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The Peopling of Sahul and Near Oceania

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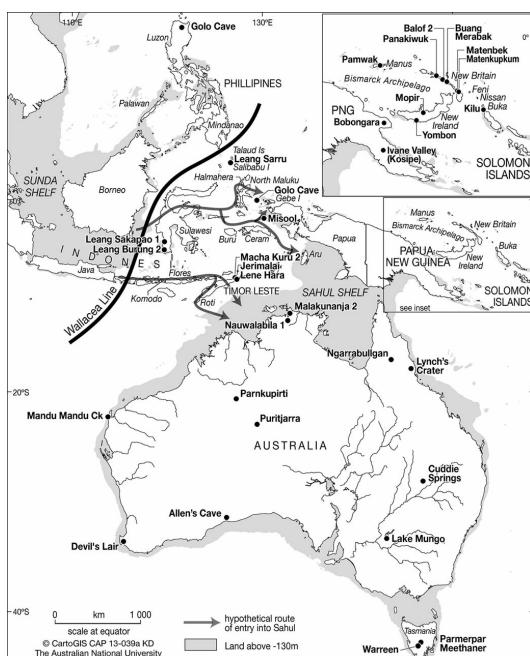
Sahul, comprising Australia, Tasmania, and New Guinea was colonized from Sunda, the enlarged southernmost extension of Eurasia, by anatomically modern *Homo sapiens* over 50,000 years ago. Pleistocene colonization of Sahul required watercraft to cross the perpetual island region of Wallacea, wherein populations adjusted to changing patterns of floral and faunal diversity. Once in Sahul, populations quickly adapted to the varying resources, developed regional differences in technology and culture, and likely contributed to megafaunal extinctions also influenced by environmental change. Ancient DNA and skeletal studies indicate that after colonization, Sahul was largely isolated from other populations. The earliest humans to inhabit Near Oceania, the islands northeast of New Guinea, arrived approximately 45,000 years ago. While the sophistication of their earliest navigational technology is debated, by 20,000 years ago these populations engaged in increasingly frequent voyaging, translocating New Guinea mainland fauna to the islands and moving valuable stone resources over hundreds of kilometers.

Keywords: Australia, anatomically modern *Homo sapiens*, maritime technology, maritime subsistence, megafaunal extinctions, New Guinea, Pleistocene colonization, Sahul, Wallacea

Introduction

During times of global low sea stands, the southernmost extension of the Eurasian continent was connected to the islands of Sumatra, Java, Bali, and Borneo. This expanded Pleistocene landmass is known in biogeography as Sundaland or Sunda (Figure 1). New Guinea, the Aru Islands, mainland Australia, and Tasmania were also combined as a separate continent known as Sahul. Between these two continental regions are the 17,000 islands of the Wallacean Archipelago. No land bridges have connected the islands of Wallacea to Sunda and Sahul over the human timespan. Likewise deep ocean trenches separate the islands of near Oceania, the Bismarck Archipelago, and the Solomon Islands from the north coast of New Guinea. Even during lowest sea stands reaching these islands required sea crossings.

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Figure 1 Map showing Sundaland, Wallacea, Sahul, and places and sites mentioned in the text.

Over 50,000 years ago modern humans left Sunda on the first ocean voyages through the island realm of Wallacea that was to culminate in the peopling of Sahul and near Oceania. The colonization of this vast region is remarkable at this early date. First, it required the development of sufficient maritime capacity to navigate the multiple water crossings separating islands along the way. Second, the colonists had to adapt to unfamiliar faunas, floras, and landscapes in each new island or continental setting. Finally, on an archaeological timescale, the journey from one continental region to the other was accomplished tens of thousands of years before the settlement of the Americas. Successful settlement of these diverse landscapes and ecosystems required different adaptations and technological innovations and it is these we explore here.

Movement toward Oceania

Oceania was colonized by groups of *Homo sapiens* whose ancestors had migrated out of Africa many millennia earlier. The pathways taken by migrating human groups throughout this journey and the motives driving successive generations to expand over such immense space have been difficult to establish, but information about the humans colonizing Oceania clarifies the dispersal process. Evidence for the out-of-Africa spread of our species comes from genetic analyses, and until recently it was proposed that humans had exited Africa relatively recently, little more than 60,000 to 65,000 years ago based on the estimated time from the common ancestor of the mtDNA haplogroups L3 (found in Africa) and the descendant M/N groups (found outside Africa). Archaeologists and geneticists alike employed this age estimate to constrain the departure of modern humans (e.g., Mellars 2006; Soares et al. 2012). It has now been shown that human mutation rates had previously been significantly overstated and that consequently the antiquity of the movement of *H. sapiens* out of Africa occurred about 120,000 years ago (Scally and Durbin 2012). This estimate means that early *H. sapiens* skeletons outside Africa, such as those in the Middle East deposited more than 90,000 years ago and at Callao Cave in the Philippines dated to almost 70,000 years ago, may be part of the early movement of humans eastward.

Ancestral Australasian populations, early Melanesians, and Australian Aboriginals inhabiting Sahul split from an ancestral Eurasian population as a result of both adaptations, drift and through hybridization with archaic hominins that had left Africa previously (Sankararaman et al. 2012). As these populations spread eastward they encountered, and sometimes interbred with, other hominins already resident in the east (e.g., Krause et al. 2010; Reich et al. 2011). Consequently, the movement toward Oceania biologically transformed the earliest migrating human populations. Later waves of *H. sapiens* into the Asia region did not hybridize with archaic hominins because they arrived after the extinctions of Denisovans and other earlier hominins. The colonization of Sahul and Near

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Oceania is in that way distinguished from later migrants to the region, biologically as well as culturally.

