been made for landfalls >50 ka (e.g. Roberts *et al.* 1990, 1994; Thorne *et al.* 1999), their validity is undercut by uncertainties about associations between dates and evidence of human activity, about the dates themselves, or both (O'Connell & Allen 2004). At present, no colonization dates >45 ka BP are reliably supported, nor indeed as widely advocated by professional archaeologists as they were in the 1990s (J. Allen & O'Connell 2003).

Number and identity of founding populations

All prehistoric human skeletal remains from Sahul are anatomically modern (Cameron & Groves 2004, 251-74). Most are terminal Pleistocene or Holocene in age, but a substantial number, representing as many as 130 individuals, all from the Willandra area (S. Webb 1989), may predate the LGM. Precise age estimates for this particular sample are problematic: most elements were recovered from stratigraphically uncertain contexts, and direct dating of the bones themselves has yet to produce consistent results. There is no consensus on their antiquity: at least one analyst (S. Webb 1989) holds that most date >20 ka BP; another (Gillespie 1997, 1998) contends that few if any do. Our own review leads us to infer that at least two sets of remains (WLH 1 & 3) probably predate the LGM and may be as old as 42 ka BP (J. Allen & O'Connell 2003; see also Bowler *et al.* 2003). If this estimate is accurate, then anatomically modern humans were present from the time the continent was first occupied.

Genetic data add further detail. Y-chromosome and mtDNA samples from modern indigenous Sahul populations indicate substantial intra-continental genetic diversity, comparatively distant links with presumed African ancestors, and few close connections with other non-Africans (e.g. Friedlaender *et al*. 2005; Huoponen et *al*. 2001; Ingman & Gyllensten 2003; Kayser *et al.* 2001; Merriwether *et al*. 2005; Redd & Stoneking 1999). These data can be read to show that ancestral Sahul populations were among the first modern humans to spread well beyond Africa, a move estimated on the basis of mutation rate calculations to have occurred roughly 40-70 ka BP, broadly consistent with the archaeological record (cf. Eswaran *et al*. 2005). Whether early colonists ultimately arrived in Sahul as members of a single relatively homogeneous group that later diversified *in situ*, as elements of one already diversified population, or in several separate streams, some from different source groups, is still unclear. Once established, some populations apparently remained in essentially the same locations until historic times. Post-establishment contacts between New Guinea and Australia were evidently limited, as were additional inputs from beyond Sahul until the mid-Holocene or later (e.g. Redd *et al*. 2002).

Arrival mode and implications

New Guinea and Australia are separated from Southeast Asia by a major biogeographic barrier, the Wallacean archipelago (Fig. 1). Although eustatically-lowered sea levels periodically exposed large areas of the adjacent Sunda and Sahul shelves, and so simplified travel across them, the archipelago itself remained a significant impediment to trans-regional movement until modern humans appeared on the scene (Metcalfe *et al*. 2001). Island-hopping along either of the two main routes across it required at least 8-17 separate crossings (Birdsell 1977). All routes included one leg >70 km and at least three ≥30 km. Prior to the arrival of *H. sapiens*, no large-bodied terrestrial animal had ever managed a complete crossing in either direction, at least not in numbers sufficient to establish a population on the opposite continental shore.

How modern humans made the leap has been an issue of special interest since the mid-1960s, when the Pleistocene colonization of Sahul was first confirmed archaeologically. The minimalist view favors accidental transit via storm-driven natural rafts, the "pregnant woman washed ashore on a log" being an especially romantic if biologically improbable scenario (Calaby 1976; J. Smith 2001). The transit of *H. sapiens* appears to have been much more purposeful. Despite the distance and possible numbers of crossings involved, the earliest uncontested dates for modern humans across the entire region are all essentially the same (Fig. 2), roughly 40-45 ka BP in Borneo (Barker 2002), various parts of Sahul (O'Connell & Allen 2004, Table 2), and the Bismarck Archipelago (Leavesley & Chappell 2004), implying relatively rapid movement. Simulation studies further indicate that successful colonization following each landfall probably required not only a founding population that included several women of reproductive age (McArthur *et al*. 1976), but also repeated later contact with outside groups, at least for a time, in order to avoid problems associated with incest and sidestep the effects of unbalanced sex ratios (Moore 2001).

These observations strongly suggest that colonists had access to effective marine technology (at minimum, bamboo rafts), and that they frequently moved back and forth across water barriers between islands and continents (Irwin 1992, 18-30; see also J. Allen 2000; Anderson 2000). The demands of vessel construction, trip planning and conduct on route imply modern human cognitive, linguistic and behavioural capabilities (Davidson & Noble 1992). This inference is reinforced by evidence for the occupation of the northern Solomon Islands by 28 ka BP (Fig. 1), an exercise that required an open-ocean crossing of >130 km to a narrow target invisible from the nearest likely launching points (New Britain or New Ireland) until the travelers were >30 km offshore (Wickler & Spriggs 1988). The next progression, a voyage where the target island could not be seen until long after the departure point had disappeared from view, was completed by 20 ka BP with the occupation of Manus Island in the Admiralty group, a minimum crossing of about 200 km (Fredericksen *et al*. 1993). These are the earliest known open ocean voyages of this magnitude, feats apparently not equaled elsewhere in the world until the Holocene.

(We recognize that there is increasing evidence of partial transits of Wallacea as far east as Flores by non-modern humans as early as 800 ka BP (Morwood *et al*. 1998, 2005; Brown *et al*. 2004). On the logic of the argument outlined for "moderns," the presence of marine technology is implied at a similarly early date, though given the difference in numbers of crossings achieved and overall distances traveled (Fig. 1), it strikes us as having been a significantly less effective form than that associated with the mid-Upper Pleistocene transit.)

<u>Pre-LGM archaeological record</u>

The pre-LGM archaeological record from Sahul is substantial. More than 70 sites have yielded reliable radiocarbon and/or luminescence dates >20 ka BP (O'Connell & Allen 2004; Smith & Sharp 1993). Of these sites, about 30 have components dated >30 ka, and at least eight contain deposits that fall in the 40-45 ka range (Fig. 2). Records from several areas, notably the Willandra-Darling region (Balme 1995; Bowler 1998; Hope 1993; Johnstone & Clark 1998), indicate the presence of many additional sites, still not directly dated, but in apparent association with pre-LGM sediments. If these associations are valid, the total sample of early sites at least partly described in print is well in excess of 100.

The amount of cultural material present in pre-LGM sites is highly variable. The smallest assemblages include only a few flakes and/or human-transported food remains (e.g. Balme 1995; Johnstone 1993). The largest are dense concentrations of debris containing thousands of stone artefacts and tens of thousands of bone fragments (Cosgrove & Allen 2001; Holdaway 2004; McWilliams *et al.* 1999). Most pre-LGM assemblages fall toward the lower end of this size range.

<u>Technology</u>

Artefact assemblages at early Sahul sites are made up almost entirely of flaked stone. The bulk of this material is debitage; retouched pieces comprise less than 2% of most collections. These latter items are generally identified either as cores or unifacially-modified flakes (Fig. 3). Functional analyses suggest that all were used in a limited array of tasks: flakes for cutting and scraping, cores for chopping and flake production (e.g. Cosgrove 1995; Holdaway 2004; Holdaway & Stern 2004; Jones 1985; Kamminga 1982; Morwood & Hobbs 1995)

None of this material displays much formal patterning. Well-defined morphological types, comparable to those typical of the West Eurasian Upper Palaeolithic or the African Later Stone Age, are almost completely absent. Though it is sometimes suggested that this finding is the product of a "peculiarly Australian" approach to analysis (Holdaway 1995), treatment of at least one large collection in terms comparable to those routinely applied to Afro-European materials has failed to produce a more familiarly Upper Palaeolithic- or LSA-like result (Holdaway 2004).

