Chapter

The Southern Route to Sahul: Modern Human Dispersal and Adaptation in the Pleistocene

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Abstract

In this chapter we examine the evidence for modern human dispersal, early settlement and later adaptations to the southern islands of the Wallacean Archipelago. We discuss the features that distinguish modern human occupation in southern Wallacea during the Pleistocene from those in the northern islands. In this context we examine the location of sites in the landscape, as well as technology and subsistence across this maritime realm between 50,000 and 20,000 years ago. We then look at the changes that occurred in the terminal Pleistocene after ~20,000 years ago. Such changes include an increase in marine resource use and occupation intensity more generally, as well as initial occupation of inland regions and very small islands. Accompanying these changes is the appearance of new maritime technology in the form of shell fishhooks and adzes. Perhaps most remarkable, is the onset of an obsidian exchange network connecting at least three of the southern islands from ~17,000 years ago. These changes coincide with new forms of artistic expression, in both personal ornamentation and rock art. Greater social connectivity during the terminal Pleistocene in the southern islands seems to have ushered in new symbolic concerns.

Keywords: Wallacea, maritime colonisation, marine resource use, island connectivity, symbolic expression, LGM, Indonesia, Timor-Leste

1. Introduction

Modern humans, *Homo sapiens*, are thought to have arrived in Sahul at least 60,000 years ago. Although the date is not universally accepted [1–5] the earliest occupation of the rock shelter known as Madjedbebe in Arnhem Land has been dated using Optically Stimulated Luminescence to 65,000 ± 6000 years ago [6]. To the northwest, evidence from the site of Lida Ajer in Sumatra indicates that *H. sapiens* were present in Sunda at least 68,000 ± 5000 years ago [7], while recent dating efforts from Tam Pà Ling, Laos, have recovered evidence for modern humans in mainland Southeast Asia as early as 77,000 ± 9000 years ago [8]. As yet, however, we have no firm evidence approaching this antiquity for the settlement of Wallacea; the enormous archipelago of islands to the east of Sunda and north of Australia. The early mariners who arrived in northern Australia must have passed through and settled many of the islands in this archipelago, and thus the lack of evidence presents something of a conundrum.

There are many thousands of islands in the Wallacean archipelago, and most are archaeologically unexplored. However, in the last decade there has been a targeted effort to investigate islands positioned along the hypothesised most likely routes to Sahul (Australia+New Guinea). Two main routes were proposed by Birdsell [9]; a northern route through Sulawesi, the Maluku islands, and into Papua; and a southern route crossing from Bali to Lombok, into the Nusa Tenggara archipelago to Timor, and then onto the expanded Pleistocene Sahul Shelf of north western Australia (**Figure 1**). Various attempts have been made at modelling migration along these routes; with the northern route being most supported in terms of intervisibility of islands, minimum distances between islands, and least cost of crossings [11–15]. The early dates for occupation on islands along the southern route, and at Madjedbebe, have however been seen by some as favouring arrival via a southern route [6, 16, 17]. Despite intensified field exploration over the past decade, thus far neither route has been resolved as that of first passage, because dates for earliest occupation are similar for sites on islands lying along both routes and do not pre-date arrival in Australia [18–20]. In this chapter we summarise the results of the archaeological excavations with Pleistocene dates which are on southern route islands and look at what these tell us about the nature of early settlement. We pay particular attention to the occupation records from sites in Flores, Alor and Timor islands as these islands have been most intensively investigated and have the earliest dated sequences on the southern route. For the terminal Pleistocene we extend this coverage to include Kisar; a very small island off the eastern tip of Timor.

2. Lower Pleistocene settlement of western Wallacea and the Philippines by archaic hominins

The islands of Wallacea have never been connected by a land bridge to Sahul to the east, or Sunda (mainland southeast Asia) to the west (**Figure 1**), thus their settlement has always required the animals or hominins reaching them to have made sea crossings. Archaic hominin remains and their stone tools dating back to the Middle and Early Pleistocene have been found in the larger western islands of Wallacea, Flores and Sulawesi, as well as in Luzon [20–25], immediately to the east of Huxley's Line. These islands are notable for supporting medium to large-sized terrestrial fauna in the Pleistocene, such as rhinoceros and stegodons on Luzon, and stegodons, large land turtles, and Komodo dragons (*Varanus komodoensis*) on Flores and Sulawesi. The early hominins who reached these islands preyed on these large terrestrial animals for their subsistence [21–25].

Early hominins did not succeed in onward migration to the east of these large islands on current evidence - not even to islands on which large to medium-size prey species were intermittently available, such as Timor and Sumba [26, 27]. This, coupled with the island endemism of these hominins, suggests that their maritime abilities were limited, and their early establishment on the larger western islands resulted from incidental sea crossing, such as drift on logs or vegetation bundles following storms [10, 28–30].

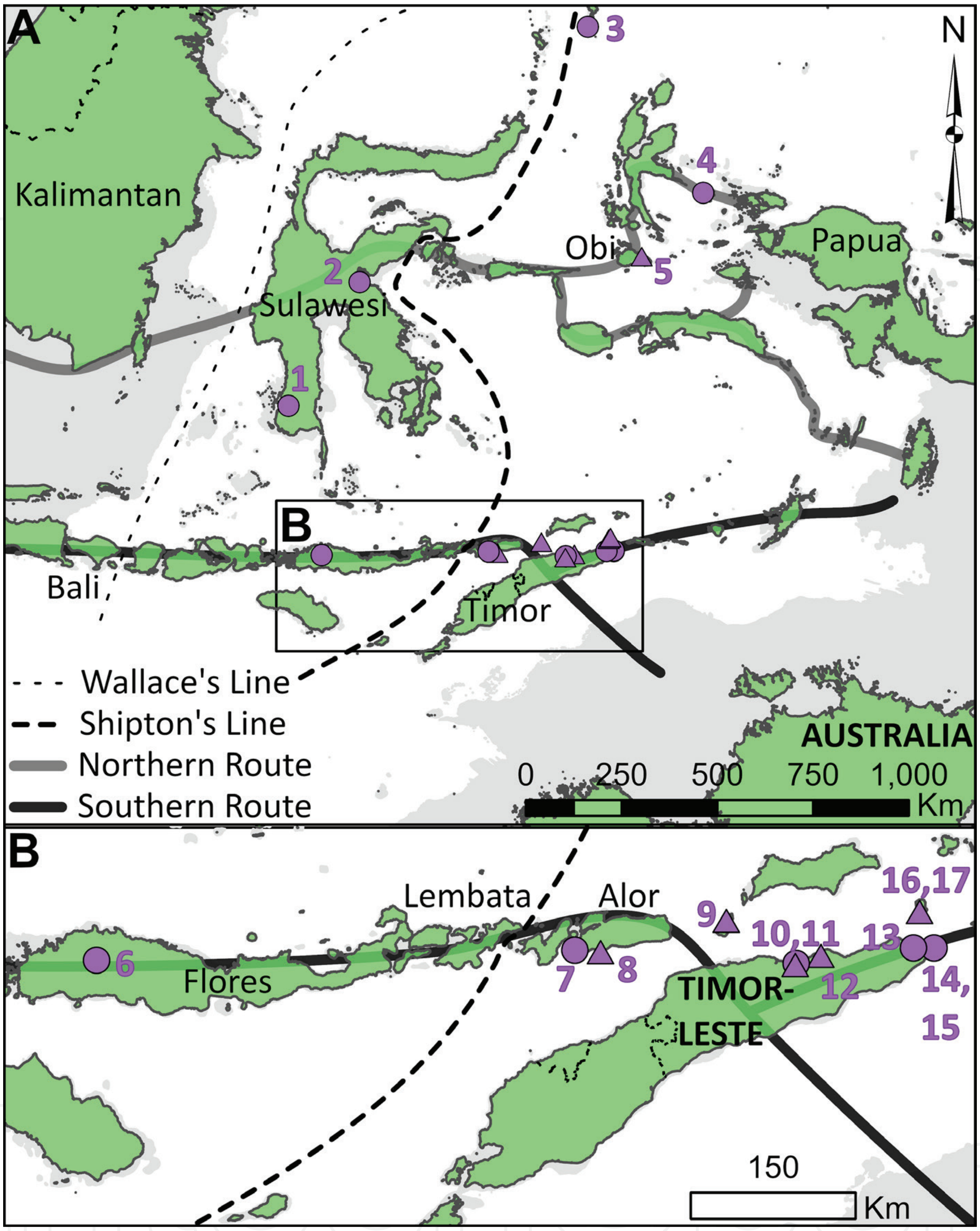

Figure 1.
Map showing the location of southern routes sites and key northern route sites mentioned in the text. Circles indicate sites which record occupation prior to 20,000 years ago, triangles indicate sites where occupation does not begin until after 20,000 years ago. 'Shipton's Line' refers to the Lower Palaeolithic line identified by Shipton et al. [10] as the most easterly extent of archaic hominins in Wallacea. The grey shading delineates the -120 m bathymetric contour. A) Regional map showing the location of inset B. B) Southern Wallacean islands which are the focus of this chapter. Numbers refer to the following archaeological sites: 1. Leang Tedongnge & Leang Burung 2; 2. Goa Topogaro 2; 3. Leang Sarru; 5. Golo Cave; 6. Kelo 6; 7. Liang Bua; 8. Makpan; 9. Tron Bon Lei; 10. Arlo; 11. Hatu Saur; 12. Laili; 13. Bui Ceri Uato; 14. Matja Kuru 2; 15. Lene Hara; 16. Asitau Kuru; 17. Here Sorot Entapa; 18. Ratu Mali.

3. After 50,000 years BP: Modern humans arrive in Wallacea

In contrast, modern human colonisation of Wallacea seems to have been purposive [10, 16]. Although in the past some researchers have suggested accidental drift passage could account for the initial settlement of Sahul [31, 32], if this were the case one would expect archaic hominins to have reached Sahul, given the more than one million years of opportunity during which they were resident in Sunda and on the western Wallacean islands of Sulawesi and Flores. Further support for a purposeful rather than accidental movement into the region comes from population genetic modelling. The most comprehensive of these models suggests a minimum founding population of ~1300–1550 individuals would have been required in order to establish a successful population on Sahul [33, 34].

The radiometric dating for Wallacea and Sunda sites shows that modern human populations moved quite rapidly through the archipelago which also supports purposive migration. Thus far there are no clear indications of directionality shown via the patterning of the earliest dates from archaeological excavations across Wallacea [35]. Earliest dates from cave and rockshelter occupation deposits on the southern route range between 48,000–44,000 years ago. On the northern route comparable dates have been obtained with a minimum age of 46,000 years ago from Uranium-Thorium dating of calcite deposits overlying painted art in southern Sulawesi [36] and recent excavations at Goa Topogaro 2 in central Sulawesi recovering radiocarbon dates for human occupation back to ~42,000 cal. BP [37].