The Maritime Migration to Wallacea

The characteristics of these early colonizing groups have been much debated but evidence is slight. We know little about the process and rate of dispersal, the connection between population growth and onward migration, the modes of settlement, or the ways in which colonizing groups used the fauna and flora of the small and varied islands of Wallacea (O'Connor 2007; O'Connor et al. 2010; O'Connor and Aplin 2007). There has been significant debate about the route that the early colonists took to get from mainland Asia to Sahul. A southern route through the Lesser Sunda islands (including Flores and Timor) with landfall on the expanded northwest Sahul Shelf of Australia has usually been preferred, as overall it would have involved shorter water crossings between larger islands (Figure 1) (Birdsell 1977; Butlin 1993: 15, 44–51; O'Connor 2007; O'Connor and Chappell 2003). An extended southern route through Buru, Ceram, and onto the expanded Sunda shelf near the Aru Islands is another possibility (Birdsell 1977). O'Connell and Allen (2012) favor a northern route from Borneo to Sulawesi, through northern Maluku and into Papua. Archaeological evidence does not currently discriminate between these alternate models.

The degree of sophistication of the rafts or other craft in use over 40,000 years ago has also been debated (Anderson 2000: 15–16; O'Connell, Allen, and Hawkes 2010). Large platform rafts similar to those used on the rivers and estuaries in Southeast Asia would probably have been adequate for the water crossings between Timor and northern Australia in good weather conditions. Bamboo rafts are buoyant, reasonably stable, and can support a good number of people/goods (O'Connor 2010; Thorne and Raymond 1989). However, more critical in the voyaging equation than the sophistication of the craft used is wind, which provides both momentum and direction for seafaring.

During the northern Australian wet season, the wind regime at the sea surface is strongly vectored southeastward from Timor and evidence suggests that this would have been the case from ~90,000 B.P. to 58,000 B.P. Boats drifting off the coasts of Timor or Roti during the summer northwest monsoon could easily have been blown across the Timor sea onto the expanded northwest Australian coastline. After 58,000 B.P. the absence or reduction of the northwest monsoon would have reduced the likelihood of a Sahul landfall (O'Connor and Chappell 2003). The implication of this pattern is that an early (> 58,000 B.P.) colonization may not have required technically complex watercraft.

Although it is often assumed that maritime migrations would have been easier during times of low sea level as distances between islands were shorter, tropical coastal populations are more likely to be equipped for, and engaged in, activities requiring watercraft, at times of rising sea levels, and maritime habitats such as estuaries were more developed than during low sea stand. The rising sea level of 62,000 to 59,000 years ago would seem to be an opportune time for the exploration of the region (O'Connor and Chappell 2003). Given the chronological evidence indicating population movements through the region at that time, sketched earlier, it is likely that dispersals were facilitated by rising seas.

Currently the debates concerning routes and rate of migration are hypothetical, as the dates obtained for earliest occupation from islands on potential southern and northern routes do not allow us to infer directionality or speed of migration. Accelerator mass spectrometry (AMS) dates of ~43,000 years B.P. have been obtained for the earliest occupation in the Bismarck Archipelago to the northeast of New Guinea, and caves sites in East Timor have comparable AMS radiocarbon ages (Leavesley and Chappell 2004; O'Connor 2007; O'Connor et al. 2010). Although O'Connell and Allen (2012: 7) have suggested that this "archaeologically instantaneous" pattern suggests that the 4,500 km northern arc of the Wallacean Archipelago could have been traversed "well within a millennium," it must be kept in mind that dates for settlement in Sahul are older than those from the islands en route. This pattern of "archaeologically instantaneous" passage is likely an illusion and due to inadequate sampling.

Most of the islands to the north of Australia remain archaeologically unexplored. The earliest Australian dates have resulted from the use of techniques such as luminescence dating of sediments Optically Stimulated Luminescence and Thermal Luminescence(Roberts et al. 1994, 1998; Bowler et al. 2003; Veth et al. 2009). These techniques have not been widely applied in archaeological contexts in Island Southeast Asia where age estimates have thus far been mostly based on the radiocarbon technique, making comparison between the two regions problematic

(O'Connor 2007). This suggests that with more exploration earlier dates will be forthcoming from the islands to the north (O'Connor et al. 2010). When this is done, it may be possible to discriminate the migration pathways through Wallacea. However, it is likely that colonization proceeded simultaneously along different routes once people had made the first substantial water crossing east of the mainland Sunda shelf and mastered island ecosystems (O'Connor 2007).

Once people reached Sahul it appears they stayed put. There is no archaeological or genomic evidence for back voyaging from Sahul to Wallacea in the Pleistocene. For example, the translocation of animal species endemic to Sahul into Wallacea did not occur prior to the Holocene. The genetic evidence suggests that colonization of Sahul occurred as a single, or several closely spaced events, and that after this even the populations of New Guinea and Australia were effectively separated (Hudjashov et al. 2007).

Early Subsistence in the Philippines and Wallacea

The Philippines, although not formally part of Wallacea, is important as it registers the earliest presence of humans in the broader region over 60,000 years ago. These finds come from the lower levels of Callao Cave in northern Luzon and comprise a third metatarsal "provisionally ascribed to an anatomically modern human" and directly dated by U-Series ablation to ~67,000 B.P. (Pawlik, Piper, and Mijares, forthcoming), as well as bones of animals such as pig, deer, and rodents, but no stone artifacts. As the island of Luzon has never been connected to the Sundic region, this find provides evidence of our species ability to undertake sea crossings by this time (Mijares et al. 2010; Pawlik, Piper, and Mijares, forthcoming).