This is not to say that patterning of any kind is absent. It has long been proposed, partly on the basis of ethnoarchaeological observations, that most of the variation in artifact form and assemblage composition apparent in Sahul collections is a product of differences in toolstone quality and availability. Holdaway (2004) explored this proposition in a detailed analysis of Late Pleistocene assemblages from Bone Cave, southwest Tasmania (see also Hiscock & Allen 2000). His results show that differences in artefact form and assemblage composition are correlated with changes in the relative proportions of toolstone from different sources. Pre-LGM assemblages contain relatively high proportions of exotic chert and are marked by high flake/tool ratios and low levels of flake fragmentation. Post-LGM, the percentage of exotic chert is significantly lower: occupants relied more on a quartzite source immediately adjacent to the site and worked material drawn from it more thoroughly. This is reflected in lower flake/tool ratios and greater degrees of flake fragmentation.

Holdaway makes a compelling argument that the shift in toolstone frequency and the changes in other aspects of artefact form and assemblage composition are functionally related. He reads them as a product of regional human population growth post-LGM that reduced forager mobility, limited access to distant toolstone, favored longer periods of site occupation, and so increased the intensity of local quartzite exploitation. The inferences about reduced mobility and longer periods of site use are supported by evidence of an increase in the rate of refuse deposition across the LGM threshold.

Two other aspects of pre-LGM lithic technology merit mention. Groube (1986) and others report the presence in several parts of northern Sahul of large, axe-like implements, defined by broad, blunt working edges. Some of these items are flaked, some ground; some are double-bitted, with pronounced "waists;" others are single-bitted, with tanged or stemmed projections opposite the bit. The waists, stems and tangs were presumably intended to facilitate hafting (Fig. 4). The largest reported sample of these specimens (>70) was recovered from erosional surfaces and buried deposits at Bobongara, northeast Papua New Guinea (Fig. 1). Dates on the buried items are >40 ka BP (Groube *et al*. 1986; see also O'Connell & Allen 2004, 838-40). Other pre-LGM examples are known from at least six sites in the New Guinea Highlands, Arnhem Land and Cape York (Golson 2001). Groube (1989) argues that they were used in forest clearance, a point we return to below.

Also notable is the evidence for grinding tools, possibly used in connection with plant processing. Slabs and handstones have been reported from parts of the Willandra-Darling system in apparent association with Late Pleistocene sediments, but their ages remain unresolved (H. Allen 1990; Balme 1991; Johnstone & Clark 1998). Gorecki *et al*. (1997) review the evidence for Late Pleistocene grinding tools and bedrock grinding surfaces elsewhere in Sahul, but again the dating remains uncertain. More compelling evidence comes in the form of six ground stone fragments, including one partial grinding slab, recovered from sediments dated 30-36 ka at Cuddie Springs, northern New South Wales (Fig. 4; Field *et al*. 2001; Fullagar & Furby 1997; Roberts *et al*. 2001). The uses to which these tools were put are uncertain, but their overall form and the presence of silica residues on one of them suggest a role in seed processing.

Evidence of organic technology in pre-LGM contexts is very limited. Small numbers of bone tools have been reported from several sites on the southern margins of the continent (e.g. Bowdler 1984; Dortch 1984; Flood 1974; Lampert 1981; Ranson *et al*. 1983; C. Webb & Allen 1990). Most were fashioned from macropod long bones, have sharply pointed or spatulate working ends, but are otherwise little modified. Analysis of damage morphology suggests that the spatulates were used in connection with dry skin, possibly having served as clothing fasteners. Pointed items display damage of the sort associated with piercing softer, more pliable materials. Some may have functioned as weapon tips (C. Webb & Allen 1990); others may have been used in net- or basket-making (Bowdler 1984, 123-7).

Six worked fragments of *Turbo* and *Trochus* shell were found in LGM and pre-LGM deposits at Matenkupkum and Matenbek, New Ireland. Although their functional significance is uncertain, at least one resembles debris produced in the manufacture of shell fishhooks (A. Smith & Allen 1999). The presence of pelagic fish remains at these sites offers support for this proposition (see also below).

<u>Subsistence and settlement</u>
The largest and best data sets on pre-LGM subsistence and settlement patterns are from southwest Tasmania and the Willandra-Darling region,

respectively. Both areas have witnessed extensive survey and excavation programs on regional scales.

The southwest Tasmanian sample comes primarily from a dozen small caves and rock shelters scattered along high-energy river drainages in an area now covered by temperate rainforest (J. Allen 1996; Cosgrove 1995, 1999; Kiernan *et al*. 1983). All sites were occupied intermittently at various times in the period 11-35 ka BP. Only two were large enough to have served as multi-family base camps; the rest were occupied by smaller groups. Most contain dense accumulations of debris, mainly flaked stone and animal bones. Faunas are dominated by the remains of Bennett's wallaby (*Macropus rufogiseus*, ~70 per cent of NISP in assemblages from all sites combined) but other medium and small-sized marsupials are also represented.

Cosgrove and Allen (2001) argue that the record as a whole reflects a specialized hunting strategy, aimed primarily at the pursuit of Bennett's wallaby. Modern examples of this species favor lightly wooded grasslands and have relatively small (5-20 ha) home ranges. Cosgrove and Allen appeal to Charnov's (1976) marginal value theorem in suggesting that hunters periodically visited patches where wallaby were abundant, quickly reduced their numbers to the point that hunting return rates fell below those available elsewhere, then moved on to the latter areas, returning to those they had targeted initially only after wallaby populations there had recovered. Given the general ability of macropod populations (including Bennett's wallaby) to rebound quickly from demographic stress, this process may have operated at a relatively short time scale, measured in years rather than decades or millennia.

The intermittent pattern of site use over longer time periods is probably explicable by two dimensions of climate and related habitat change: a millennial-scale pattern of cooler, drier conditions alternating with warmer, wetter ones, and a longer term trend toward generally cooler, drier cold periods, culminating with the LGM (Holdaway & Porch 1995). Cooler conditions generally pushed grasslands and associated wallaby populations to lower elevations. When climate improved, the process was reversed. Site use tracked these changes in habitat, increasing in intensity as grassland habitats developed nearby, falling off as they shifted away. Bone Cave, for example, was occupied most heavily in four intervals, ca. 29 ka, 23-24 ka, ca. 17 ka, and 14-16 ka, each associated with the presence of grasslands in the surrounding site catchment (Holdaway & Porch 1995). The interesting implication is that foraging opportunities associated with other upland habitat types were generally ignored. The above-noted trend toward higher post-LGM population densities notwithstanding, humans must have been relatively few on the ground region-wide.

The southwest Tasmanian record ends with the Holocene, when the onset of significantly warmer, wetter climates favored the invasion of dense temperate rainforest, sharply reducing resource availability and forcing local human populations that had been exploiting the region for 25,000 years to abandon it entirely (Cosgrove & Allen 2001; Holdaway & Porch 1995; Porch & Allen 1995).