When the large standard deviations on the ages are taken into account the dates for first occupation at these sites are statistically indistinguishable. It is likely that the early colonists did not navigate 'a least-cost pathway' from west to east, but rather explored and utilised islands in proximity to their home island, venturing out to distantly visible islands at times when currents, tides and winds were favourable. In this way they would have built up maritime knowledge that could be shared with other resident groups, thereby enabling longer journeys and eventual settlement. If this is the case, islands on both routes may have been colonised within the same time frame. It should be noted that the remote Talaud group of islands was initially occupied by 35,000 years ago demonstrating long distance maritime voyaging was not beyond the capabilities of these Pleistocene mariners [38].

Modern human migration must have involved some form of watercraft as well as knowledge of seafaring and associated technologies to make it across the Indonesian throughflow to islands such as Timor. These early mariners must also have had versatile economic strategies as the environments and resources they encountered moving through the archipelago would have been very different from island to island [35, 39]. The islands of the northern route were more densely forested and in the case of the larger islands like Sulawesi had a range of medium to large terrestrial game as seen in the faunal records from Leang Burung 2, Goa Topogaro 2 and Leang Sakapao 1 [37, 40, 41].

In contrast, the southern Wallacean islands are distinguished by being depauperate in terrestrial fauna, although the larger southern islands, Flores, Alor and Timor had giant murids at the time of modern human occupation. One giant murid, *Papagomys armandvillei* is still found in Flores and large murids persisted in Timor and Alor until the late Holocene [42]. By the time modern humans arrived in Flores and Timor it would seem that the stegodons were extinct, or at least there is no evidence of their prolonged co-existence with modern humans in these islands [26, 43]. Modern humans had to adapt to a limited range of terrestrial fauna alongside an abundance of marine resources.

The southern Wallacean islands have six sites which register settlement between ~50,000 years ago and 40,000 years ago; Liang Bua on Flores, Asitau Kuru, Lene Hara, Laili and Matja Kuru 2 on Timor-Leste, and Makpan on Alor Island (**Figure 1**). Below we outline the salient findings from these sites, including their excavation, dating, and the cultural materials which characterise their settlement and occupation in the Pleistocene. We then briefly discuss some of the sites occupied in the terminal Pleistocene and the changes that occur after this time.

4. The sites

4.1 Liang Bua, Flores

Liang Bua is a large limestone cave located in the western part of Flores ~14 km north of the city of Ruteng in the Manggarai Regency (**Figure 1**). Liang Bua is the only southern Wallacean site which was a substantial distance from the coast when first occupied by modern humans ~46,000 ± 2000 years ago [23], (~30 km from the coast at the time modern humans arrived), however it is only a few hundred metres from the confluence of two major rivers, the Racang and Mulu Rivers. The skeletal remains assigned to *H. floresiensis* which were originally thought to date to the early Holocene are now known to date between ~100,000 and 60,000 years ago, while the stone artefacts thought to be associated with this species date between ~190,000 and 50,000 [20, 23]. Modern humans arrived on Flores ~46,000 years ago. A change in the dominant material used to make stone artefacts from silicified tuff to chert occurs following the arrival of *H. sapiens* [23]. A major shift is also observed in the composition of the faunal assemblages after this time, reflecting changes in palaeoecology, hominin behaviour or both. It seems probable that the extinction of *H. floresiensis* and the associated giant endemic fauna (Stegodon, giant marabou stork and vulture) occurred at Liang Bua ~50,000 years ago either coincident with or just preceding modern human arrival. Recent research at Liang Bua, indicates that large murids were also an important prey species, in both the *H. floresiensis* and modern human occupation levels [24, 44].

4.2 Asitau Kuru (formerly known as Jerimalai), Timor-Leste

Asitau Kuru is a small limestone rockshelter at the far eastern end of Timor-Leste southeast of the village of Tutuala (**Figure 1**). It was previously called Jerimalai but was renamed at the request of local elders in 2017. Asitau Kuru is formed in an uplifted coralline terrace approximately 75 m above sea level and within 1 km of the current coastline [45] (**Figure 1**). Due to the steep offshore bathymetric profile in this region and calculated uplift rates for the nearby coralline terraces [46] the shelter would have been less than 3 km from the coast when initially occupied and only a little more than this during the Last Glacial Maximum (LGM) when sea level was 121 m below present (based on Lambeck and Chappell's [47] curve). Although the distance to the coast was not much further during the LGM, the intervening landscape would have been much steeper and this factor may explain why the shelter was little used during this time.

Asitau Kuru was first investigated in 2005 with the excavation of two 1 x 1 m pits, Squares A and B, [17, 48]. In 2017 another 1 x 1 m pit (Square C) was excavated adjoining the east wall of Square B [49]. Shipton et al. [49] divided the sequence into three occupation phases: a Pleistocene occupation from ~44,000 to 15,000 years ago, an early to middle Holocene occupation from ~10,000 to 5000 years ago and a Neolithic occupation from ~4000 years ago to the recent past. It was the lowest layer of Square C which produced the earliest direct date of 44,000 ± 1000 years ago for modern human occupation at Asitau Kuru. The site also produced a rich assemblage including stone and shell artefacts, and abundant remains of marine fauna including turtle, fish, shellfish, crab and urchin [17, 49].

4.3 Lene Hara, Timor-Leste

Nearby to Asitau Kuru, Lene Hara is a large limestone solution cave at the eastern end of Timor-Leste (**Figure 1**). The entrance faces east and is over 40 m wide at the dripline, and the main cave extends more than 50 m into the hillside. Today Lene Hara is ~100 m above sea level and less than 1 km from the coastline. As is the case with Asitua Kuru, the cave would have been less than 2 km distant from the coast at the time of initial occupation ~45,000 years ago, and within walking distance of coastal resources even when sea-level was at its lowest during the LGM.

Lene Hara was first excavated in 1963 by the Portuguese anthropologist de Almeida but no radiometric dates were obtained and the finds were not fully published. It was re-excavated in 2000 by a team from the Australian National University when a 1 x 1 m exploratory pit, Pit A, was placed adjacent to Almeida's trench near the southern entrance [44]. Pit A produced a sequence comprising a ceramic horizon dating to the late Holocene and a preceramic horizon containing stone artefacts and vertebrate and invertebrate fauna [50]. The fauna throughout indicates a heavy reliance on marine foods such as turtle, fish and shellfish, especially in the Pleistocene levels, although bones of large and small rodents, snakes, and lizards also occur. The late Holocene ceramic horizon also contains a small quantity of introduced fauna such as dog and Phalanger [51]. The stone artefact assemblage is dominated by unretouched flakes made on chert. Radiocarbon dating of the 2000 excavation [44] showed that the deposit of Pit A was predominantly accumulated during the Pleistocene between ~39,000 and 34,000 years cal. BP [44]. This Pleistocene-aged deposit was directly overlain by the pottery bearing layer, suggesting that occupation of the cave was either discontinuous with a lengthy hiatus, or that erosion had removed part of the deposit at some time in the past.

In September 2002 further test-pitting was carried out at Lene Hara in other parts of the cave to clarify the chronology of occupation. Pits B, D and F were excavated at different locations across the cave floor [50]. In short, this demonstrated that substantial erosion had occurred in the past with different areas of the cave floor preserving different chronostratigraphic sequences of occupation [50]. Pit B was shown to date between ~30,000 and 21,500 years cal. BP and Pit D and F to have Holocene-aged deposits [50]. A subsequent survey of the cave in 2009 resulted in the discovery of a breccia deposit which contained inclusions of cultural materials such as marine shell, stone artefacts and bone, cemented on the underside of a large speleothem and at a height of approximately 50 cm above the current floor in this area of the cave [50]. Marine shell from the breccia dated to ~42,500 ± 500 years ago, making it very similar in age to nearby Asitau Kuru. The lithic and faunal assemblages from test pits B, D and F indicate a similar focus on chert for lithic production and heavy use of marine resources. Pit F which was positioned in a well lit area close to the cave mouth contained several shell fish hooks and shell beads, with one hook directly dated to the early Holocene [52, 53].

4.4 Matja Kuru 2, Timor-Leste

Matja Kuru 2 (MK2) is small cave in an uplifted limestone ridge located northeast of the modern village of Poros at the eastern end of Timor-Leste (**Figure 1**). The shoreline of Timor's largest lake, Ira Lalaro, is to the south of the cave and would have been only a few hundred meters from the entrance during lake high stands. Today the site is ~370 m above mean sea level and around 6 km in straight-line distance from the north coast (**Figure 1**). MK2 was first excavated in 2001 with a 1 x 1 m test pit (Square D), but due to time constraints excavation was discontinued without reaching bedrock. In 2014, the excavation was reopened in order to extend the original pit to bedrock and enlarge the excavation. In total, a 3 x 2 m area was excavated, including the original Square D, and five new squares, DD, C, B, BB and AA [39]. The site has two main phases of occupation; the first spanning the Pleistocene from ~42,000 until ~30,000 years cal. BP, which is followed by a hiatus, and then the second phase begins in the terminal Pleistocene ~13,000 years cal. BP and continues through to the Late Holocene [39]. The earliest direct date on modern human occupation at MK2 (41,000 ± 1000 cal. BP) overlaps the date recovered from Lene Hara, indicating that these two sites were likely initially occupied at approximately the same time.

Based on analysis of the material remains from the 2001 and 2014 excavations undertaken thus far, stone artefacts and invertebrate marine fauna are most abundant in the Pleistocene levels, whereas vertebrate faunal remains are most abundant in the terminal Pleistocene and early Holocene [54–56]. Analysis of all the finds from both excavation seasons is nearing completion and will refine our understanding of the pattern of occupation at MK2. Stone artefacts are predominantly small in size and made on chert although occasional obsidian pieces occur. Terrestrial fauna hunted include giant and large rodents [39]. Freshwater turtle and fish occur alongside marine fish and shellfish remains throughout the two occupation phases. The presence of marine fish and shellfish shows that from the outset people regularly made the 6 km trip from the coast carrying these resources [56]. Pottery and introduced fauna such as dog, pig, civet cat and cuscus occur in the late Holocene levels [56, 57].

While camped at MK2 people spent their time making shell jewellery from the *Nautilus* shells they collected at the coast [52]. Bone tools are rare but small pieces of worked ochre were recovered throughout the sequence [58, 59]. It would seem that the cave was an attractive base from which to pursue a range of activities when freshwater was available in the nearby lake. Conversely, MK2 appears not to have been used during the LGM, likely the result of the lake dry during this time making the cave a less appealing location for occupation.

4.5 Laili, Timor-Leste

Laili is a partially collapsed limestone cave located adjacent to the modern village of Laleia, ~4.3 km from the north coast of Timor-Leste (**Figure 1**). The entrance to the cave is at 86 m elevation and overlooks the lower Laleia river and its floodplain to the east [19]. Even during maximum low sea stand of the LGM the coast would have been ~5 km distant from the cave entrance. Laili was first excavated in 2011 [19], and again in 2019 when the excavation area was enlarged with the addition of three 1 x 1 m squares (Squares C, D and E) adjoining the original Square A producing a total excavation area of 2 x 2 m.