The areas east and west of the Wallacea line differ markedly in terms of animal species richness and diversity. Sunda shares its fauna with mainland Asia and is extremely rich in animal species, whereas with the exception of Sulawesi the islands of Wallacea are depauperate in land mammals and the island faunas display high endemisms due to isolation. The islands east of the Sunda shelf would likely have presented many challenges for early colonizing groups that would have been faced with a marked reduction in the diversity of terrestrial species available to hunt, particularly in the smaller islands. A number of megafaunal species are known to have existed in Wallacea in the past including varanids, giant land tortoises, and proboscids (Corlett 2010: 121). For most islands, the fossil records are poorly known and the cause of the extinctions is currently unclear. With a few exceptions, the megafauna appear to have gone extinct during the Pleistocene but it seems that the extinctions occurred at different times in the different islands (Corlett 2010: 121). With the exception of Flores, there is currently no evidence that they overlapped with hominins, although this clearly requires further investigation.

In the island of Flores one or more species of stegodon coexisted with the unique dwarf hominin *Homo floresiensis* from 95,000 B.P. until the late Pleistocene (Moore et al. 2009; van den Bergh et al. 2008). The komodo dragon *Varanus komodoensis* was present throughout the Pleistocene and survives on Flores and the small island of Komodo to the present day (Corlett 2010: 119). In Timor two species of pigmy *Stegodon*, a giant extinct land turtle *Geochelone atlas*, and a Komodo dragon-sized varanid have been recovered from Pleistocene-aged deposits but as yet there is no evidence for their coexistence with humans (O'Connor and Aplin 2007). Sulawesi also had a number of now extinct megafauna including giant tortoises, stegodonts, elephants, and a large suid, *Celebochoerus heeckereni*, but with these taxa as well there is no evidence that they overlapped with human settlement (Corlett 2010: 122).

The only terrestrial species found in the Pleistocene levels of the archaeological sites in East Timor were a variety of large and small murids and bats, lizards, and snakes (O'Connor and Aplin 2007). Some of the large murid species had body weights of up to 5 kg and were certainly human prey. However, it is the marine environment that seems to have been the prime focus of subsistence for the people living in East Timor at this time. At Jerimalai shelter and Lene Hara Cave, the fauna in the levels dated between 42,000 and 20,000 years ago shows that the emphasis was on marine turtles, fish, crabs, sea urchins, and a wide array of shellfish. Marine turtle bone and fish bone dominate the faunal record. The fish bones include large fast-moving pelagic species such as tuna. Indeed over 50% of the fish in the lowest levels at Jerimalai are from pelagic species (O'Connor, Ono, and Clarkson 2011). The shellfish include some species of large size such as *Trochus* sp., *Turbo* sp., and *Lambis* sp., which provide a lot of flesh, but small nerites, such as *Nerita textilis*, dominate the Pleistocene shellfish record in terms of minimum number of individuals (MNI).

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Even the tiny and remote islands of the Talaud-Sangihe archipelago, between Mindanao in the Philippines and North Sulawesi, were settled by 35,000 B.P. The dates from the limestone shelter Leang Sarru on Salibabu Island suggest episodic occupation, with an early settlement phase between 35,000 and 32,000 B.P. and a second and more intensive phase occurring during the height of the Last Glacial Maximum between 22,000 and 17,000 B.P. (Ono, Soegondho, and Yoneda 2009: 324). The Leang Sarru fauna consists solely of marine shellfish; predominantly Neritidae, Turbinidae, and Trochidae, as well as a few sea urchins (Ono, Soegondho, and Yoneda 2009), raising questions about what resources were underpinning habitation on this small island. The fauna in Golo Cave, Gebe Island, eastern Indonesia, between Halmahera and New Guinea similarly lacks faunal remains other than shellfish in the earliest Pleistocene occupation levels and possibly throughout the Pleistocene (Szabó, Brumm, and Bellwood 2007: 707). This is not due to lack of faunal preservation as conditions in these limestone shelters would preserve bone if it had been deposited. It also seems improbable that the populations of these islands could have been supported on a diet of shellfish alone even if settlement was episodic. The missing ingredient and the answer to this conundrum is probably plants.

The large island of Sulawesi has a more diverse terrestrial fauna (O'Connor and Aplin 2007). Only two sites of certain Pleistocene age are known from Sulawesi; Leang Sakapao 1 and Leang Burung 2. Both are on the southwest Peninsula. The earliest Pleistocene levels at Leang Burung 2 are older than ~30,000 B.P. They include individuals of the endemic pig-deer or babirusa, and two species of pygmy water-buffalo (*Anoa* spp.) (Bulbeck, Hiscock, and Sumantri 2004; Simons and Bulbeck 2004). The main Pleistocene horizon dates from 30,000 B.P. to 20,000 B.P. Babirusa and *Anoa* spp. decline in this horizon and there is a greater emphasis on hunting the endemic pig, *Sus celebensis*. This faunal change may reflect more open vegetation surrounding the site following the onset of drier conditions during the last glacial maximum (LGM). After ~20,000 there is no evidence that either site was used again in the Pleistocene or early Holocene (Bulbeck, Hiscock, and Sumantri 2004; O'Connor and Aplin 2007; O'Connor and Bulbeck, forthcoming).