The Willandra-Darling area lies on the broad plain of New South Wales, west of the Great Dividing Ranges. This region is crossed by several major river systems, each including one or more sets of broad, shallow lake basins linked by multiple stream channels. Some of these systems were active in the Late Pleistocene but are now dry and subject to widespread wind erosion (e.g. Bowler 1998; Hope 1993). Hundreds of archaeological sites, most of them dating 15-45 ka BP, have been exposed by recent deflation over wide areas along former lake and channel margins (e.g. H. Allen 1998; Balme 1995; Johnstone & Clark 1998; see also Bowler 1998; Bowler & Price 1998; Bowler *et al*. 2003 for chrono-stratigraphic background). Surveys and excavations indicate that most of the pre-LGM sites are small, shallow middens, rarely covering >10 m^2 or reaching thicknesses >10 cm (Balme 1995; Johnstone 1993). Food remains are mainly those of fish and shellfish, but small terrestrial fauna are also represented (e.g. H. Allen 1998; Walshe 1998). Deposits made up entirely of one prey taxon - usually mussels (*Velesunio* spp.) or perch (*Macquaria*) - are not uncommon. The numbers and size distributions of the fish are sometimes seen to indicate mass capture with nets (e.g. H. Allen 1998; Balme 1983, 1995) but are more parsimoniously read as the product of selective spearing or even harvesting by hand, particularly in situations where fish were concentrated in seasonally drying pools and somewhat "stupified" by high salinity levels (Bowler 1998, 147-8). The size and content of the middens suggest that most were deposited over relatively short periods of time (days or weeks, possibly over a few seasons), probably by small, relatively mobile human groups (H. Allen 1998). As in the Tasmanian case, these deposits are spatio-temporally patterned: widespread during periods when lake and river systems were most extensive; restricted to remnant segments as those systems became more attenuated in LGM times and later (Bowler 1998; Hope 1993). Again, the high level of mobility and absence of evidence for use of other local habitats and associated resources both point to low human population densities.

Other pre-LGM sites throughout the continent show the same general pattern: indications of short-term occupation by small, wide-ranging groups exploiting a relatively narrow subset of potential foraging opportunities (e.g. Dortch 1984; Morwood & Hobbs 1995; O'Connor 1999; Przywolnik 2005).

Theoretical considerations suggest that plant foods are likely to have been important in pre-LGM diets (Edwards & O'Connell 1995), but direct evidence of this remains limited. The grinding implements noted by H. Allen (1990) and others were probably connected with seed processing, but as indicated above their suggested Late Pleistocene age has so far been difficult to verify. White *et al*. (1970) argue for the use of *Pandanus* in highland New Guinea at or before 26 ka BP, but strong support has yet to be presented. The best immediately available evidence for pre-LGM plant use comes from the grinding tools and associated silica residues in the 30-36 ka deposits at Cuddie Springs, and from Loy and associates' (1992) report of taro (*Colocasia* and *Alocasia*) starch grains on flaked stone tools from ~28 ka deposits on Buka, in the northern Solomons.

Evidence of littoral and marine resource use in pre-LGM times is also scarce, probably because most of the relevant archaeological deposits are now under water. Recent ethnoarchaeological work among coastal foragers in Torres Strait indicates that for reasons of transport efficiency fish and especially shellfish are likely to be processed close to shore, and that (depending on processing costs) few elements susceptible to archaeological preservation will be moved more than a kilometer or so off the beach (D. Bird *et al*. 2002). Most Late

Pleistocene sites now located on or near the modern shoreline were 10-100 km inland at the time they were occupied (O'Connor & Veth 2000). Some have yielded the remains of fish and shellfish, but the quantities involved are very small (Morse 1988; Przywolnik 2005).

The only substantial evidence of pre-LGM marine resource use comes from two sites on New Ireland, Buang Merabak and Matenkupkum (J. Allen 2003), and from Buka, in the northern Solomons (Wickler 2001). All three sites are located on steeply sloping coast lines, and were never more than a few hundred metres from the shore, even at low sea levels. All have produced fish and shellfish remains from deposits dated 20-40 ka BP. The large sizes of the shells in the New Ireland samples suggest low levels of exploitation by relatively mobile human foragers, a pattern similar to that inferred for the southwest Tasmanian case. The fish remains at all three sites are mostly inshore species that could have been taken by hand or speared in tide pools or in simple stone fish traps. The presence of some pelagic taxa (9 per cent of >300 NISP at Buka [Wickler 2001, 224-6]) implies that line fishing was also practiced, consistent with the possible evidence for shell fishhooks noted above.

<u>Habitat modification</u>

At the time of European contact, fire was used as a habitat management tool throughout Australia-New Guinea (e.g. Bowman 1998). Ethnographic and experimental work confirm that, properly controlled, anthropogenic fire favors increased biological diversity, patchier habitats, higher encounter rates for important food resources, and improved foraging returns (e.g. D. Bird *et al*. 2005). It is commonly proposed that management by fire dates to the initial colonization of Sahul (e.g. Jones 1969). The techniques involved are fairly simple and were widely applied ethnographically, not just in Australia-New Guinea but in many other parts of world as well (Keeley 1995); hence, there is good reason to think the general practice has great antiquity.

Whether this proposition can be supported empirically for pre-LGM Sahul is another matter. Early attempts to do so involved monitoring charcoal and pollen deposits for evidence of increased fire frequency and the development of more fire-tolerant plant communities. Indicators of major changes in these directions have often been flagged as the product of human activity, and are sometimes cited as evidence for a human presence on the continent well before the beginning of an archaeological record (e.g. Wang *et al*. 1998). Recent work undercuts this line of argument by showing that anthropogenic fire may be difficult to trace in the fossil pollen and charcoal records, mainly because its impact will frequently be masked or mimicked by the effects of climatic and other factors (e.g. Haberle & Ledru 2001). That said, the expectation about early habitat management by fire remains plausible.

Groube (1989) offers a related argument based on the presence of the axes noted above, suggesting that these implements were used in tandem with fire to clear small patches of forest, and so favor the abundance and productivity of economically important plants and animals. Again, though plausible, Groube's idea has so far proven difficult to test.

<u>Megafaunal extinctions</u>

Sahul witnessed the disappearance of about 60 species of large bodied marsupials, birds and reptiles in the relatively recent pre-Holocene past (Flannery & Roberts 1999). Phrased another way, 23 of 24 terrestrial genera with adult body weights >45 kg that were present as recently as the Middle Pleistocene were gone by the LGM. Examples include (but are not limited to) all of the quadrupedal diprotodons (eight genera, nine species, estimated adult weight for the largest >1000kg), more than two dozen types of macropods (seven genera, 27 species, max. adult wt. 250 kg), a flightless bird (*Genyornis newtoni*, 100 kg), and several large reptiles (six genera, six species, max. adult wt. 1000 kg).

Recent opinion has generally favored the arrival of humans as the primary catalyst for these extinctions, the most frequently cited mechanisms including over-hunting, habitat disruption, or some combination of the two (e.g. Barnowsky *et al*. 2004; Brook & Bowman 2004; Flannery 1994; Miller *et al*. 2005; Roberts *et al*. 2001). The strongest support lies in the broad coincidence between the latest palaeontological evidence for some taxa and the earliest archaeological indications of a human presence on the continent (e.g. Miller *et al*. 2005; Roberts *et al*. 2001), a datum consistent with the catastrophic impact envisaged in most anthropogenic extinction scenarios.