Only the 2011 excavation has thus far been published. Earliest occupation occurs 43,500 ± 500 years ago and the site registers episodic use through to the present, although most of the Holocene deposit is represented only by small patches of cemented brecciated cultural material adhering to the cave walls [60]. The Holocene floor deposit is thought to have been removed by local villagers for garden soil, at least in the area of the excavation [60]. Two main occupation phases were differentiated in this excavation, The initial Pleistocene occupation period spanning from ~44,000 through until ~36,000; followed by an LGM through to initial Holocene occupation phase (~22,500 and 8500 years ago) [19, 61].

The Laili fauna shows the exploitation of a broad range of environments including the coast and hinterland. Large and small rats, bats and a variety of birds were represented. Marine turtle and freshwater turtle indicate that both the coast and the nearby river were important for subsistence. Molluscs occur throughout the occupation sequence with over 40 species identified from a range of habitats including marine, mudflat/mangrove and freshwater environments. The Laili fish assemblage is also diverse with at least ten different taxa from both freshwater and marine environments [62]. Surprisingly, no fishing technology was recovered at Laili. Laili does however, contain an enormous number of lithic artefacts made mostly on good quality chert which is locally available in the nearby river terraces and gravels [19]. Square A alone produced over 28,000 flaked stone artefacts, making this the largest excavated collection of stone artefacts per unit volume from Pleistocene ISEA. Lithic artefacts were identified throughout the sequence, with the highest frequencies found from the end of the LGM to the onset of the Holocene.

4.6 Makpan, Alor

Makpan is a large lava tube cave on the southwest coast of Alor that dates first occupation to ~39,500 ± 500 years ago [63]. The cave entrance faces the ocean and today it is ~386 m from the shoreline and ~ 37.5 m above current mean sea level. As on the north coast of Timor, the offshore topography in this region drops away steeply to a depth of 100 m, less than 1.8 km off the current shoreline so Makpan would have not been much further from the coast when first occupied ~40,000 years ago. The 2016 excavation produced a remarkably rich assemblage comprised predominately of marine resources, including fish, shellfish and sea urchins.

The initial phase of occupation at Makpan from ~40,000 until 22,000 is marked by relatively low-density bone and shell accumulations suggesting that occupation was limited and sporadic early on. Marine fauna dominates the subsistence resources in this level with a focus on urchin exploitation [63]. This was followed by a terminal Pleistocene phase showing an increase in occupation intensity beginning ~14,000 years ago. The densest phase of occupation is marked by the deposition of a dense shell midden and marine fauna during the Pleistocene-Holocene transition beginning ~12,000 years ago. The site appears to have been little used from ~7000 until 3500 years ago when the Neolithic to historic occupation begins. In this upper level marine resource use continues and pottery and domestic animals appear in the assemblage.

Makpan contained a remarkably rich assemblage of shellfish hooks and beads dating from ~15,000 years ago [64, 65]. The lithic assemblages included fine and course grade volcanic flakes and cores with a small assemblage of chert and obsidian [63]. Unlike nearby Tron Bon Lei, most of the obsidian artefacts are probably derived from local sources. A number of grindstones were also recovered from Makpan including a basalt muller with a polished surface from the initial occupation phase, and a grindstone from the terminal Pleistocene with red staining, possibly from grinding ochre [66].

5. Initial occupation and adaptation

Initial occupation of southern Wallacea seems to have focussed on the coast, with all early sites on Timor and Alor being within 6 km of the shore and preserving evidence for the use of coastal resources. This is likely because the most transferable resource strategy during the colonisation phase of occupation on these depauperate islands was marine resources [61, 67]. Such a hypothesis is directly attested by stable isotope analysis of a ~ 40,000 year old human tooth from Asitau Kuru which shows significantly more marine specialisation than later teeth from the region [39]. The furthest inland sites in this early phase are Laili and Matja Kuru 2, but these are associated with a larger river and lake, respectively, which were exploited for freshwater fish and turtles [54, 55, 62]. Rather than marine resources exclusively, it seems then that aquatic resources in general were the key transferable resource allowing hominins to rapidly adapt to new island environments. The only early site in southern Wallacea beyond foraging range from the coast is Liang Bua on Flores, and here again the site is near large rivers and there is evidence for the use of freshwater fish and shellfish coincident with the arrival of modern humans [23].

The number of stone artefacts that accumulate per m2 of sediment per year has provided an intra-site and intra-island index of occupation intensity [61]. This shows that at Liang Bua and Makpan initial occupation was relatively low density before increasing in the terminal Pleistocene. The sites on Timor present a similar story with initially relatively low density occupation at Asitau Kuru and MK2 followed by a hiatus around the LGM and a higher density occupation in the terminal Pleistocene. Laili, which has great integrity in preservation of the initial occupation with an individual hearth preserved and dated [19], presents a slightly different picture. Here initial occupation appears to have been a higher density than even the terminal Pleistocene occupation at Asitau Kuru and MK2. There is then a drop-off in intensity, before a large increase during the LGM at Laili, rather than shortly after as for the other sites [61].

The general picture across southern Wallacea is that occupation intensity was initially relatively low, but still represents a substantial human presence in the region that seems to have established itself within a few millennia at most. Climate change and sea-level rise in the terminal Pleistocene seem to have prompted increases in occupation intensity and by extension population density, with the timing of this intensification variably expressed according to the particular landscape circumstances of each site [61]. Faunal exploitation before and after this time also seems to change. While in the initial stage of settlement subsistence at the coastal sites suggest a focus on marine resources, the terminal Pleistocene to early Holocene period saw more concerted exploitation of fish and shellfish, particularly at sites such as Makpan and Asitau Kuru. While this likely reflects the increased proximity of these sites to the coastline with rising sea level, the trend is also apparent at Here Sorot Entapa on Kisar which was first occupied ~15,500 years ago. At Here Sorot Entapa the period between 15,000 and 12,000 years ago has more intensive evidence of coastal resource use than at any time following. Faunal exploitation at the inland sites MK2 and Laili seems to have been heavily influenced by the effects of precipitation on local lake and river levels [19, 55]. For example, MK2 was more intensively occupied when water levels in nearby Lake Ira Lalaro are projected to have been medium to high. This would have made the lake edge attractive for a range of game such as birds, and provided freshwater turtles and fish [54]. MK2 appears to have been abandoned during the Last Glacial Maximum from 30,000 through until ~13,000 years ago while nearby MK1 was first used ~16,000 years ago [55]. Below we discuss the material culture of the initial occupation phase, and the remarkable changes that occurred in the terminal Pleistocene after about 20,000 years ago.

5.1 Lithics

Earlier syntheses of the modern human Pleistocene stone artefact assemblages from the southern Wallacean islands paint them as relatively simple with little evidence of change over time. Assemblages were said to be comprised of small unretouched flakes and cores with low percentages of retouched tools and no evidence of specialisation in retouched forms [67–71]. However, several recent studies have detected much greater variability. Re-evaluation of the stratigraphy at Liang Bua suggests a change in material selection and size occurred between the *H. floresiensis* levels and *H. sapiens* occupation [20, 23, 66]. The preference for finer-grained chert by modern humans after 50,000 years ago is also seen in the Timor sites Laili, Matja Kuru 2, Lene Hara, and Asitau Kuru [19, 49, 50]. These chert flakes are distinctively very small (<20 mm) with the continued reduction of cores beyond the point where they could only produce small flakes suggesting small products were desired [49]. This miniaturised technology [72] is also represented at Makpan, where the dominant materials are fine-grained volcanics including obsidian, though chert is also a major component of the assembage [66]. The preference for fine-grained materials here is noteworthy as coarser-grained basalt was more immediately available but less favoured. In terms of reduction strategies, discoidal knapping, core-on-flakes, and bipolar reduction were all utilised, the latter two particularly suited to the production of flakes from small clasts. However, the availability of large clasts at sites like Laili and Makpan, suggests that small flake size was not merely a function of clast size, but there was a genuine preference for small pieces, as has been documented in other parts of the world [73, 74].

Makpan contains a few large, double-patina artefacts (i.e. old reflaked artefacts) in the initial occupation levels and these have been argued to hint at an earlier dispersal in eastern Wallacea that remains to be elucidated [66]. It has been hypothesised that an early dispersal wave of *H. sapiens* may have initially produced the large artefacts when they crossed through Wallacea during MIS4 (71,000–58,000 years ago) [6], leaving little other trace of their presence [66].

5.2 Bone tools and 'invisible technology'

While the presence of pelagic fish remains in the lowest Pleistocene occupation levels at Asitau Kuru has been argued to indicate that complex fishing technology and watercraft must have been used in their capture [48], this has not been universally accepted [75, however see reply from 76]. No fishhooks or other fishing equipment has yet been found dating to the earliest occupation phase. A recent study which includes ecological information specific to the waters off Asitau Kuru, suggests that this area of coastline is uniquely positioned for the capture of pelagics [77], with the deepwater habitats and coastal upwelling bringing pelagic species such as dog tooth tuna (*Gymnosarda unicolor*) unusually close to shore [78: 44, 55]. While we cannot be sure that the same conditions existed in the Pleistocene, due to the steepness of the offshore profile it is likely that similar conditions prevailed from the time of initial occupation, perhaps explaining the early abundance of such fish taxa in the absence of complex fishing technology at Asitau Kuru. However, even if pelagic species came close to shore, it is almost certain that some form of watercraft was used for their capture, as indeed it must have been to reach Timor in the first place [76].

Presumably due to the paucity of animals that would need to be hunted with spears, as well as the paucity of animals large enough to provide bone for bone artefacts, there is a dearth of bone artefacts in all the southern route island assemblages. One notable exception is the remarkable piece from Matja Kuru 2 dated to ~35,000 years cal. BP. This is the butt or haft end of a projectile point which was probably an insert in a wooden shaft. It has deep notches to facilitate binding as well as adhering mastic and evidence of wear from a fibre binding [79]. The bone artefact from MK2 has been argued to show that hafted composite technology was known but underrepresented in the archaeological record and wood was likely used for the pointed projectile tips as well as the shafts but has not survived. In view of the lack of terrestrial game in Timor at this time, the MK2 spear may have been used to hunt large marine prey [79].

5.3 Mollusc shell and other invertebrate artefacts

Shell artefacts are some of the earliest artefacts found in the southern island assemblages. Beads made on whole modified gastropods of *Oliva* spp. occur at Asitau Kuru down to the lowest occupation levels and one has been directly dated to ~37,000 cal. BP (S-ANU-48106, 33,294 ± 380 BP), making it the oldest piece of personal ornamentation in Southeast Asia [52]. *Oliva* beads were made by removing the apex of the shell and display manufacture and use traces such as having flaking on the apex as well as faceting and wear on the lip. Many of these beads also display traces of red ochre. Microscopic analysis of the beads from the sites, and experiments made on modern *Oliva* shells, indicate that they were strung consecutively creating a beaded strand which was worn against the body or an item of fabric which was coloured with red ochre [52].