Different strategies were pursued in these different island settings, but there is no evidence that contact between colonizing groups on different islands was maintained following settlement. Despite the limited land-based fauna, there is no evidence that first settlers brought captive species with them. Such a strategy would only work for groups settling out from islands where terrestrial species were comparatively rich, such as those crossing from the Philippines or Sulawesi to the Talaud Islands. Halmahera has evidence of the translocation of a wallaby from nearby Misool Island and a bandicoot from mainland New Guinea, but not prior to the Holocene (Bellwood et al. 1998). While it was previously thought that *Phalanger orientalis* was translocated from New Guinea to Timor in the early Holocene (O'Connor 2006), recent direct dating of the cuscus bone indicates a mid- to late Holocene timing for the introduction.

Pleistocene Technology in the Philippines and the Wallacean Islands

Pleistocene lithic assemblages are described from cave and rock shelter contexts in the Philippines, Sulawesi, the Talaud Islands, Gebe Island, and East Timor. They can be broadly characterized as core and flake assemblages containing low numbers of retouched flakes and with no repeatedly produced distinctive forms (types).

Interestingly the 67,000 year-old occupation at Callao Cave in the Philippines is not associated with stone artifacts but with a humanly modified bone assemblage. Cut marks identified on the animal bones are consistent with those produced in experimental studies using knives made of bamboo (Mijares 2011, personal communication) and Mijares et al. (2010) have raised the possibility that a technology based entirely on bamboo, bone, and antler was used in place of stone in the immediate post-colonization phase in the Philippines. Stone artifacts at Callao Cave do not occur prior to ~30 kya cal B.P. The small assemblage is predominantly made of locally available chert using simple direct percussion techniques (Mijares 2008: 103).

The small stone artifact assemblages from the earliest levels of many of the Wallacean island sites (e.g., Leang Sarru, Leang Burung 2, Jerimalai, Lene Hara Cave, and Golo Cave) can similarly be characterized as low-density flake and core assemblages made on locally available raw materials and with low levels of retouch. The low numbers of artifacts and apparently expedient production suggest either occasional use of the caves and/or the predominant use of perishable tools made of wood or bamboo (O'Connor and Bulbeck, forthcoming).

While these island sites show a surprising degree of technological similarity in the flaked lithic assemblages through

time, a number of sites preserve bone and bone artifacts, which provide a rare window into the range and complexity of organic technology and subsistence pursuits. Examples include the notched base of a bone projectile from Macha Kuru 2 and a range of fine bone points manufactured on fish spines at Jerimalai (O'Connor, Robertson, and Aplin, forthcoming). The function of the latter are not yet clear, but they appear to be too delicate to have been used as insets in composite spears. Wear on the tip suggests they were used for drilling fibrous organic material; perhaps for making holes in soft bark or leaves. The oldest fish hook is made of marine shell and is found in terminal Pleistocene at Jerimalai shelter, dated between 23,000 and 16,000 years B.P.; however, the prevalence of fish remains and the species represented in the earliest occupation layer dated 42,000 and 35,000 B.P. suggests that angling or netting must have been routinely practiced at this time (O'Connor, Ono, and Clarkson 2011).

A number of sites in the Wallacean islands also contain flaked shell tools. The earliest Pleistocene deposits at Golo Cave have large opercula of *Turbo marmoratus* shells that were unifacially knapped to produce a steeply angled edge with a form reminiscent of a scraper. Some of the removed flakes may have also been utilized (Szabó, Brumm, and Bellwood 2007: 707). Similar retouched opercula have been identified at Jerimalai shelter in the Pleistocene layer. It seems likely that such shell tools are widespread in Wallacea but are underrepresented in excavated assemblages because they have often gone undetected during excavation and been discarded.

Pleistocene industries in Wallacea contain no evidence for the edge ground axes found in early northern Australian sites and discussed later, although hafting technology was known, as demonstrated by the Macha Kuru bone projectile. It must be remembered that stone is only a single component in a broad technological repertoire which was likely made on wood, bamboo, fibrous vines, shell, bone, and other perishable materials. Unfortunately, because tools made on perishable materials are rarely preserved, we often have little evidence of the diversity and elaborateness of organic technology in the Pleistocene tropics, but the few assemblages we have with good preservation give an indication of the technological sophistication and flexibility of the early island colonists.

Colonization of Sahul

Archaeological evidence currently dates the arrival of humans in Australia at between 50,000 and 60,000 years B.P., an antiquity that is congruent with the emerging evidence that ancestral human groups had left Africa more than forty millennia earlier and spread eastward over many generations. The appearance of humans in the landscape of northern Australia is documented in the rock shelters of western Arnhem Land. At the Malakunanza II shelter the lowest artifacts were in sands estimated, by luminescence analysis of associated sand grains, to be 50,000 and 60,000 years old. At Nauwalabila, the lowest artifacts were estimated to be between 53,500 and 67,000 years old (Roberts et al. 1993). Critiques of these associations, and suggestions that all of the lowest artifacts have moved down vertically through the deposit (O'Connell and Allen 2004), overlook stratigraphic evidence in Malakunanza II of a small pit dug more than 40,000 BP, and this cannot have been vertically displaced. Humans were occupying these sites more than 45,000–50,000 years ago, and this represents a minimum date for the occupation of Sahul (Hiscock 2008). Sites with a similar antiquity are found around Sahul, confirming the widespread presence of people across the continent at or not long after 50,000 years. For instance, in central Australia open sites such as Parnkupirti (Veth et al. 2009) and cave sites such as Puritjarra (Smith et al. 2001) were occupied in excess of 40,000–45,000 years ago; in the southwest the Devil's Lair cave was occupied about 46,000–47,000 years ago (Turney et al. 2001), and in southeastern Australia debris from human occupation was present at Lake Mungo at least 45,000–50,000 years ago (Bowler et al. 2003). It may have taken some time for population levels to grow to levels where material indicators of human activity became sufficiently common that they can still be found by archaeologists today, and hence humans may have been present in landscapes for a prolonged period before they become archaeologically visible at about 50,000 years B.P. However, archaeologists currently have no reliable indications of an earlier human presence and it is the sites dating known from the period 45,000 to 55,000 years ago that appear to record the expansion of people across the continent.