Critics of this view point to the absence of direct evidence of human predation on any of these species, even in very large Late Pleistocene data sets (e.g. Cosgrove & Allen 2001), the clear-cut demonstration that at least four genera (*Diprotodon, Genyornis, Protemnodon, Sthenurus*) were still present in some parts of the continent more than ten thousand years after the arrival of humans (e.g. Field & Dodson 1999; Trueman *et al*. 2005), and the failure of anthropogenic models to adequately integrate data indicating that until mid-Holocene times human populations were probably very small relative to continental area and so likely to have had relatively little impact on prey populations at that spatial scale.

Wroe and Field (2006) offer an especially crucial basis for skepticism, showing that 39 of the 60 or so species in question are absent from deposits dated <80 ka BP, and that only eight were certainly present at 42-45 ka BP, the best documented date for human arrival. They make a good case for climate change - specifically a long-term trend toward increased aridity beginning ca. 400 ka BP - as the principal factor responsible for the disappearance of Sahul megafauna. If they are right, human hunting and/or habitat modification was critical to the disappearance of no more than eight species, probably fewer.

<u>Art and ornament</u>

Red and yellow ochres, probably intended for use as coloring agents, are known from several pre-LGM sites, including some dated as early as 40-45 ka BP (e.g. Bowler & Thorne 1976; O'Connor & Fankhauser 2001; Smith *et al*. 1998). Source analyses indicate that some of these pigments were transported >100 km from quarry sites to their respective points of final deposition (e.g. Bowler 1998; Smith *et al*. 1998).

Evidence of pre-LGM rock art proper is more limited. Watchman's (2001) comprehensive summary includes just two possible examples, both from Cape York, both described as red ochre smudges or smears on rockshelter walls, covered by oxylate crusts. The crusts themselves have yielded maximum dates of 24 ka and 28 ka BP, respectively; thus the smudges – and the now heavily weathered art works they might represent – are older, though how much so cannot be determined (for further discussion see Brumm & Moore 2005, 163-5; Morwood & Hobbs 1995; O'Connor & Fankhauser 2001, 294-6).

It is sometimes argued that a widespread petroglyph style ("Panaramitee"), defined by heavily eroded geometric and figurative elements, also pre-dates the LGM (e.g. McDonald 2005; Morwood 2002), but there is no firm support for this proposition.

Ornaments or parts thereof are reported from five sites. These materials include: a perforated shark's tooth (probably a pendant) from Buang Mertabak, New Ireland, dated 28-40 ka BP (Leavesley 2004); a collection of 22 *Conus* shells, found in close association with one another, modified for use as pendants or parts of one or more necklaces, from Mandu Mandu Creek rock shelter, Western Australia, dated 32 ka BP (Morse 1993); and several fragments of marine shell, judged by investigators to have been used or intended for use as ornaments, from three sites in the Kimberley region, dated 19-30 ka BP (Balme 2000; O'Connor 1999, 121).

Mortuary practices

The only source of information on this topic for pre-LGM times is the skeletal sample noted above from Willandra (S. Webb 1989). All but three of the ~130 individuals represented were found on rapidly deflating land surfaces; thus their respective ages remain uncertain. As indicated above, attempts at developing direct dates on the bones themselves have so far produced mixed results.

It is generally assumed that all of these individuals represent burials. The three recovered *in situ* (WLH 1, 3 and 135) definitely do. Eighteen show signs of post-mortem burning, and at least eleven of these are said to represent probable cremations. One of the burials (WLH 3) was partly covered with red ochre drawn from a quarry source about 200 km away. Two individuals (WLH 3, 22) show evidence of bilateral tooth avulsion (S. Webb 1989, 66-7), a common marker of social identity in various parts of Australia at the time of European colonization.

For stratigraphic reasons explored in detail elsewhere (Allen & O'Connell 2003; Bowler *et al*. 2003; O'Connell & Allen 2004), it seems likely that at least two of the three definite burials, one involving cremation (WLH 1), pre-date the LGM and may be as old as 40-42 ka. The third (WLH 135) may also be about this old. Given that most of the rest of the skeletal sample is superficially associated with sedimentary deposits that formed in the period 15-50 ka (Bowler 1998; Bowler & Price 1998; Bowler *et al*. 2003; S. Webb 1989), it may be that many of these remains, perhaps all of them, can be assigned to this time range as well. If so, then formal burial and cremation were well represented in pre-LGM Sahul, at least in what is now southeastern Australia.

Discussion

Modern humans are characterized by an unusual set of qualities: a capacity for abstract thought and communication, a remarkable degree of behavioural flexibility, and significant innovative capabilities, notably in the realm of technology. The interesting evolutionary questions are when, where, how, and why these characteristics developed.

The archaeological record is an obvious source of answers. The conventional approach to using it involves identifying material markers for the capabilities of interest, tracking their distribution in time and space, then offering explanatory arguments for their emergence based on the patterning they display. Standard lists of putatively critical indicators include: complex lithic and organic technologies (notably blade and bone tools), reliance on large-bodied prey as a dietary mainstay, use of plant and animal foods whose capture and/or processing requires complex technology (e.g. nets, snares, boiling or leaching equipment), evidence of habitat management, long distance trade (marked by the transport of "flashy" materials, such as marine shell, unusual toolstone, or ochre), the "organised" use of domestic space (said to be shown by clear-cut patterns in site structure), and indicators of symbolism in material culture and treatment of the dead. Nearly all arguments among archaeologists about the origins of modern human behaviour entail disputes about when and where these markers first appeared (e.g. Klein 2000, McBrearty & Brooks 2000; Mellars 2005).

The archaeology of pre-LGM Sahul presents a critical challenge to this approach. It is generally agreed that the people who first colonized Sahul had essentially modern behavioural capabilities; in other words, that they were fundamentally "like us," at least as far as capacities for abstract thought and communication, behavioural flexibility and innovation are concerned. The fact that they crossed Wallacea and founded viable populations throughout much of Australia-New Guinea and the Bismarcks in less than five thousand years – perhaps much less - offers strong support for this inference.

But the archaeological record they produced over next twenty millennia includes very few other indices of "modernity." Unlike contemporary datasets from Africa and western Eurasia, those from pre-LGM Sahul offer almost no evidence of complex lithic and organic technology. Watercraft and related manufacturing gear implied by voyaging are the only major exceptions. Though ornaments are represented, the quantities involved are meagre, barely more than a handful of examples known from more than 70 excavated sites. There is nothing in the record that can be identified unequivocally as art or "style." .The two examples of tooth avulsion in the Willandra human skeletal collection are the closest approximations. Apart from data indicating the movement of ochre and small numbers of marine shells, there is no basis for inference about long distance trade, and even these items may not indicate it. Subsistence and settlement records point to small, highly mobile populations focused on the exploitation of a relatively narrow range of plant and animal resources, none of which required sophisticated collecting or processing gear. Again, the only exceptions – evidence for pelagic fishing and the use of high cost plant foods – are few in number. There is no direct evidence for the hunting of animals larger in size than humans themselves, even though the opportunity to do so was available in some areas for more than ten thousand years after humans arrived on the continent. Habitat management by fire, though likely to have been practised, has yet to be clearly demonstrated. There is no indication of the "organised" use of domestic space, even in the Willandra-Darling region, where the presence of pre-LGM erosional surfaces covering thousands of hectares, many of which have been surveyed repeatedly by archaeologists, suggests that such patterning if present should by now have been reported. Only in the treatment of the dead does a modern human signature clearly emerge. Burial and cremation are both represented, though a strict approach to chronology would eliminate all but one burial (WLH 3) and one cremation (WLH 1) from the sample, and the pre-LGM status of even these is open to question (Gillespie 1997; O'Connell & Allen 2004, 843). As other analysts have observed, the overwhelming bulk of the pre-LGM Sahul record is far more reminiscent of the simplest Mousterian or MSA datasets than it is of LSA or Upper Palaeolithic (e.g. Brumm & Moore 2005; Foley & Lahr 1997; Holdaway & Cosgrove 1997; White 1977). In short, it does not appear to be the product of modern human behaviour as such products are conventionally defined. If we are prepared to stipulate that the people who first colonized Sahul were indeed fully modern, how do we account for this?