Two *Nautilus* shell fragments were recovered from contexts dating to ~40,000 years ago at Asitau Kuru, that exhibit probable manufacturing traces such as drilling, pressure flaking, grinding. These also exhibited traces of red staining suggesting that, like the *Oliva* beads, they were previously part of items of personal decoration utilising ochre [45].

Fragments of operculum of large gastropods have also been found in Pleistocene contexts at Asitau Kuru and Makpan. These have evidence of deliberate reduction to produce sharp edges [66]. Similaraly modified shell has been reported from the early levels of Bubog 1 in the Philippines [80] and Golo Cave on Gebe Island on the northern route [81].

5.4 Rock art and ochre use

Ochre crayons and pieces with wear facets and striations are present from the earliest levels of the caves and shelters in Timor-Leste [59]. The rock art of Wallacea is amongst the oldest evidence of modern human artistic expression in the world, with red painted art in Sulawesi featuring hand stencils, complex hunting scenes and life-sized animals, including one painting of a Babirusa dated by the U-series method with a minimum age of ~46,000 years ago [18, 36]. Painted rock art also adorns the walls of caves in Timor, Alor, Kisar and other islands on the southern route [50, 82–88].

While most of the surviving art on the southern route is probably late Holocene in age, in Timor-Leste U-series dating of a wall fragment with red pigment from Lene Hara Cave has shown that painting has also been an ongoing tradition on the southern route for over 30,000 years [89]. Rock art thought to be Pleistocene in age identified in both Timor-Leste and Kisar consists almost exclusively of red and purple hand and arm stencils [85, 90]. Hand stencils in Lene Hara and the nearby cave of Lene Kici in

Timor-Leste have been argued to be likely Pleistocene in age based on their degree of weathering [90, 91], as well as their location in the internal (darker) areas of the caves, which contrasts with the positioning of Holocene paintings [85, 91]. As mentioned above in the context of shell beads, ochre also seems to have been used to apply to items worn as body decoration [45, 59].

6. After 20,000 years ago

Following the end of the Last Glacial Maximum, major new items of technology appear beginning ~17,000 years ago in the Southern Wallacean archaeological assemblages, transforming these island societies. Lithics made on obsidian from an as yet unknown source make their first appearance in archaeological assemblages in the islands of Alor (Tron Bon Lei), Timor (Hatu Sour, Laili, Bui Ceri Uato, Matja Kuru, Asitau Kuru, Lene Hara), Atauro (Arlo), and Kisar (Here Sorot Entapa, Ratu Mali) (**Figure 2**). At about the same time the first fishhooks also appear. Ground shell adzes emerge in the record in the following millennia, a technology ethnographically recorded as used in the production of dugout canoes; watercraft that would have facilitated the voyaging necessary to sustain this inter-island obsidian exchange network [93]. Standardised items of personal decoration also appear in the Terminal Pleistocene, specifically small disc beads and appliques made on *Nautilus* shell. We have suggested that these decorations may have been worn to signal the special relationship or bond between communities on distant islands that were connected in the exchange. In addition to the first appearance of microliths made of exotic imported obsidian, shell fish hooks, ground shell adzes, and new standardised forms of shell beads, this period also sees the earliest engraved art, the initial occupation of very small islands, and evidence of increased use of the caves and shelters in islands that had been settled earlier. These changes in material remains and occupation records from sites on the southern route reflect the major technological, social and demographic changes which occurred in the terminal Pleistocene.

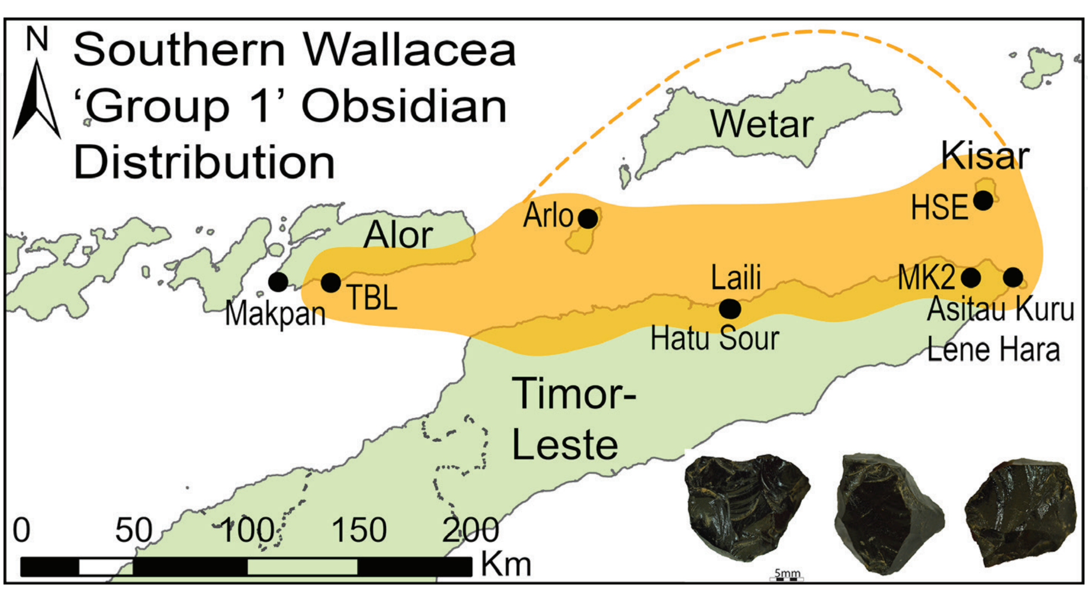

Figure 2.
The southern Wallacean 'Group 1' network incorporating the islands of Alor, Atauro, Timor, and Kisar in the terminal Pleistocene. Photo inset from Maloney et al. [92:figure 4].

6.1 New occupation records

6.1.1 Tron Bon Lei

Tron Bon Lei is the name given to two adjoining rock shelters located within a volcanic ridgeline near Lerabain village on the south coast of Alor Island (**Figure 1**:6). The shelters are ~35 m asl and 160 m inland. In 2014 three 1 x 1 m test pits were excavated in the two separate shelters; two in the west-facing shelter (A & C), and a third pit (B) in the south facing shelter ~15 m to the east. Pit B reached bed-rock at 3 m depth and had an occupation record extending back to ~21,500 years ago. Radiocarbon dating results for pit B suggest three occupational phases: Late Pleistocene (~21,000–18,000 years ago), terminal Pleistocene-early Holocene (between ~12,000 and 7500 years ago), and Late Holocene (beginning ~3500 years ago).

Only Pit B is discussed further here as it had the deepest and oldest sequence with abundant cultural material and faunal remains. Vertebrate and invertebrate fauna were abundant in Pit B, of which the overwhelming majority were from the marine environment, mostly shellfish and fish [94, 95]. Pottery was found in the upper spits and lithics throughout. The lithics included flakes and cores made on basalt, chert and obsidian [92, 96]. The obsidian included pieces made on the same exotic source material identified in the Timor-Leste sites [96]. The crania of a female individual was recovered which had 5 shell fishhooks placed as grave goods near the neck. The burial and hooks were dated to ~12,000 years cal. BP [97]. Shell beads were also found in the excavation [98]. In 2018 Tron Bon Lei was again excavated to recover the post-cranial remains of the burial in pit B. The original B pit was extended to the southeast (Squares D & E). The recovery of the remainder of the skeleton in 2018 confirmed the burial as female and an additional fishhook was found with the post cranial remains [99].

6.1.2 Here Sorot Entapa

Here Sorot Entapa (HSE) is a cave and shelter complex in a raised coralline terrace approximately 80 m from the southern coast of Kisar Island (**Figure 1**:14). Today it is at ~24 m elevation. The excavation of two 1 x 1 m test pits in 2015 revealed an occupation sequence rich in marine fauna dating from ~15,500 years ago until the late Holocene, with a hiatus from ~9500 through to ~5000 years ago [100]. Stone artefacts and faunal remains and all categories of material culture were densest from the initial occupation phase through until ~13,000 years ago. The fauna in the pre-ceramic levels comprised predominantly fish, shellfish, crustacea and urchins. Artefacts included fishhooks, a coral file thought to be used for fishhook manufacture, shell beads and a bone point. The stone artefacts comprised small flakes made on chert, obsidian and quartz. The obsidian used for the artefacts is exotic to the island [100].

6.2 The obsidian exchange network in southern Wallacea

Although artefacts made on obsidian occur in the earliest occupation levels of Makpan dating from ~40,000 years cal. BP, they are likely made on obsidian from a local source on Alor Island [63]. This same obsidian is also found in the Pleistocene levels of Tron Bon Lei [101]. One obsidian source on Alor Island has been identified approximately 15 km east of Tron Bon Lei, in an area known as Kulunan. However, from ~12,000 years ago artefacts made from two other obsidian sources make their appearance - provisionally named 'Group 1' and 'Group 2'. The Group 1 and 2 sources are thus far unknown. Group 1 obsidian has also been found in assemblages on the Timor, Atauro, and Kisar (**Figure 2**) and therefore must be exotic to at least three, if not all four, of these islands [35, 96, 101, 102]. The earliest dated evidence for Group 1 obsidian is in Asitau Kuru, Timor-Leste, where it was recovered in a context dated to ~17,000 years ago [49, 102]. On Kisar, Group 1 obsidian appears in the earliest levels of Here Sorot Entapa dated to ~15,500 years ago [96, 100]. We have argued elsewhere that Group 1 obsidian is unlikely to derive from Timor, Atauro, or Kisar islands due to the geological makeup of these islands [35]. We have also suggested that its distribution in Tron Bon Lei only from the terminal Pleistocene, coincident with its first appearance in the other island records, suggests that it was also an import to Alor Island [96].

While we currently do not know the source island of this exotic obsidian or the extent of its distribution, it demonstrates maritime material transport across the southern islands by ~17,000 years ago making this amongst the world's earliest evidence for a maritime trade network [35]. It should be noted that comparably early obsidian movement has been documented in the Philippines [103] and future research efforts in these islands may find similar patterns of inter-island connectivity as those identified here in southern Wallacea.

6.3 Fish hooks, other fishing gear and the intensification of marine resource exploitation

Another major technological innovation in the archaeological record of southern Wallacea that occurs at about the same time as the imported obsidian tools are fishhooks (**Figure 3**). The earliest example comes from Square A in Asitau Kuru and is dated between ~23,000 and 16,000 years ago [48: 1120]. Fishhooks were also found in Here Sorot Entapa in Kisar from ~15,500 years ago [100]. The largest and most diverse assemblage of hooks thus far recovered is from Makpan where 214 hooks, including examples in all stages of production from blanks through to fully finished hooks, were recovered from a single 1 x 1 m pit (Square B). In addition, Makpan also produced four shell artefacts identified as probable fishing lures, a coral sinker and a coral fishhook file [64: 38]. Both jabbing and rotating forms of hooks are found in these assemblages with rotating hooks being significantly larger in size. The fishhooks at Makpan range from 1 cm to 5 cm in size and are mostly made from large species of marine mollusc such as *Turbo* sp. and *Rochia nilotica* [64: 38]. The inner layer of shell of these species is highly nacreous and this lustrous quality may have aided fish capture [97: 1460, 104:129].