Our record of the physical form of people who dispersed across Sahul comes principally from the skeletons that have been recovered from the southeast. Human skeletons dating back about 43,000 years B.P. have been preserved at Lake Mungo. A key example is the body of the individual labelled WLH3. The individual was most likely male, although this has been difficult to establish, and he was an older adult with osteoarthritis in the vertebrae and right arm, and teeth worn down so much that the pulp cavities were exposed (Webb 1989; Brown 2006; Durband,

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Rayner, and Westaway 2009). The head of WLH3 was spherically shaped, with a high forehead and moderately thin cranial bones; the face was relatively flat and above the eye sockets there was only a slight thickening of bone along the supraorbital ridge, giving it a modern appearance (Cameron and Groves 2004). Ancient mtDNA has been extracted from this skeleton, and although there have been some concerns about the extent of postmortem destruction of the DNA and the chance of contamination, the results offer clear evidence that WLH3 was from a distinctive ancient Aboriginal lineage (Adcock et al. 2001a, b). This individual was an ancestor of modern Australian Aboriginal people. The mtDNA sequences of WLH3 are still known in living people, showing that those ancient lineages still exist (Cooper et al. 2001). This demonstrates that after the colonization there were no substantial later migrations into Australia during prehistory, and certainly the founding populations were never replaced by later incoming populations (Cooper et al. 2001; Gutiérrez, Sanchez, and Marin 2002; Hudjashov et al. 2007). This outcome reflects the extent to which the colonizing population grew in size as it progressively occupied each part of the continent, until the overall population was very large; small groups who subsequently arrived would not have had much impact on the gene pool across the continent (Pardoe 2006). The Sahul mtDNA evidence is consistent with a single phase of colonization followed by a long period of genetic isolation. Physical and cultural variation evident in the Australian archaeological, historical, and biological records emerged largely from adaptations to social and physical environments within the continent.

WLH3 was buried at Lake Mungo in southern Australia after his/her ancestors had gradually spread from landing points along the northern coast. The dispersion of humans across Australia probably began shortly after humans arrived on the shores of the continent. Even acknowledging the ambiguity created by uncertainties in radiometric dating techniques, the minimum antiquity for sites in many portions of Australia is little different. As described earlier, the earliest sites in Arnhem Land show evidence for occupation about 50,000–55,000 years ago and archaeological sites further south across mainland Australia and to the northeast in New Guinea have evidence of initial occupation dating to more than 45,000 years ago. This evidence documents human settlement of many ecosystems: in sandy deserts (Puritjarra), rocky deserts (Allen's Cave), semi-arid grasslands (Cudlee Springs), tropical savannah (Malakunanja), tropical woodland (Ngarrabullgan), tropical coasts (Mandu Mandu Creek), and southern alpine uplands (Parmerpar Meethaner) (see summary in Hiscock 2008). *H. sapiens* dispersed across the accessible portions of the continent, settling multiple different environments but did not penetrate locations surrounded by substantial geographical barriers such as Bass Strait. At ~40,000 a drop in sea level produced a narrow land bridge connecting Tasmania to the mainland and earliest human presence is registered in Warreen Cave at about this time (Cosgrove et al. 2010; Hiscock 2008). From before 50,000 years ago the colonizing population was not restricted to any specific environment or to the coastal margins. Settlers entering each environment had flexible and adjustable economic systems and this, combined with expanding populations, created the capacity to occupy the diversity of environments within the Sahul landmass. Economic strategies may have been transformed early in the colonizing process following humanly induced changes to the environment of Sahul.

The noteworthy example of that process is the extinction of animal suites soon after the arrival in each region of the humans dispersing across Australia. Fossil bones show that a suite of very large animals had lived in Australia at some time prior to the arrival of humans: giant kangaroos (such as *Macropus rufus* and *Macropus giganteus titan*) and giant wombat (*Phascolonus gigas*), tall flightless birds (*Genyornis* sp.), four-legged marsupial browsers and grazers the same size as some species of hippopotamus and rhinoceros (such as *Diprotodon optatum*, *Zygomaturus* sp., *Palorchestes* sp.). In island landscapes such as New Zealand there is a repeated pattern of human hunters entering the environment for the first time, targeting and overexploiting large animals to such an extent that human predation was a significant contributor to the extinction of species. Since in Australia some studies found a broad coincidence between the time at which species of large marsupials disappeared and the time that humans arrived (Roberts et al. 2001; Miller et al. 1999), it seems likely that the human colonization of Australia might have triggered a trophic collapse in which particular kinds of animals were driven to extinction. As skillful predators whose hunting behaviors were unfamiliar to marsupial prey, the dispersing humans no doubt had the capacity to reduce the viability of vulnerable species.