Henshilwood and Marean (2003) have recently suggested that many of the commonly nominated markers of modernity, specifically all those related to diet and associated technologies, are demographically determined (see also James & Petraglia 2005). The reasoning is simple. Higher human population densities generally imply more competition for resources, forcing greater reliance on foods that are costlier to exploit, and so favoring the development of "complex" technologies designed to handle them more efficiently (Hawkes & O'Connell 1992). Genetic evidence suggests that Upper Palaeolithic and LSA population densities were indeed much higher than those of their Mousterian and MSA predecessors (Rogers 1995). The archaeological signatures of the former are, as Henshilwood and Marean observe, generally consistent with the use of a broader, more expensive resource base (see also O'Connell 2006; Stiner *et al*. 2000).

The *post*-LGM Sahul record fits well with this line of argument and provides a basis for extending it in an important way. Putative markers of modernity began to multiply in Australia-New Guinea after 20 ka BP, sharply so in the early Holocene. By 6 ka BP, they were widespread. Detailed review is beyond us here, but papers in Allen and O'Connell (1995) offer comprehensive regional and topical summaries (see also Brumm & Moore 2005, 165-7; Hablerle & David, 2004; Lourandos & David 2002 for more recent treatments). Included in the post-LGM list are complex food collecting and processing technologies, definite evidence of habitat management (notably the translocation of wild plants and animals and the establishment of breeding populations outside their usual ranges), significant achievements in plant domestication, elaborate art and ornaments, clear-cut examples of style in material culture, and striking investments in human body modification for symbolic purposes. Evidence of a parallel increase in population density continent-wide, probably by an order of magnitude or more over pre-LGM levels, is now emerging (Fig. 5; see also Haberle & David 2004; Lourandos & David 2002).

Though Henshilwood and Marean hold that evidence of the capacity for symbolic communication remains the archaeological *sine qua non* of modern human capabilities, the broad coincidence between the appearance of such evidence and indicators of population growth and subsistence intensification – now apparent on three continents – strongly suggests that all are causally related and that population growth is the driving force behind the appearance of the other two. Other analysts have come to the same conclusion, and have outlined arguments in support of it, primarily with reference to the post-50 ka Afro-Eurasian record. For example, Kuhn *et al*. (2001) propose that the use of ornaments to mark aspects of an individual's social status is likely to be correlated with the probability of encountering unfamiliar conspecifics to whom that information would be useful, a development they reckon is likely to be associated with increases in population density. They take the near-simultaneous appearance of shell beads in East Africa, Southwest Asia and Eastern Europe, coincident with local indicators of mid-Upper Pleistocene population increase, as consistent with this hypothesis. Bird and O'Connell (2006) draw on costly signaling theory in suggesting that investment in a broad range of symbols, including those associated with both individual and group identities, may be correlated with high levels of inter-personal and inter-group competition, both seen as products in part of population growth. They point to changes associated with the Middle/Upper Palaeolithic transition in Europe in support of this proposition. Shennan (2001) appeals to cultural transmission theory in suggesting that innovations of any kind are more likely to occur as populations grow and patterns of interaction become more complex. He too sees the Middle/Upper Palaeolithic transition as exemplifying the process. Haberle and David (2004) and Brumm and Moore (2005) apply versions of these arguments in accounting for the increase in markers of modernity in mid-Holocene Australia as a function of population growth. Brumm and Moore specifically propose that the Australian case directly parallels earlier developments in Afro-Eurasia.

Though none of these suggestions has yet been developed in fully compelling terms, their implications are important. The basic argument is that the trait list commonly used to identify the presence of modern human behavioural capabilities is in significant part an artefact of demography. Its presence in the record certainly indicates modern capabilities, *but its absence does not necessarily mean those capabilities were lacking*. There simply may not have been enough people on the ground to promote their material expression. Among other things, this suggests that the intermittent appearance of style, art, and ornament in the pre-50 ka African MSA can be read as evidence of transient increases in human population density. It may also mean that the near-complete absence of material display in the west Eurasian Middle Palaeolithic says more about Neanderthal demography than it does about their cognitive or behavioral capabilities (cf. d'Errico et al. 1998; Zilhao 2001).

Assuming there is in fact a causal relationship between human population density and conventionally identified markers of modernity, several important questions are immediately begged. What factors determine the underlying pattern of population growth? Why should Sahul populations have remained so low for the first 20-25,000 years of continental occupation, then begun to grow so sharply, particularly during the Holocene? And why should African and Eurasian populations have experienced similar patterns of growth, but at much earlier dates?

Climate change is likely to have been an important factor in the Sahul case. A wide range of proxy data indicate that most of the last glacial cycle was marked by sharp, short-term temperature changes (shifts of 5-10°C over periods of less than a century) at intervals no more than a few millennia, often much less (Fig. 6; see also Burroughs 2005; Chappell 2001; Richerson *et al*. 2001). Changes of this magnitude may have had an especially devastating impact on human populations living in areas of low relief, like nearly all of Sahul, where their effects on resource availability would have been similar over very wide areas. Higher levels of aridity and lower levels of CO^2, both of which limited plant productivity over much of this time period, probably also had an important impact. Conditions during the Holocene have been very different: much less sub-millennial climatic variability, temperatures warmer, moisture conditions generally improved, CO^2 levels higher – all contributing (at least initially) to the greater availability of subsistence resources, and so setting the stage for a sustained period of human population growth (Richerson *et al*. 2001).

Promising as this explanation is for Sahul, it does not match up well with data from other parts of the world, notably western Eurasia, where relatively high human populations appear to have persisted through the more severe climatic fluctuations of the latter half of OIS 3 (30-59 ka BP). That said, the case for a causal connection between human population growth and the development of a "modern human" archaeological record as customarily defined still looks promising.

Summary

We conclude by underlining our main points and some of their more important implications:

- Modern human behavioural capabilities can exist in the absence of conventionally defined archaeological markers. We have made this point on the basis of the pre-LGM Sahul record alone, but these are not the only regional data we might have cited. The late Holocene archaeology and ethnography of Tasmania presents another well-documented example (e.g. Jones 1971, 1977).

- The archaeologies of pre-50 ka modern human and Neanderthal (and indeed other "archaic *sapiens*") populations should be reconsidered from this perspective (see also d'Errico *et al*. 1998; James & Petraglia 2005; McBrearty & Brooks 2000; Speth 2004; Zilhao 2001). The relative simplicity of these records may reflect a facultative response to low population densities rather than innately limited behavioural capabilities.