As noted above, fish remains are found throughout the sites on Timor and Alor from first settlement [48, 49, 63, 94, 97, 105], however, no fishhooks have yet been unearthed in the Pleistocene deposits dating between ~45,000 and ~ 16,000 years ago. The appearance of fishhooks in the Alor sites coincides with a major increase in the intensity of fishing [63, 95]. The large rotating hooks of the type found in the Tron Bon Lei burial and at Makpan [64, 97] are best suited for offshore fishing from watercraft [106, 107], and for fishing larger fish in rougher deeper waters. Their appearance may indicate an increased focus on pelagic species occurred at this time [35], although this is not evident in the fish bone assemblage which rather suggests a greater emphasis on reef fishing from the terminal Pleistocene to early to mid-Holocene [48, 63, 77, 94, 105]. It is possible that our small-scale excavations do not do justice to the full range of fish caught, or that large fish were consumed near the point of capture.

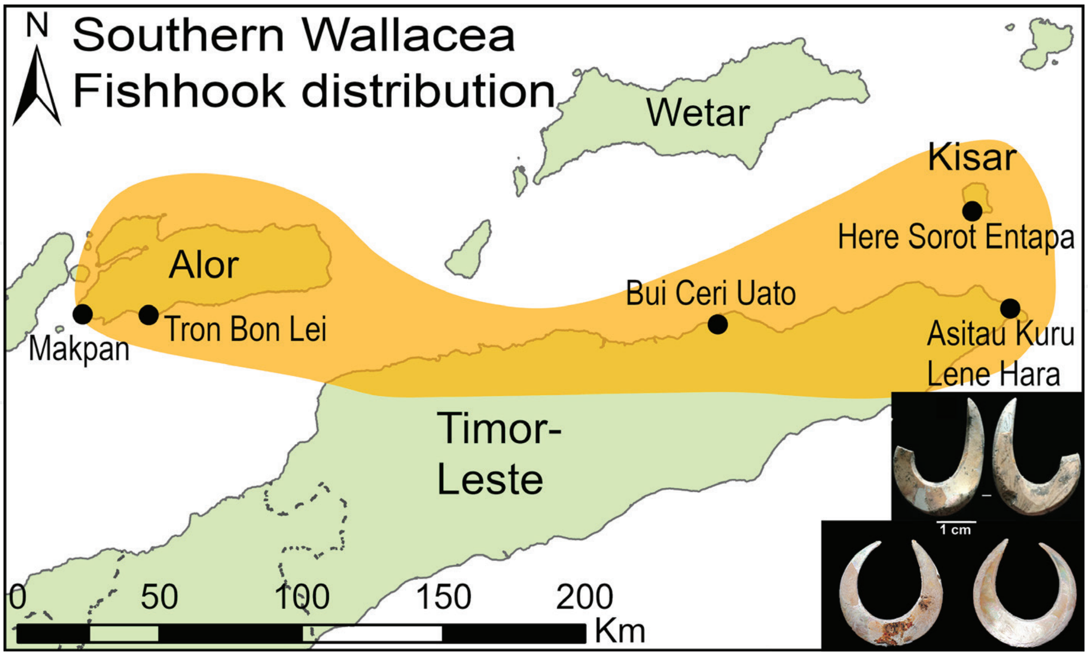

Figure 3.
The distribution of shell fishhooks in southern Wallacea, encompassing the islands of Alor, Timor, and Kisar in the terminal Pleistocene. Photo insets from [100:figure 7] TOP, and [97:figure 7] BOTTOM.

6.4 Shell beads, applique and evidence for shared symbolic concerns

New forms of personal ornaments appear in the terminal Pleistocene assemblages in the southern island sites in the millenia after the exotic obsidian artefacts first appear (**Figure 4**). These comprise small round beads with drilled central perforations, as well as elongate or oval beads with two drilled holes, made from pieces of the body whorl of *Nautilus pompillus* shells. The earliest directly dated bead comes from Makpan Cave in Alor at 12,125 ± 315 cal. BP (Wk-53,581, 10,667 ± 28 BP) [65:815]. Round and elongate *Nautilus* beads have also been found at Tron Bon Lei in Alor [98] and in firm terminal Pleistocene contexts in Timor-Leste in Asitau Kuru, Lene Hara, MK1 and 2 and Bui Ceri Uato [45, 98, 108:117, 109:305] as well as in Here Sorot Entapa in Kisar [100]. They have been recovered in less securely dated preceramic contexts in Lua Meko and Pia Hudale Cave in Rote Island [110], and at Nintal in Flores [111].

On the basis of the wear evident on the double-holed beads they have been argued to have been sewn onto some sort of material that was worn on the body or used for decoration. There is direct evidence that at least some of these beads were made on site. Small roughed out tabs of *Nautilus* shell and preforms which had the edges smoothed but which had not yet had the central perforation drilled were found at Makpan [65]. Conversely, in one example from Matja Kuru 2 in Timor-Leste, the perforation has been drilled into a geometric-shaped unsmoothed fragment of *Nautilus*. The perforations were made using both uni-or bifacial drilling [65]. It seems that while bead shapes were similar between sites and all made on the same material, there was no standardised method for production of the *Nautilus* beads.

6.5 Shell adze and scraper technology

Other major changes in technology in the terminal Pleistocene also support an increased investment in the exploitation of the sea and its resources. Evidence

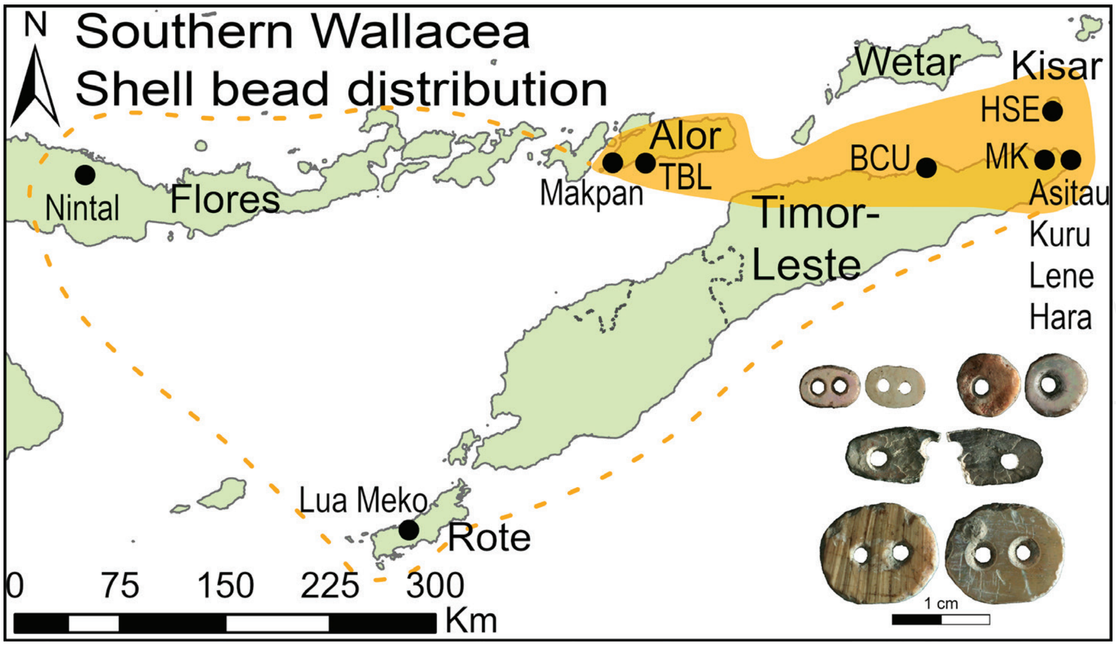

Figure 4.
The distribution of shell disc beads in southern Wallacea showing the terminal Pleistocene extent (solid shading) incorporating the islands of Kisar, Timor, and Alor, and the possible extended distribution (dashed line) incorporating the undated beads from Flores and Rote. Note that MK indicates both MK1 and MK2 sites. Photo inset from [63:figure 12].

for edge-ground adze manufacture occurs on the northern Wallacean island of Obi by at least 14,000 years ago [93]. On the southern islands, whole adzes and flakes detached from adzes with evidence of grinding, have been recovered in early Holocene contexts in Asitau Kuru [93]. The adzes were made on the umbo or folds of large *Tridacna* and *Hippopus* clams. Complete adzes are curated long-life artefacts so few would be expected to enter the archaeological record whole, with unfinished preforms and rejuvenation flakes the most reliable way of detecting such technology [112]. However, mollusc assemblages are rarely sorted in their entirety and preforms, broken fragments, and flakes are likely to have gone unrecognised in some assemblages. Closer examination of the fragmentary shell from excavated assemblages in Wallacea is needed in order to address this. Similar shell adzes are also found in the Gebe Island assemblages [113], in Island Melanesia [114:59–60], and in the Philippines [80, 115, 116] and we have suggested elsewhere that this technology probably had a more continuous distribution across Wallacea and neighbouring regions (**Figure 5**) [35].

Shell flakes also appear in the assemblages in the terminal Pleistocene alongside fishhooks, suggesting wider engagement with this material. One of the shell flakes from Makpan appears to have been struck from the base of a large operculum and may have been from the manufacture of an operculum scraper; a technology also documented in the Pleistocene occupation at Golo Cave in north-eastern Wallacea [81].