However, archaeologists have never found killing sites in Australia where large extinct animals were killed and their bodies butchered in preparation for transport. This is curious because in other lands, most notably the Americas and New Zealand, kill sites have been found in abundance during periods of large game targeting. Perhaps no butchering sites are preserved because of the antiquity of the extinction event (see Surovell and Grund 2012), but

at one site, Cuddie Springs, there is preservation of the bones of megafauna, and evidence for butchery of naturally trapped animals, but no clear indication of the hunting of megafauna. However, there are doubts about the apparent association between artifacts and fossil bones at Cuddie Springs with indications that dating and stratigraphic associations are complex and that extinctions might have occurred earlier, near the initiation of human occupation (Grün et al. 2010; Roberts and Brook 2010). This possibility is consistent with a variety of environmental signatures that consistently point to the reduction in range and density of large animals, if not their final extinction, between 40,000 and 50,000 years ago (Miller et al. 1999; Roberts et al. 2001; Rule et al. 2012).

For instance, cores drilled into the deep sediments of Lynch's Crater, a swamp in northeast Australia provide a record of pollen, charcoal, and spores of the fungus *Sporormiella*, which is passed through the bowel of large herbivores and can be used as a proxy for their presence in a landscape (Feranec et al. 2011). Counts of *Sporormiella* spores, and by implication the abundance of large herbivores, declined markedly about 41,000 years ago. Immediately afterward, charcoal fragments in the sediments, and by implication fire frequency/intensity, increased in response to increased fuel load created in a landscape devoid of the herbivores that had previously eaten them. The timing of population reductions in these animals coincides with intensification of long-term continental drying, reductions in resource levels, and restructuring of the environment, and so even low levels of predation by the new human hunters may have tipped some species into terminal declines or accelerated declines already underway (Field et al. 2013).

Settlement of new territories across the continent may have been assisted by the exploitation of substantial meat packages represented by the large herbivores, but that prey would have been found in small numbers, geographically variable in abundance, and for only a limited period, and consequently early foraging practices were reasonably diverse. This is documented in the early archaeological assemblages of animal bones, which are dominated by a range of small to medium-sized game, indicating the prevalence of flexible foraging strategies focused on hunting a wide range of prey. Prey composition in each locality reflected a selection of animals from the suite of game locally available. For example, early desert economies, at least in the period 35,000–45,000 years ago were often based on the exploitation of large, permanent desert lakes as reliable resource-rich zones. Sites of this kind, such as at Lake Mungo, contain the remains of marsupial species, reptiles, as well as fish and mussels. Fishing was accomplished with a range of technologies, including spears, nets, and hook and line; while terrestrial hunters used spears and perhaps traps and thrown artifacts such as sticks or perhaps even boomerangs (though these are not reliably dated before 10,000–15,000 years ago). It is likely that plant foods such as yams and seeds would have supplemented meat in the deserts, and that these would have varied between environments, though the archaeological evidence for this foraging is rare. Regional differences in economic strategies, probably combined with disparate demographic histories, most likely underpinned regional differences in cultural practices that emerged as each landscape was settled and groups adapted their social life to the specific circumstance they encountered.

Regional traditions of behavior are also clear in this period, and especially visible in technology and symbols. Geographical differences in technology are revealed in the stone artifact assemblages, which have preserved extremely well (see Hiscock 2008). Most obvious is the manufacture and use of hafted edge-ground axes in northern Australia (e.g., Geneste et al. 2010; O'Connor 1999: 76), the flaked and waisted axes of New Guinea, and the complete absence of axes in southern Australia. Additionally, the technology for making tools through flaking differed across the continent in response to raw material characteristics and the economic incentives to produce expedient or maintained, and large or small tools. Such technological variations are not simply adaptations to local stone materials, they also indicate the transmission of local conventions of tool manufacture and tool use directed toward the exploitation of specific environments. A good example of this can be seen at a number of high altitude wetland occupation sites in New Guinea dated to between 45 ka and 39 cal BP, which appear to have been focused on the extraction and management of plant resources (see White's essay). A number of locations in the Ivane Valley at ~2,000 m (Kosipe) have been excavated which contain well-preserved evidence for the exploitation of plant foods such as charred *Pandanus* drupes as well as starch from a yam compatible with *Dioscorea* (Summerhayes et al. 2010: 79) along with flakes, cores, and axes made in differing sizes and on a range of raw materials (Summerhayes et al. 2010). These axes were waisted for hafting and like the more massive waisted axes found at the Bobongara site on the Huon Peninsula, New Guinea, are thought to have been used in combination with fire for forest clearance and to maintain open patches in the canopy thereby promoting the growth of useful plants (Groube 1989; Summerhayes et al. 2010). While larger axes were probably required to thin

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saplings, slash undergrowth, and ring-barking trees, the smaller axes may have been used for lighter extractive tasks like shaping timber to make wooden tools—such as digging sticks and the axe hafts themselves. These tool functions underscore an important point made in a seminal paper by Golson (1971) “Both sides of the Wallace Line” in which he hypothesized that while most of the animal resources in Sahul would have been foreign to the arriving colonists, plant resources such as pandanus and yams would have been familiar. Recent synthetic models have underplayed the importance of plant resources; however, these are likely to have been as central to successful settlement on the small islands of Wallacea as they were once groups reached Sahul.