- The absolute origins of modern human capabilities may be impossible to track archaeologically, particularly in the absence of a theoretical framework that identifies the circumstances that might have led to their emergence and suggests archaeological tests. Attention to the development of such a framework, especially one that attends to material implications, is certainly in order.

- Absent such a framework, archaeologists might reconsider how best to deploy their efforts on questions about human evolution in the later Pleistocene. Especially attractive targets include: 1) climatic and environmental determinants of long term stability and change in human population density, 2) links between variation in population density and changes in human subsistence economy and technology, and 3) relationships between population density, resource competition and patterns in the symbolic aspects of material culture. All of these topics deserve much more attention than we have given them here. Recent advances in the study of human behavioural ecology suggest promising approaches to each of them (Bird & O'Connell 2006).

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Figure captions

1. Map of Sahul showing sites, localities and regions mentioned in text. Site names are abbreviated: BB – Bobongara, BK – Buka, BM - Buang Merabak, CS – Cuddie Springs, MB - Matenbek, MK – Matenkupkum, MM – Mandu Mandu.

2. Distribution of Sahul archaeological sites with reliable dates >20 ka BP. Niah, on Borneo, is the only >20 ka site shown outside Sahul (see O'Connell & Allen 2004 for additional information on pre-LGM dates from Late Pleistocene Sunda and Wallacea).

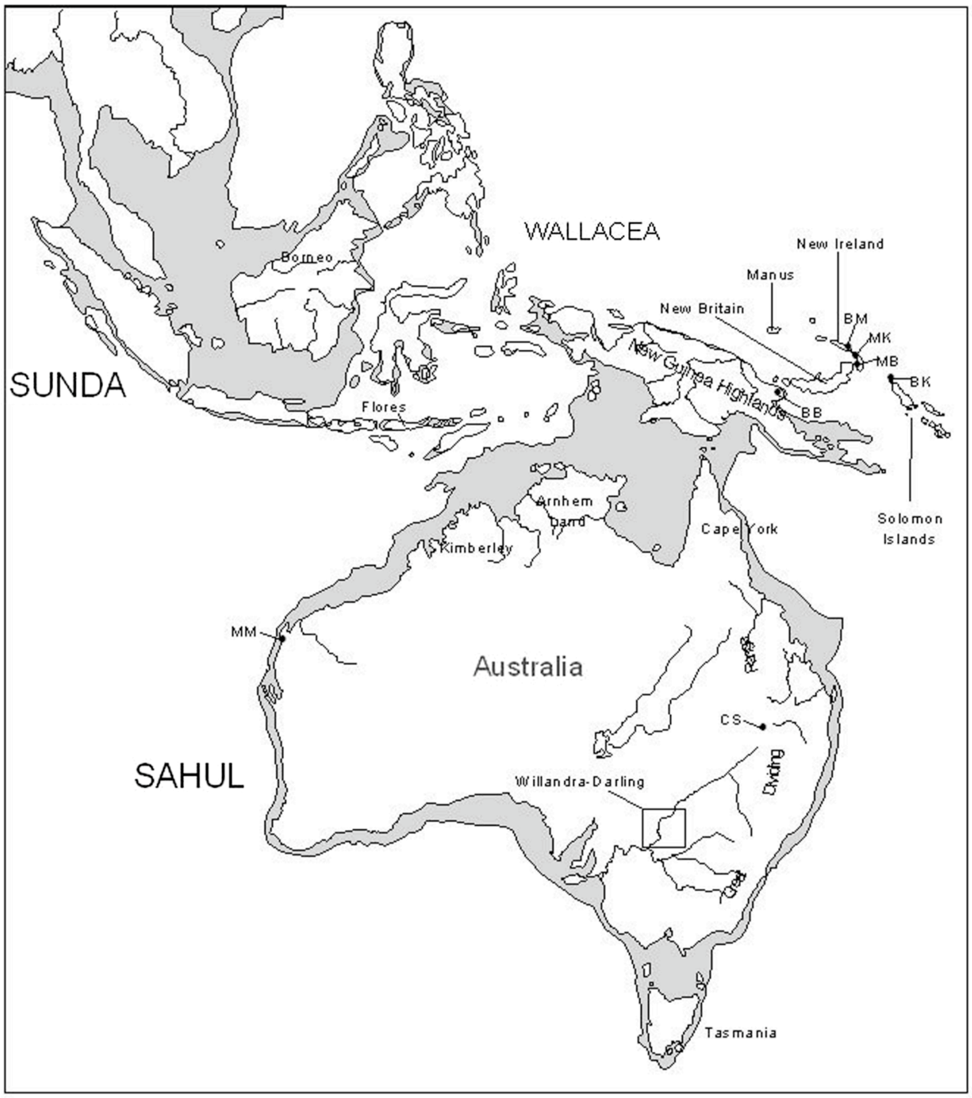
3. Examples of typical pre-LGM cores and scrapers (after Lampert 1981, Fig. 67).

4. Examples of pre-LGM tanged and waisted axes (a, b [after White & O'Connell 1982, Fig. 3.10]); grinding tools (c, d [after Fullagar & Field 1997, Fig. 3]).

5. Changes in relative numbers of sites occupied and stone tools deposited in Australia, 35 ka BP to present. Data assembled by Beaton (n.d.) in the mid-1990s. 5a shows the proportion of 1267

dated open sites continent-wide first occupied during each 5000-year period. 5b shows proportion of 70,873 artifacts from dated strata in 34 rockshelter sites continent-wide deposited during each 5000-year period. These data may be interpreted in several different ways, one of which is that they mark a sharp increase in human population size throughout Australia during the Holocene. Parallel changes in human stature, range of habitats occupied, diet breadth, and technology are consistent with this inference (see also Brumm & Moore 2005; Haberle & David 2004; Lourandos & David 2002).

6. Variation in O^{18} ratios in a Greenland ice core (GISP2) spanning the last glacial cycle (modified from Chappell 2001). Values indicatehigh amplitude millennial and sub-millennial scale changes in temperature from 60 ka through the LGM, less extreme fluctuations thereafter (see also Richerson et al. 2001).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CS
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Dividing
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Figure 1.