6.6 A new type of rock art

In the terminal Pleistocene a new type of rock art, engraved anthropomorphic forms and faces, appear in the rock art repertoire of the southern islands. One of a number of engraved faces carved into speleothem columns in Lene Hara has

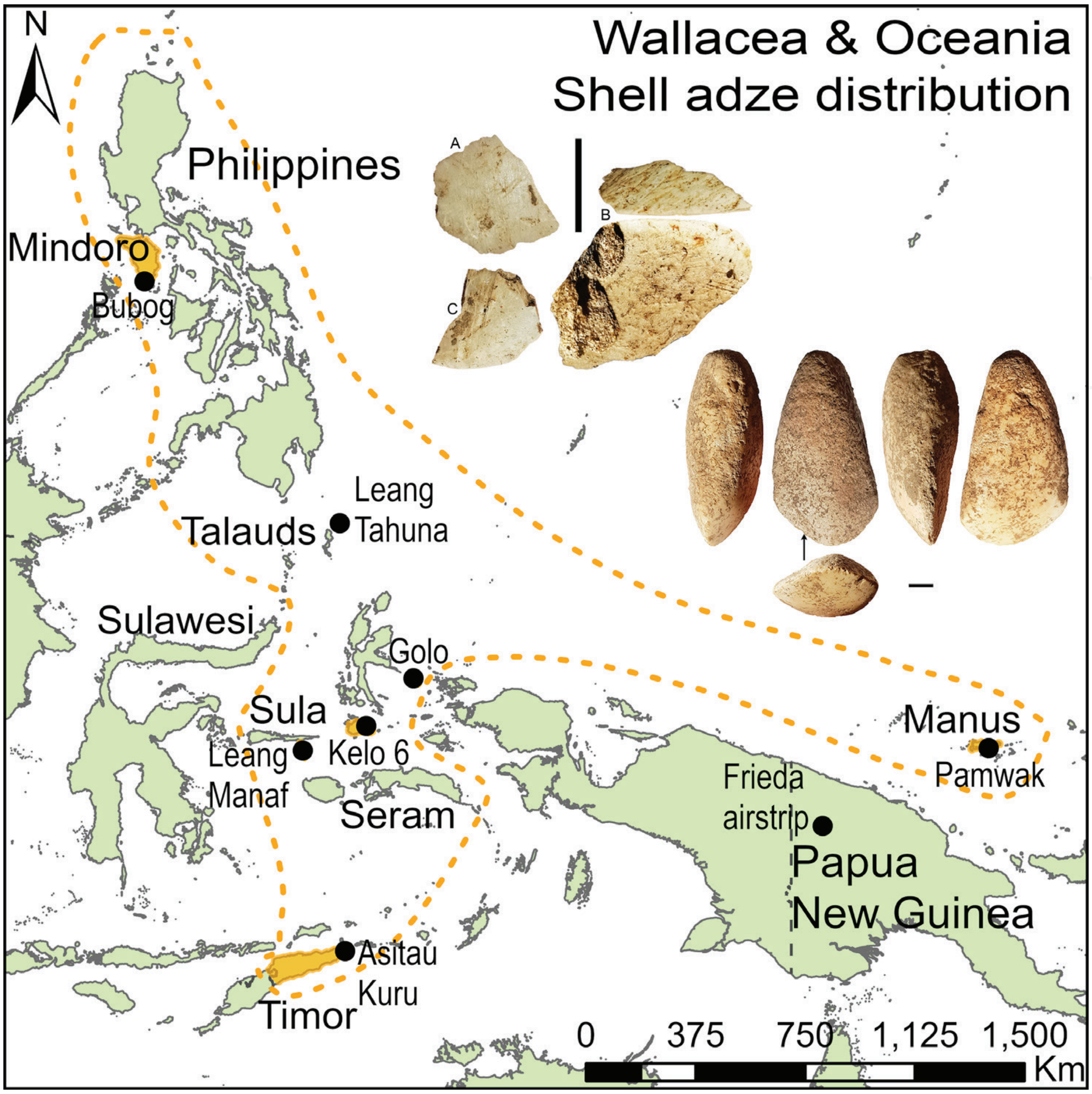

Figure 5.
Distribution of ground shell adzes across Wallacea and Oceania from the terminal Pleistocene to early Holocene. Incorporating the islands of Ilin (Mindoro), Merampit (Talaud), Gebe, Obi, Sanana (Sula), Timor, and Manus. Dotted line shows possible extent of this distribution. Photo insets from [93:figure 12] LEFT and [117:figure 9] RIGHT.

been dated by the U-series technique to the terminal Pleistocene, between 13,000 and 11,000 years ago [50]. Many of the facial features incorporate cupules. Other examples of carved anthropomorphic forms and faces carved into speleothems have been found in Pati Patinu and Kiiru 4 also at the eastern end of Timor-Leste [118]. While they are undated, it is likely that they were created at about the same time as the carved faces in Lene Hara. In Lembata Island a large number of engraved faces have recently been found in a limestone overhang known as Liang Pu'en [119]. Many of these also use cupules to form the eyes and mouths. Indeed some bear a striking resemblance to the dated Lene Hara face, e.g. [119:59, Gambar 5.9 Pahatan Wajah No. 7]. While the author concludes that they may belong to the Austronesian Engraving Tradition [119:xi] the weathered state of many of the Lembata engraved faces and their similarity to the terminal Pleistocene engravings in Lene Hara suggests a much greater antiquity (**Figure 6**).

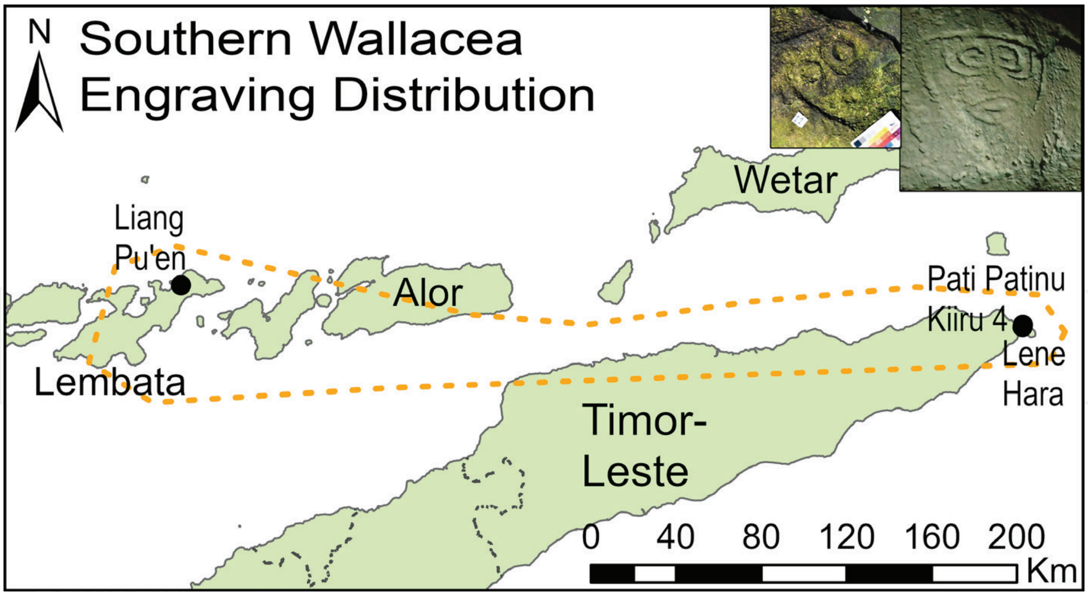

Figure 6.
Possible distribution of distinctive anthropomorphic rock art engravings linking the islands of Timor and Lembata in the terminal Pleistocene. Photo insets from [119:figure 5.10] LEFT and [118:figure 2A] RIGHT.

7. Discussion

Determining the nature of *Homo sapiens* migrations to Sahul is critical for understanding how our species diversified outside of Africa, adapting to the challenges and opportunities of novel environments including insularity. The islands of southern Wallacea pose a particular challenge as aside from Sulawesi they are depauperate in terrestrial prey, with rats, bats, and reptiles comprising the larger land-based fauna. That modern humans not only succeeded in settling these islands but adapted their economy to embrace a diverse array of marine resources is testimony to the adaptability of our species.

From the outset, the assemblages on the southern route share several common features. With the exception of Liang Bua in Flores, they are all located on or near the Pleistocene coastline. The number of sites spanning the first 30,000 years of occupation is small, and all record a number of chrono-stratigraphic breaks in their sequences, but the emerging pattern is rapid occupation of the larger islands by 47,000 to 40,000 years ago. In Timor, the only island where inland regions have been surveyed and caves and shelters excavated, there is as yet no evidence for occupation of inland regions greater than 10 km from the Pleistocene coastline, during the first 30,000 years following initial settlement.

Not only do early sites on large islands all appear within a small time window, they also have a shared material culture. The modern human lithic assemblages of southern Wallacean are characterised by small flakes made on fine-grained raw materials. Small flakes coupled with a preference for fine-grained raw materials are regarded as distinguishing traits of modern human lithic reduction throughout the world over the last 67,000 years, allowing longer use life of cores and lessening the cost of lithic transport [72–74, 120]. The identification of miniaturisation in the lithic assemblages of the earliest sites of Flores, Timor, and Alor shows this to be a persistent *H. sapiens* trait even in this island realm, and sets the assemblages apart from the lithics produced by earlier hominins on the larger western islands [66]. Also found in the first

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occupation levels is red ochre which appears to have been used for cave art as well as to colour items worn on the body [10, 45, 59].

In the absence of any plant remains, the grindstone found in the lower levels of Makpan may indicate plant processing [66]. Plant foods would have been essential for survival on the southern islands in combination with the heavy focus on marine resources for protein. This scenario is also supported by isotopic analysis of human teeth that indicates the consumption of more terrestrial foodstuffs than preserved in the fauna-rich archaeological record [39]. Like plant remains, tools made of organic material are rare in sites along the southern route, owing no doubt to poor preservation in this tropical monsoonal region where deposits undergo seasonal wetting and drying, as well as the lack of large-medium game animals requiring composite tools for capture. However, the few that are preserved such as the haft end of the projectile from Matja Kuru 2 demonstrate that composite tools using binding and mastic were in use by 35,000 years ago. These hafted projectiles may have been used for spearing marine mammals or for self-defence. The large pelagic species in Asitau Kuru show that advanced fish capture strategies were in place from initial settlement [48]. This attests to the remarkable adaptations that early modern humans made to the dry, depauperate limestone coastlines of southern Wallacea.

The end of the Last Glacial Maximum saw significant changes in settlement throughout the archipelago. These included 1) more intensive use of sites which were already occupied, 2) the use of very small islands which had not previously been occupied, 3) the appearance of a range of single piece shell fishhooks, 4) ground shell adze technology signalling a step up in watercraft technology, 5) an increased focus on marine resources, particularly fish, 6) the onset of an obsidian exchange network, and 7) new forms of personal ornamentation held in common across island communities. There is some variation between sites in when such changes occur with the earliest signs of intensive occupation appearing at Laili during the LGM, but for most sites, and particularly those nearest the coast, the changes seem to coincide with rising seas in the terminal Pleistocene. These patterns demonstrate the capacity of *H. sapiens* to innovate and thrive in the face of environmental change, in particular intensifying maritime activity in the face of sea-level rise.

8. Conclusion

Modern humans crossed Wallace's Line moving east into the southern Wallacean islands between ~50,000 and ~ 45,000 years ago. With the exception of Liang Bua on Flores, the oldest sites in the southern islands are caves and shelters located close to, or within walking distance of, the Pleistocene coastline – within 8 km. The southern islands are depauperate in terrestrial fauna and the first settlers focused on the abundant marine resources such as fish, shellfish, urchin, crab and turtles, although sites more than a few kms from the coast demonstrate that early subsistence included lacustrine and riverine resources, as well murids, bats, snakes and birds. Settlement on the larger islands appears to have occurred fairly rapidly, but once settled there is no evidence for connectivity between islands. Tool kits in the early settlement phase mainly comprise retouched and unretouched flakes, although many tools would have been made of perishable materials which would not have survived. A few bone artefacts have been recovered from the Timor archaeological sites but these are rare. Evidence for personal ornamentation comprises beads made on whole modified gastropods with adhering ochre residues. No rock art has yet been firmly dated to the early phase of settlement however hand stencils found in Timor-Leste are believed to be of Pleistocene antiquity.