Regional variation in lifestyles and activities can also be seen in the distribution of bone points which in the Pleistocene are found almost exclusively in southern Australian assemblages. They are particularly common in the upland Tasmanian sites where they are made primarily on wallaby fibulae. The function of the bone points is uncertain although Cosgrove (1999: 382) points out that they lack evidence for hafting and are not correlated with prey species so are unlikely to have been used as insets in spears for hunting prey. Recently Gilligan (2010: 45) has suggested that they were used as awls to pierce hides and make the clothing necessary for survival in these cold upland environments. This interpretation is consistent with the representation of wallaby bone elements present in the sites which indicate deliberate removal of the wallaby skins (Cosgrove and Allen 2001: 413; Pike-Tay, Cosgrove, and Garvey 2008: 2541), and information derived from the dental growth patterns of the wallaby mandibles from Warreen Cave showing that the cave was occupied during autumn and early spring—the coldest part of the year (Pike-Tay and Cosgrove 2002: 138), when fur clothing would be most needed.

Regionality in behavior, and the emergence of regional traditions of cultural practice, in the period during and after colonization of different landscapes across Sahul is further substantiated by the regional-scale difference in symbol use 40,000–50,000 years ago. In this period jewelry, probably in the form of necklaces or bracelets, made of perforated shells or bones with mastic and ochre was made only in the northwestern portion of the continent (Balme 2000; Balme and O’Connor, forthcoming; Morse 1993). Their absence in the east and south is not a consequence of poor preservation, since in some localities, especially the Tasmanian uplands, there are well-preserved faunal assemblages but no beads. At the very least this indicates regional traditions in the way ornamentation was produced, with only perishable plant materials being used for jewelry in the southeast, and it may well indicate the absence of ornamentation across a substantial portion of the continent in the millennia following settlement. A similar pattern of regional difference exists in the residues of painted art production. Small ochre fragments have often been recovered from the sediments of occupied caves, often the only visible evidence of art on the walls which disappeared long ago, and the changing abundance of ochre in different levels of the deposit may indicate changing intensities of rock painting. This phenomenon is most pronounced in the northern and western portions of the continent and has rarely been reported in the southeast. Furthermore, ochre pallets with ground facets are typical of northern Australia, and it may be that paint was prepared in a different way in the south. Ochre was used in the southeast, such as in the burial of WLH3, where it was scattered around the interred body before the grave was closed, so we know these regional differences were not the presence/absence of symbol use or ritual, but different expressions of those activities. Hence, a range of archaeological indicators reveal different symbolic expressions between north/northwestern regions and south/southeastern ones, and perhaps more local traditions that have not yet been defined (Balme et al. 2009; Balme and O’Connor, forthcoming).

These cultural differences emerged as human groups settled different environments, most likely in part through a process of drift and also as they adjusted their social and cultural systems to historically contingent situations confronting them. Even during the early millennia of settlement, it was geographical diversity and cultural adaptation rather than pan-continental uniformity and cultural stability that were the features of human occupation of Sahul.

Colonization of Near Oceania

By 45,000 B.P. people had migrated east into the Pacific as far as the Bismarck Archipelago (see Specht’s essay; Leavesley and Chappell 2004) and by 35,000 years ago they had reached the northern Solomon Islands (Wickler 2001). The islands of near Oceania have much in common with the smaller islands of Wallacea in terms of the impoverished land-based fauna (Allen 2000: 144–145). Although only 30 km wide, the Vitiaz Strait forms an effective biogeographic barrier. Whereas the mainland of New Guinea has at least fifty-two terrestrial mammals of

sufficient size to represent potential game, New Britain on the other side of the strait has only four marsupials and two rats, and two were humanly transported tens of thousands of years after first settlement (Allen 2000). Bird species also diminish from around 265 on the mainland to around one-third of this number across the Strait (see Allen 2000 and Specht 2005 for discussion of the different estimates). Because of this Allen (2000: 144) has argued that the staples for the populations that crossed the Vitiaz Strait would have been fish, shellfish, marine animals, and birds, together with the tropical food plants.

Two cave sites on New Ireland, Buang Merabak and Matenkukum, were initially occupied between 45,000 and 40,000 cal B.P. and were episodically used throughout the terminal Pleistocene (Allen 2000). Due to the combination of geological uplift and a steep offshore profile, these sites have always been within easy reach of the coast and the Pleistocene deposits show that the first inhabitants collected common rocky platform marine shellfish such as *Turbo* spp., *Chiton* sp., and *Nerita* spp., as well as echinoderms. Both sites are said to have a predominance of large individuals of large species in the lower levels followed by an increase in species diversity and decrease in size of individual shellfish within species through time. This has been interpreted as a direct reflection of changing predation intensity with the early occupants foraging in small highly mobile groups so shellfish beds had time to replenish between their visits to the cave, and later occupants depleting the shellfish beds and moving on to lower ranked smaller species (Gosden and Robertson 1991: 38). Although fish remains are present, the “bones are few in the earliest levels at Matenkukum and suggest neither specialized technology (nets, lines, poisons, fish spears) nor deliberate pursuit. Fortuitous accidental or deliberate trapping or spearing on reefs on outgoing tides would account for the evidence” (Allen 1993: 144). At Buang Merabak only two elements of shark and a solitary fish bone were recovered from the lowest Pleistocene unit (Leavesley and Allen 1998: 75). Indeed, despite their coastal location, the Pleistocene faunal assemblages of the New Ireland sites are dominated by rats, bats, and reptiles (Allen 2000; Leavesley and Allen 1998: 75). In Buang Merabak, bones of the fruit bat *Dobsonia moluccensis* are abundant. This species roosts in caves and Leavesley and Allen (1998) have suggested that the early settlers may have come to the cave expressly to hunt them.