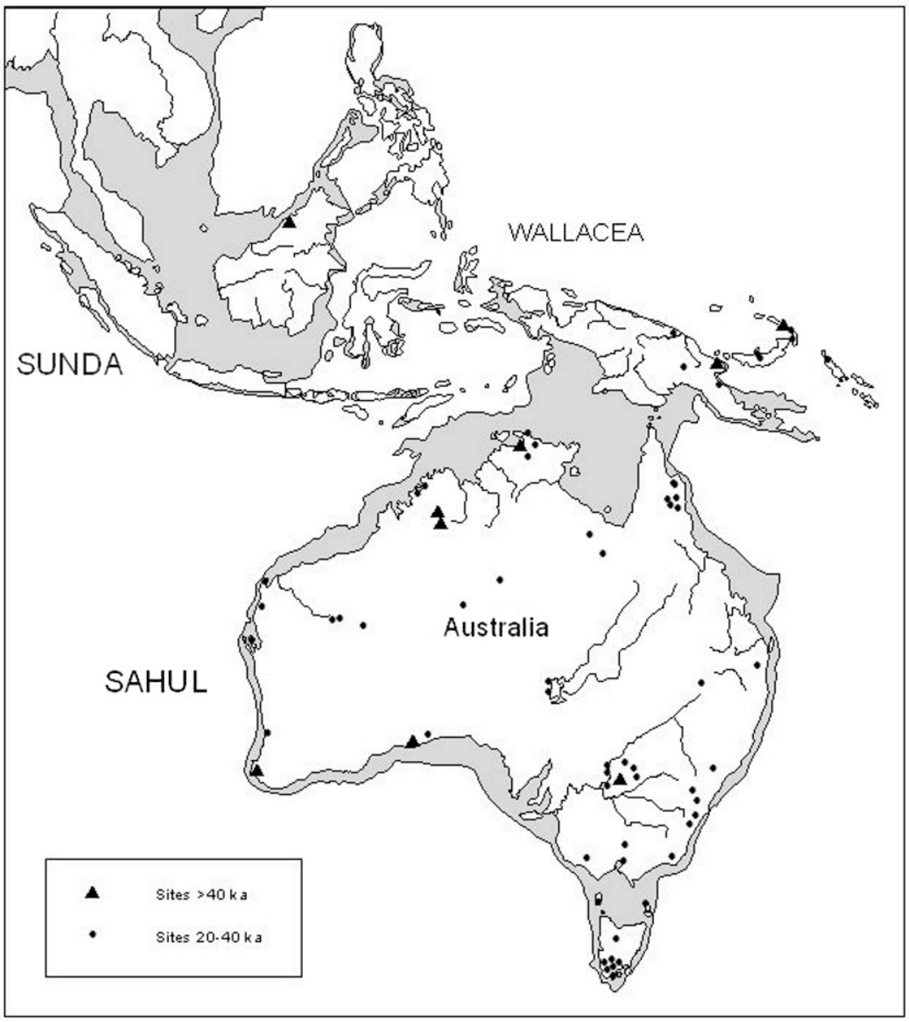
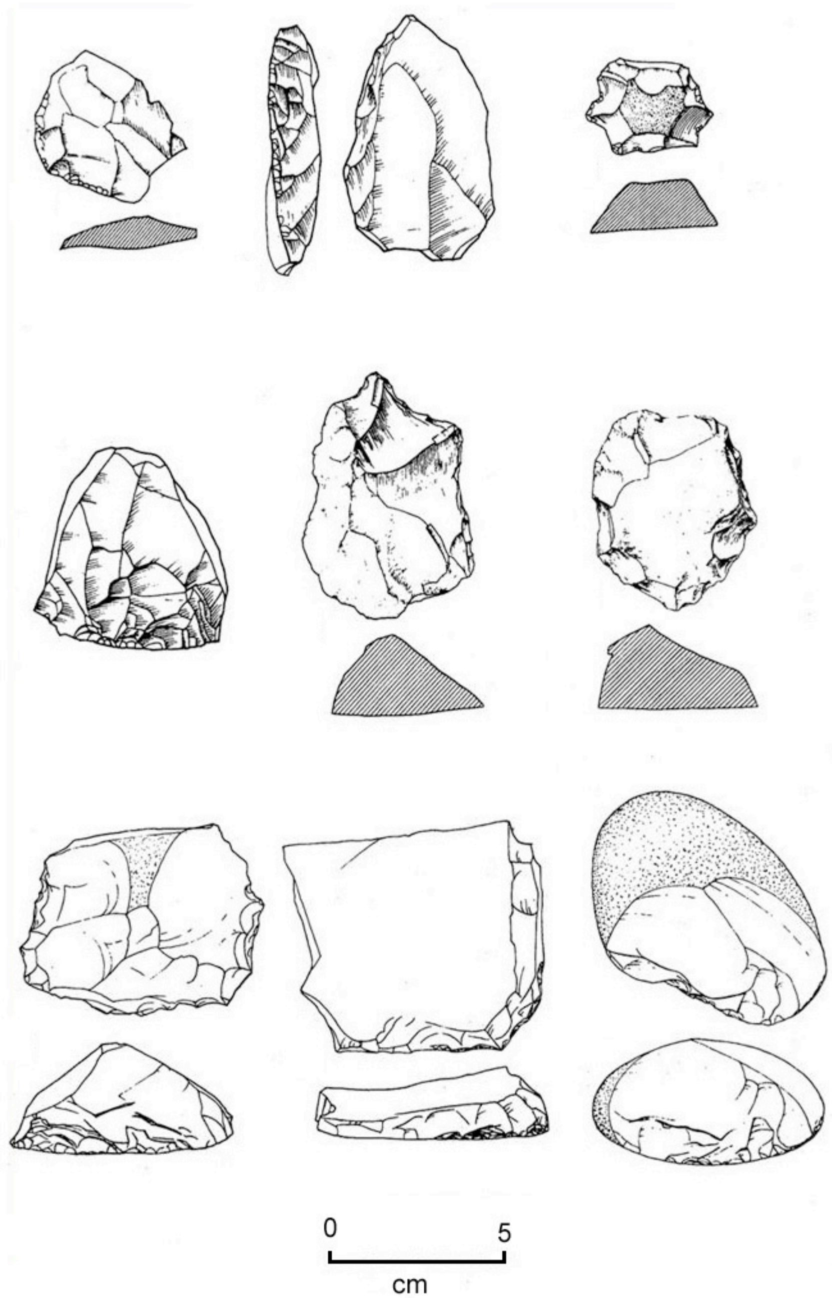


Figure 2.



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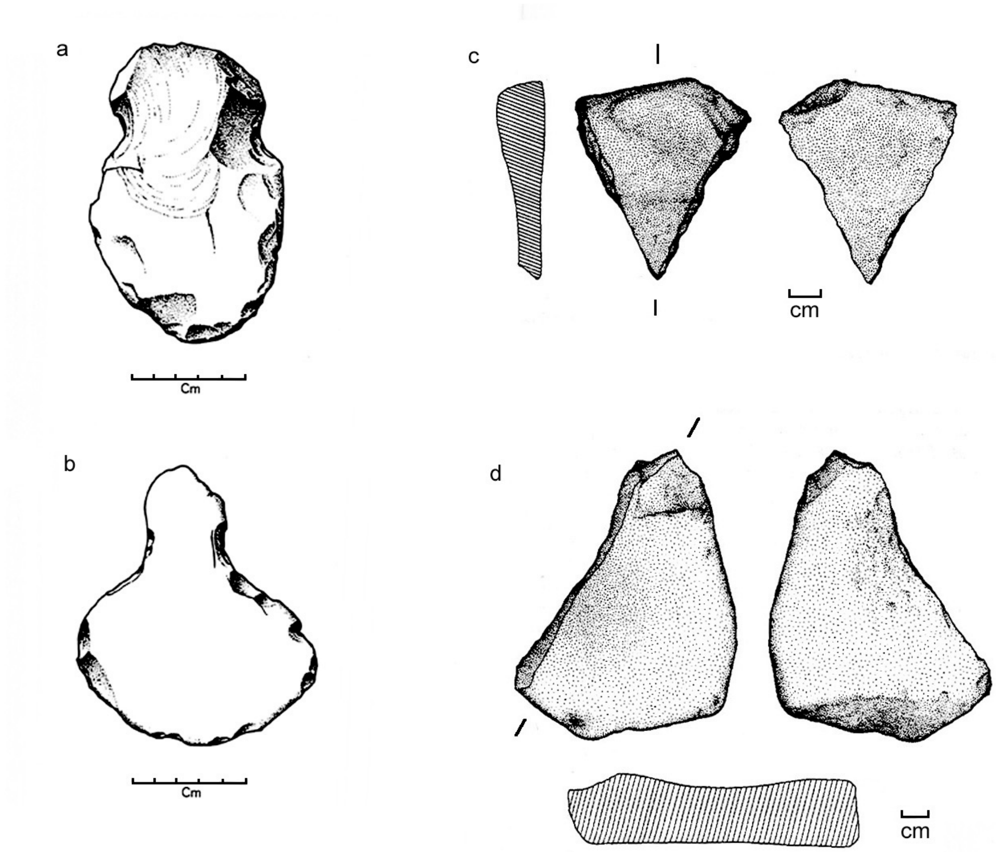