At the end of the LGM, after ~20,000 years ago, major societal changes are registered in the southern Wallacean sites. These include a significant increase in marine resource use and occupation intensity more generally, as well as initial occupation of inland highland regions, and very small islands. Accompanying these changes is the appearance of new technology in the form of shell fishhooks and adzes. An obsidian exchange network with an onset after ~17,000 years cal. BP shows that populations on the different islands were in contact after this time. Beginning about 12,000 years ago there is an efflorescence in personal ornamentation with new bead types and a radical new rock art expression -anthropomorphic engravings - signalling new symbolic concerns.

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References

[1] O'Connell JF, Allen J, Williams MA, Williams AN, Turney CS, Spooner NA, et al. When did *Homo sapiens* first reach Southeast Asia and Sahul? Proceedings of the National Academy of Sciences. 2018;**115**(34):8482-8490. DOI: 10.1073/pnas.1808385115

[2] Hiscock P. Discovery curves, colonisation and Madjedbebe. Australian Archaeology. 2017;**83**(3):168-171. DOI: 10.1080/03122417.2017.1408544

[3] Kealy S, Louys J, O'Connor S. Reconstructing palaeogeography and inter-island visibility in the Wallacean Archipelago during the likely period of Sahul colonization, 65-45 000 years ago. Archaeological Prospection. 2017;**24**(3):259-272. DOI: 10.1002/arp.1570

[4] Williams MA, Spooner NA, McDonnell K, O'Connell JF. Identifying disturbance in archaeological sites in tropical northern Australia: Implications for previously proposed 65,000-year continental occupation date. Geoarchaeology. 2021;**36**(1):92-108. DOI: 10.1002/gea.21822

[5] Wood R. Comments on the chronology of Madjedbebe. Australian Archaeology. 2017;**83**(3):172-174. DOI: 10.1080/03122417.2017.1408545

[6] Clarkson C, Jacobs Z, Marwick B, Fullagar R, Wallis L, Smith M, et al. Human occupation of northern Australia by 65,000 years ago. Nature. 2017;**547**(7663):306-310. DOI: 10.1038/nature22968

[7] Westaway KE, Louys J, Awe RD, Morwood MJ, Price GJ, Zhao JX, et al. An early modern human presence in Sumatra 73,000-63,000 years ago. Nature. 2017;**548**(7667):322-325. DOI: 10.1038/nature23452

[8] Freidline SE, Westaway KE, Joannes-Boyau R, Duringer P, Ponche JL, Morley MW, et al. Early presence of *Homo sapiens* in Southeast Asia by 86-68 kyr at Tam Pà Ling, Northern Laos. Nature Communications. 2023;**14**(1):3193. DOI: 10.1038/s41467-023-38715-y

[9] Birdsell JB. The recalibration of a paradigm for the first peopling of greater Australia. In: Allen J, Golson J, Jones R, editors. Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia, and Australia. London: Academic Press; 1977. pp. 113-167

[10] Shipton C, O'Connor S, Kealy S. The biogeographic threshold of Wallacea in human evolution. Quaternary International. 2021;**574**:1-2. DOI: 10.1016/j.quaint.2020.07.028

[11] Irwin G. The Prehistoric Exploration and Colonisation of the Pacific. Cambridge: Cambridge University Press; 1992

[12] Allen J, O'Connell JF. Getting from Sunda to Sahul. In: Clark G, Leach BF, O'Connor S, editors. Islands of Inquiry: Colonisation, Seafaring and the Archaeology of Maritime Landscapes. Canberra: ANU E-Press; 2008. pp. 31-46. DOI: 10.22459/TA29.06.2008

[13] O'Connell JF, Allen J. The restaurant at the end of the universe: Modelling the colonisation of Sahul. Australian Archaeology. 2012;**74**:5-17. DOI: 10.1080/03122417.2012.11681932

[14] Kealy S, Louys J, O'Connor S. Least-cost pathway models indicate

northern human dispersal from Sunda to Sahul. Journal of Human Evolution. 2018;**125**:59-70. DOI: 10.1016/j.jhevol.2018.10.003

[15] Norman K, Inglis J, Clarkson C, Faith JT, Shulmeister J, Harris D. An early colonisation pathway into Northwest Australia 70-60,000 years ago. Quaternary Science Reviews. 2018;**180**:229-239. DOI: 10.1016/j.quascirev.2017.11.023

[16] Bird MI, Condie SA, O'Connor S, O'Grady D, Reepmeyer C, Ulm S, et al. Early human settlement of Sahul was not an accident. Scientific Reports. 2019;**9**(1):8220. DOI: 10.1038/s41598-019-42946-9

[17] O'Connor S. New evidence from East Timor contributes to our understanding of earliest modern human colonisation east of the Sunda Shelf. Antiquity. 2007;**81**:523-535. DOI: 10.1017/S0003598X00095569

[18] Aubert M, Lebe R, Oktaviana AA, Tang M, Burhan B, Hamrullah JA, et al. Earliest hunting scene in prehistoric art. Nature. 2019;**576**(7787):442-445. DOI: 10.1038/s41586-019-1806-y

[19] Hawkins S, O'Connor S, Maloney TR, Litster M, Kealy S, Fenner JN, et al. Oldest human occupation of Wallacea at Laili Cave, Timor-Leste, shows broad-spectrum foraging responses to late Pleistocene environments. Quaternary Science Reviews. 2017;**171**:58-72. DOI: 10.1016/j.quascirev.2017.07.008

[20] Sutikna T, Tocheri MW, Morwood MJ, Saptomo EW, Jatmiko ARD, Wasisto S, et al. Revised stratigraphy and chronology for *Homo floresiensis* at Liang Bua in Indonesia. Nature. 2016;**532**(7599):366-369. DOI: 10.1038/nature17179

[21] Brumm A, Jensen GM, van den Bergh GD, Morwood MJ, Kurniawan I, Aziz F, et al. Hominins on Flores, Indonesia, by one million years ago. Nature. 2010;**464**(7289):748-752. DOI: 10.1038/nature08844

[22] Ingicco T, van den Bergh GD, Jago-On C, Bahain JJ, Chacón MG, Amano N, et al. Earliest known hominin activity in the Philippines by 709 thousand years ago. Nature. 2018;**557**(7704):233-237. DOI: 10.1038/s41586-018-0072-8

[23] Sutikna T, Tocheri MW, Faith JT, Jatmiko ARD, Meijer HJ, Saptomo EW, et al. The spatio-temporal distribution of archaeological and faunal finds at Liang Bua (Flores, Indonesia) in light of the revised chronology for *Homo floresiensis*. Journal of Human Evolution. 2018;**124**:52-74. DOI: 10.1016/j.jhevol.2018.07.001

[24] Tocheri MW, Veatch EG, Jatmiko SEW, Sutikna T. *Homo Floresiensis*. In: Higham CFW, Kim NC, editors. The Oxford Handbook of Early Southeast Asia. New York: Oxford University Press; 2022. pp. 38-69. DOI: 10.1093/oxfordhb/9780199355358.013.2

[25] van den Bergh GD, Li B, Brumm A, Grün R, Yurnaldi D, Moore MW, et al. Earliest hominin occupation of Sulawesi, Indonesia. Nature. 2016;**529**(7585):208-211. DOI: 10.1038/nature16448

[26] Louys J, Price GJ, O'Connor S. Direct dating of Pleistocene stegodon from Timor Island, East Nusa Tenggara. Peer Journal. 2016;**4**:e1788. DOI: 10.7717/peerj.1788

[27] Turvey ST, Crees JJ, Hansford J, Jeffree TE, Crumpton N, Kurniawan I, et al. Quaternary vertebrate faunas from Sumba, Indonesia: Implications for Wallacean biogeography and evolution. Proceedings of the Royal Society B: Biological Sciences.

1861;**2017**(284):20171278. DOI: 10.1098/rspb.2017.1278

[28] Leppard TP. The evolution of modern behaviour and its implications for maritime dispersal during the Palaeolithic. Cambridge Archaeological Journal. 2015;**25**(4):829-846. DOI: 10.1017/S0959774315000098

[29] Leppard TP. Passive dispersal versus strategic dispersal in island colonization by hominins. Current Anthropology. 2015;**56**(4):590-595. DOI: 10.1086/682325

[30] D'Cunha MG, Montenegro A, Field JS. Modeling water crossings leading to the arrival of early *Homo* in Sulawesi, Indonesia, via paleoclimate drift experiments. Journal of Archaeological Science: Reports. 2021;**40**:103194. DOI: 10.1016/j.jasrep.2021.103194

[31] Anderson A. Ecological contingency accounts for earliest seagoing in the western Pacifc Ocean. Journal of Island and Coastal Archaeology. 2018;**13**(2):224-234. DOI: 10.1080/15564894.2016.1277286

[32] Smith JMB. Did early hominids cross sea gaps on natural rafts? In: Metcalfe I, Smith JMB, Morwood M, Davidson I, editors. Faunal and Floral Migrations and Evolution in SE Asia-Australasia. Lisse: A.A. Balkema; 2001. pp. 409-416

[33] Bradshaw CJ, Ulm S, Williams AN, Bird MI, Roberts RG, Jacobs Z, et al. Minimum founding populations for the first peopling of Sahul. Nature Ecology & Evolution. 2019;**3**(7):1057-1063. DOI: 10.1038/s41559-019-0902-6

[34] Bradshaw CJ, Norman K, Ulm S, Williams AN, Clarkson C, Chadœuf J, et al. Stochastic models support rapid peopling of Late Pleistocene Sahul. Nature Communications. 2021;**12**(1):2440. DOI: 10.1038/s41467-021-21551-3

[35] O'Connor S, Kealy S, Reepmeyer C, Samper Carro SC, Shipton C. Terminal Pleistocene emergence of maritime interaction networks across Wallacea. World Archaeology. 2022;**54**(2):244-263. DOI: 10.1080/00438243.2023.2172072

[36] Brumm A, Oktaviana AA, Burhan B, Hakim B, Lebe R, Zhao JX, et al. Oldest cave art found in Sulawesi. Science. Advances. 2021;**7**(3):eabd4648. DOI: 10.1126/sciadv.abd4648

[37] Ono R, Sofian HR, Fuentes R, Aziz N, Ririmasse M, Geria IM, et al. Early modern human migration into Sulawesi and Island adaptation in Wallacea. World Archaeology. 2022;**54**(2):229-243. DOI: 10.1080/00438243.2023.2172074