The lack of evidence for specialized maritime subsistence in the first 20,000 years of occupation in the Bismarcks has its counterpart in the lack of specialized maritime equipment. Although Smith and Allen (1999) have suggested that some cut *Trochus* shell pieces in the Pleistocene unit at Matenbek Cave in New Ireland may be blanks for fish hooks, the evidence is thus far inconclusive. Little information is available on the Pleistocene lithic assemblages, but it appears that the early levels Buang Merabak and Matenkukum contain mostly unmodified chert flakes and simple cores. In contrast to this is the evidence from Yombon in the densely forested interior of New Britain. Yombon was first visited about 40,000 years ago to procure and work a source of high-quality chert (Pavlides and Gosden 1994). As well as quarrying and primary reduction debris, the Pleistocene levels contain some large flake tools with regular marginal retouch (Pavlides and Gosden 1994: 609, figure 3A).

Twenty thousand years after first settlement there is evidence for a marked change in maritime capacity in the Bismarck Archipelago sites. By ~24,000 B.P. we see the appearance of the New Britain cuscus and small quantities of obsidian in the New Ireland sites Buang Merabak and Matenbek (Allen 2000: 154). Analyses of the obsidian show that the source was probably Mopir in New Britain (Summerhayes and Allen 1993). The obsidian is “most plentiful in the southern New Ireland sites ... present but less plentiful in the central New Ireland site of Buang Merabak and absent in the Pleistocene layers of Balof and Panakiwuk in the north”; a distribution which indicates that it travelled “down the line” along the east coast of New Britain and across the narrow water channel to New Ireland (Allen 2000:154) rather than by canoe “a straight line distance of some 350 km” from Mopir to the sites as some have claimed (Gosden and Robertson 1991: 44).

Perhaps the best evidence for the development of voyaging capacity over time in Near Oceania is the settlement of the island of Buka, in the northern Solomon Islands by 32,000 B.P. (Wickler 2001: 239), and Manus Island by 25,000 BP (Fredericksen, Spriggs, and Ambrose 1993). Both these journeys would have involved seafaring well out of sight of land. Buka is 180 km south of the southern tip of New Ireland and while it is possible that the trip was made in stages, the stepping stone islands of Nissan and Feni are such small targets that a direct water crossing from New Ireland to Buka seems equally probable (Irwin 1991). The voyage to Manus was a 230 km single one-way trip no matter whether attempted from the north coast of Papua New Guinea or the northwestern tip of New Ireland. Sixty to ninety kilometers of this crossing would have been out of sight of land. Unlike the assemblages from the Pleistocene horizons in the New Ireland sites, Kilu contains a significant quantity of fish bone, including some oceangoing species, as well as sharks and rays (Wickler 2001). The site of Pamwak in Manus has evidence for humanly

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assisted translocations with a cuscus (*Spilocuscus kraemerii*), a bandicoot (*Echymipera kalubu*), and the important tree crop *Canarium* all introduced from the New Guinea mainland (Spriggs 1997: 54). However, as in the New Ireland sites, there is a significant time lag between the date of first settlement of Manus and the first humanly assisted translocations in the terminal Pleistocene.

Allen (2000: 145) has argued that the early settlers in Near Oceania put in place a strategy to compensate for the reduced level of terrestrial game and to make subsistence sustainable on the small islands. This strategy involved use of boats, high mobility across large territories, and a focus on the marine resources that would have been familiar and dependable. This was predicated on the use of safe and maneuverable watercraft and in turn provided the driver for improvements in maritime technology which eventually led to a change of strategy; one where useful resources such as obsidian and animals were moved to people, rather than the reverse (Allen 2000: 146). Contra to this position is that of Anderson (2000) and Specht (2005), who point out that there is nothing in the early settlement record of Near Oceania to support the case for the possession of sophisticated watercraft or two-way voyaging between the homeland of mainland New Guinea and founder populations of the Bismarcks for the first 20,000 years following settlement. Anderson (2000) makes the case that even Manus at over 200 km from the mainland could have been reached by using the current to drift or paddle from New Hanover (Anderson 2000: 18). In support of Anderson (2000), it appears that the Pleistocene settlers did not have the maritime capacity to venture beyond the northern Solomons. The inhibiting factor to onward migration was probably the southeasterly winds which blow all year round in the southwest Pacific. While there seems little doubt that incremental development of watercraft sufficient to enable long distance voyaging did occur throughout the Pleistocene in Near Oceania, colonization beyond the northern Solomons had to await the development of sail technology capable of sailing against the wind.

Discussion

Archaeological, genetic, and environmental evidences consistently indicate an early, diverse and dynamic process of colonizing and adaptation to the varied landscapes of Sunda, Sahul, and Near Oceania. Humans most likely moved into Sundaland and subsequently the Wallacean Archipelago by 50,000–60,000 years B.P. and perhaps earlier, and by at least 50,000–55,000 years B.P. had crossed into Sahul. Shortly after that date we have evidence of the dispersal of human groups across the island landscapes of Near Oceania. These large-scale movements took place over many millennia and were probably opportunistic in nature. Substantial water crossings do not imply elaborate watercraft or navigational techniques, but do reflect exploitation of winds and currents during opportune climatic periods. However, the evidence from Near Oceania is consistent with a gradual enhancement of maritime abilities throughout the colonizing process, a trend that reflects a general pattern of adaptation. Diversification of behavioral characteristics between different environments, as human groups reshaped economic and social practices in response to regional/local resources, was a common pattern, and may have initially been facilitated by the relative isolation of colonizing groups. This diversification may underpin the differing culture-historical trajectories that are evident at later times across the Sunda/Sahul and Near Oceanic regions.

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