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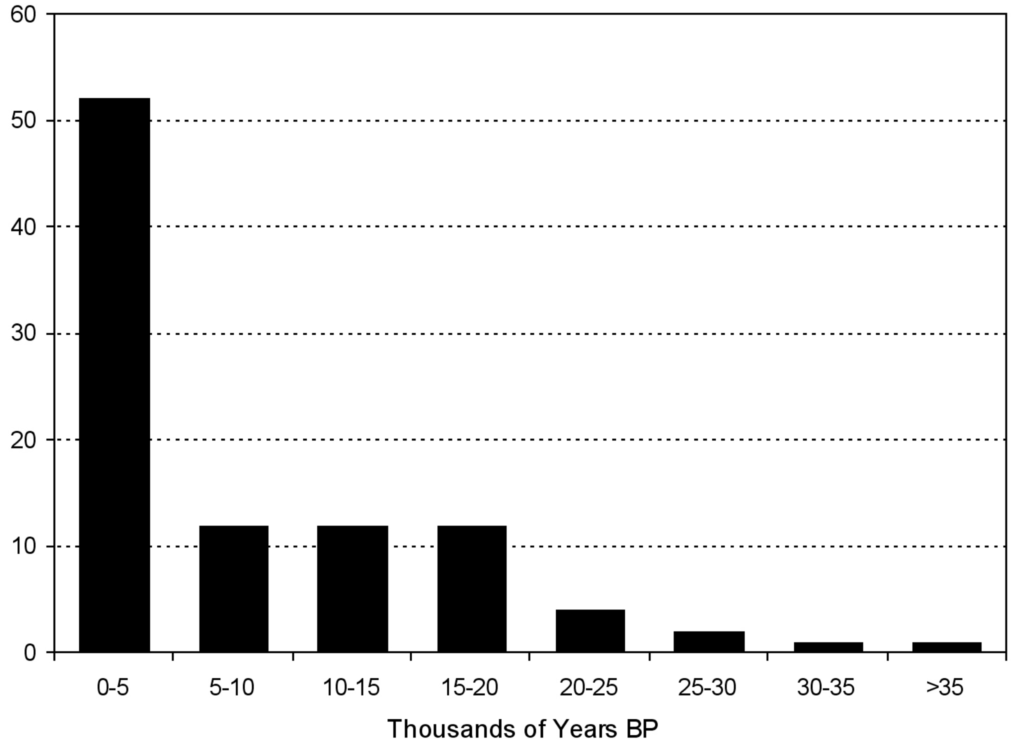
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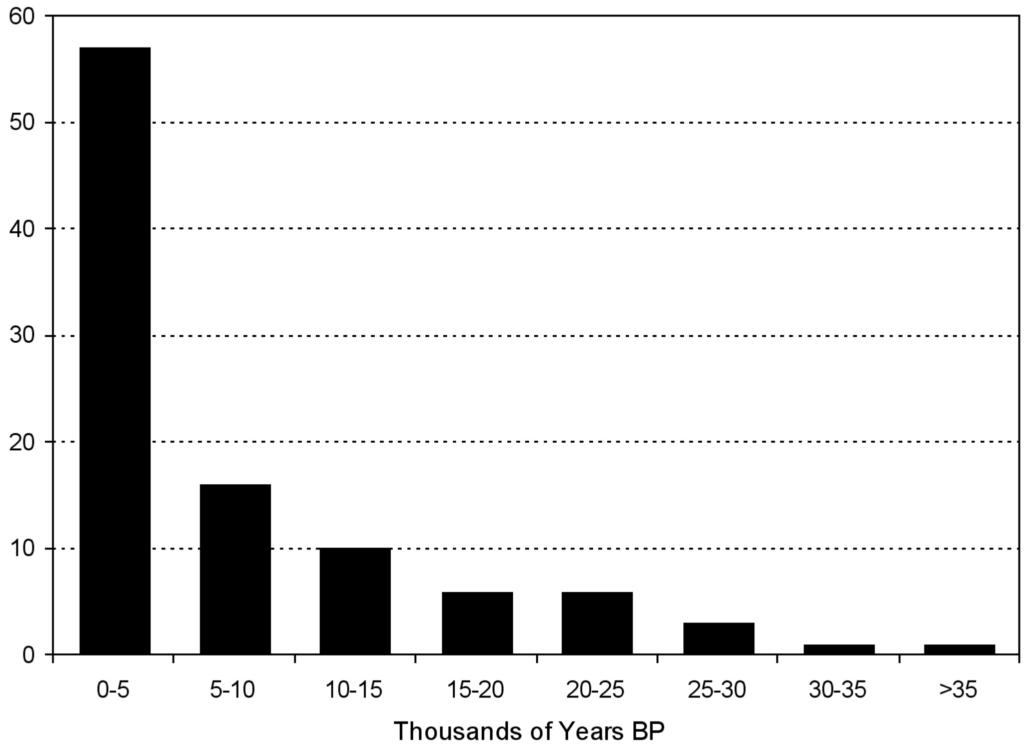
Thousands of Years BP

Figure 5a.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Thousands of Years BP

Figure 5b.

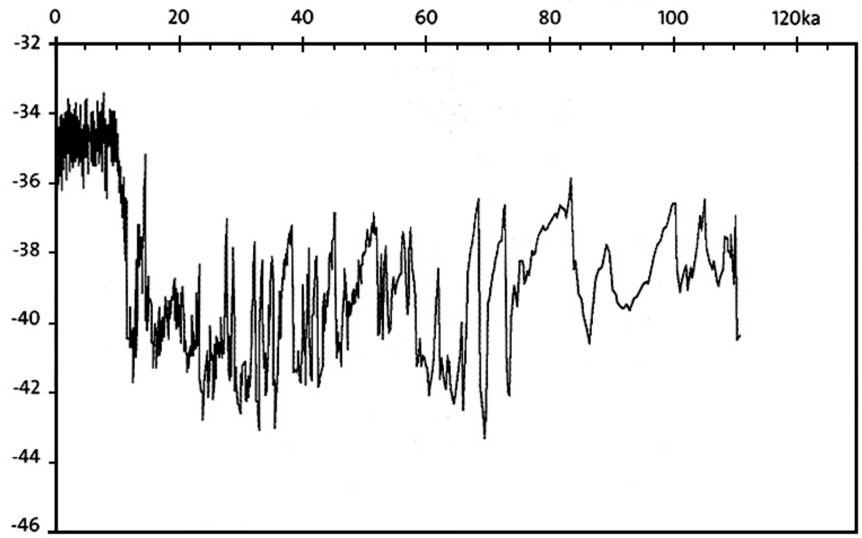

Figure 6.