[38] Tanudirjo D. Long and continuous or short term and occasional occupation? The human use of Leang Sarru rock shelter in the Talaud Islands, northeastern Indonesia. Bulletin of the Indo-Pacific prehistory association. 2005;**25**:15-20. DOI: 10.7152/bippa.v25i0.11910

[39] Roberts P, Louys J, Zech J, Shipton C, Kealy S, Carro SS, et al. Isotopic evidence for initial coastal colonization and subsequent diversification in the human occupation of Wallacea. Nature Communications. 2020;**11**(1):2068. DOI: 10.1038/s41467-020-15969-4

[40] Bulbeck D, Hiscock P, Sumantri I. Leang Sakapao 1, a second dated Pleistocene site from South Sulawesi, Indonesia. In: Keates SG, Pasveer JM, editors. Quaternary Research in Indonesia. Modern Quaternary Research in South-East Asia volume 18. London: Taylor and Francis; 2004. p. 118-128

[41] Simons A, Bulbeck D. Late quaternary faunal successions in South Sulawesi, Indonesia. In: Keates SG, Pasveer JM, editors. Quaternary Research in Indonesia. Modern Quaternary Research in South-East Asia. Vol. 18. London: Taylor and Francis; 2004. pp. 167-189

[42] Louys J, O'Connor S, Mahirta HP, Hawkins S, Maloney T. New genus and species of giant rat from Alor Island, Indonesia. Journal of Asia-Pacific Biodiversity. 2018;**11**(4):503-510. DOI: 10.1016/j.japb.2018.08.005

[43] Aplin KP, Helgen KM. Quaternary murid rodents of Timor. Part I. New material of Coryphomys buehleri Schaub, 1937, and description of a second species of the genus. Bulletin of the American Museum of Natural History. 2010;**341**:1-80

[44] O'Connor S, Spriggs M, Veth P. Excavation at Lene Hara Cave establishes occupation in East Timor at least 30,000-35,000 years ago. Antiquity. 2002;**76**(291):45-49. DOI: 10.1017/S0003598X0008978X

[45] Langley MC, O'Connor S, Piotto E. 42,000-year-old worked and pigment-stained *Nautilus* shell from Jerimalai (Timor-Leste): Evidence for an early coastal adaptation in ISEA. Journal of Human Evolution. 2016;**97**:1-16. DOI: 10.1016/j.jhevol.2016.04.005

[46] Cox NL. Variable Uplift from quaternary Folding along the Northern Coast of east timor, based on U-Series Age Determinations of coral terraces [Masters thesis]. Provo: Brigham Young University; 2009

[47] Lambeck K, Chappell J. Sea level change through the last glacial cycle. Science. 2001;**292**(5517):679-686. DOI: 10.1126/science.1059549

[48] O'Connor S, Ono R, Clarkson C. Pelagic fishing at 42,000 years before the present and the maritime skills of modern humans. Science. 2011;**334**(6059):1117-1121. DOI: 10.1126/science.1207703

[49] Shipton C, O'Connor S, Jankowski N, O'Connor-Veth J, Maloney T, Kealy S, et al. A new 44,000-year sequence from Asitau Kuru (Jerimalai), Timor-Leste, indicates long-term continuity in human behaviour. Archaeological and Anthropological Sciences. 2019;**11**:5717-5741. DOI: 10.1007/s12520-019-00840-5

[50] O'Connor S, Aplin K, St Pierre E, Feng Y-X. Faces of the ancestors revealed: Discovery and dating of a Pleistocene-age petroglyph in Lene Hara Cave, East Timor. Antiquity. 2010;**84**(325):649-665. DOI: 10.1017/S0003598X00100146

[51] O'Connor S, Aplin K. A matter of balance: An overview of Pleistocene occupation history and the impact of the Last Glacial Phase in East Timor and the Aru Islands, eastern Indonesia. Archaeology in Oceania. 2007;**42**(3):82-90. DOI: 10.1002/j.1834-4453.2007.tb00021.x

[52] Langley MC, O'Connor S. An enduring shell artefact tradition from Timor-Leste: *Oliva* bead production from the Pleistocene to Late Holocene at Jerimalai, Lene Hara, and Matja Kuru 1 and 2. PLoS One. 2016;**11**(8):e0161071. DOI: 10.1371/journal.pone.0161071

[53] O'Connor S, Veth P. Early Holocene shell fish hooks from Lene Hara Cave, East Timor establish complex fishing technology was in use in Island South East Asia five thousand years before Austronesian settlement. Antiquity. 2005;**79**(304):249-256. DOI: 10.1017/S0003598X0011405X

[54] Samper Carro SC, Raymond C, Weisbecker V, O'Connor S. Big questions

for small animals. Taphonomic analysis of small vertebrates in Matja Kuru 2 (Timor-Leste) during the late Pleistocene. Quaternary Science Advances. 2023;**12**:100102. DOI: 10.1016/j.qsa.2023.100102

[55] Samper Carro SC, O'Connor S, Kealy S, Jones RK, Raymond C, Boulanger C, et al. Exploring changing occupation dynamics at the lakeside cave site Matja Kuru 2, Timor-Leste. Quaternary Science Advances. 2024;**13**:100127. DOI: 10.1016/j.qsa.2023.100127

[56] Veth PM, Spriggs M, O'Connor S. Continuity in tropical cave use: Examples from East Timor and the Aru Islands, Maluku. Asian Perspectives. 2005;**44**(1):180-192. DOI: 10.1353/asi.2005.0015

[57] O'Connor S. Rethinking the Neolithic in Island Southeast Asia, with particular reference to the archaeology of Timor Leste and Sulawesi. Archipel. 2015;**90**:15-47. DOI: 10.4000/archipel.362

[58] Langley MC, O'Connor S. Exploring ochre use in Timor-Leste and surrounds: Headhunting, burials, and beads. In: Langley MC, Litster M, Wright D, May SK, editors. The Archaeology of Portable Art: Southeast Asian, Pacific, and Australian Perspectives. Oxon: Routledge; 2018. pp. 25-36

[59] Langley MC, O'Connor S. 40,000 years of ochre utilisation in Timor-Leste: Powders, prehensile traces, and body painting. PaleoAnthropology. 2019:82-104. DOI: 10.4207/PA.2019.ART125

[60] O'Connor S, Barham A, Aplin K, Maloney T. Cave stratigraphies and cave breccias: Implications for sediment accumulation and removal models and interpreting the record of human occupation. Journal of Archaeological Science. 2017;**77**:143-159. DOI: 10.1016/j.jas.2016.05.002

[61] Shipton C, Kealy S, O'Connor S. Pleistocene and early Holocene occupation on the eastern Wallacean islands. In: Fitzpatrick SM, Erlandson J, editors. The Oxford Handbook of Island and Coastal Archaeology. Oxford Academic Online: Oxford University Press; 2023. DOI: 10.1093/oxfordhb/9780197607770.013.26

[62] Boulanger C, Hawkins S, Shipton C, Ingicco T, Sémah A-M, Samper Carro S, et al. Inland fishing by *Homo sapiens* during early settlement of Wallacea. Frontiers in Environmental Archaeology. 2023;**2**:1201351. DOI: 10.3389/fearc.2023.1201351

[63] Kealy S, O'Connor S, Mahirta SDM, Shipton C, Langley MC, Boulanger C, et al. Forty-thousand years of maritime subsistence near a changing shoreline on Alor Island (Indonesia). Quaternary Science Reviews. 2020;**249**:106599. DOI: 10.1016/j.quascirev.2020.106599

[64] Langley MC, O'Connor S, Kealy S, Mahirta. Fishhooks, Lures, and Sinkers: Intensive Manufacture of Marine Technology from the Terminal Pleistocene at Makpan Cave, Alor Island, Indonesia. The Journal of Island and Coastal Archaeology. 2023;**18**(1):33-52. DOI: 10.1080/15564894.2020.1868631

[65] Langley MC, Kealy S, O'Connor S. Sequins from the sea: *Nautilus* shell bead technology at Makpan, Alor Island, Indonesia. Antiquity. 2023;**97**(394):810-828. DOI: 10.15184/aqy.2023.97

[66] Shipton C, Kealy S, Mahirta IA, Patridina EPBGG, O'Connor S. Miniaturized Late Pleistocene Lithic Technology from Alor Island Articulates with the Records of Flores and Timor across Southern Wallacea. PaleoAnthropology.

2021;**2021**:1-20. DOI: 10.4207/PA.2021.ART145

[67] O'Connor S, Louys J, Kealy S, Samper Carro SC. Hominin dispersal and settlement east of Huxley's Line: The role of sea level changes, island size, and subsistence behavior. Current Anthropology. 2017;**58**(S17):S567-S582. DOI: 10.1086/694252

[68] Balme J, O'Connor S. Early modern humans in Island Southeast Asia and Sahul: Adaptive and creative societies with simple lithic industries. In: Porr M, Dennell R, editors. Southern Asia, Australia, and the Search for Human Origins. Cambridge: Cambridge University Press; 2014. pp. 164-174. DOI: 10.1017/CBO9781139084741.013

[69] O'Connor S, Bulbeck D. *Homo sapiens* societies in Indonesia and South-Eastern Asia. In: Cummings V, Jordan P, Zvelebil M, editors. The Oxford Handbook of the Archaeology and Anthropology of Hunter-Gatherers. Oxford: Oxford University Press; 2014. pp. 346-367. DOI: 10.1093/oxfordhb/9780199551224.013.018

[70] Marwick B, Clarkson C, O'Connor S, Collins S. Early modern human lithic technology from Jerimalai, East Timor. Journal of Human Evolution. 2016;**101**:45-64. DOI: 10.1016/j.jhevol.2016.09.004

[71] Moore MW, Sutikna T, Morwood MJ, Brumm A. Continuities in stone flaking technology at Liang Bua, Flores, Indonesia. Journal of Human Evolution. 2009;**57**(5):503-526. DOI: 10.1016/j.jhevol.2008.10.006

[72] Pargeter J. Lithic miniaturization in late Pleistocene southern Africa. Journal of Archaeological Science: Reports. 2016;**10**:221-236. DOI: 10.1016/j.jasrep.2016.09.019

[73] Shipton C, Blinkhorn J, Archer W, Kourampas N, Roberts P, Prendergast ME, et al. The Middle to Later Stone Age transition at Panga ya Saidi, in the tropical coastal forest of eastern Africa. Journal of Human Evolution. 2021;**153**:102954. DOI: 10.1016/j.jhevol.2021.102954

[74] Pargeter J, Shea JJ. Going big versus going small: Lithic miniaturization in hominin lithic technology. Evolutionary Anthropology: Issues, News, and Reviews. 2019;**28**(2):72-85. DOI: 10.1002/evan.21775

[75] Anderson A. The antiquity of sustained offshore fishing. Antiquity. 2013;**87**:879-885. DOI: 10.1017/S0003598X00049541

[76] O'Connor S, Ono R. The case for complex fishing technologies: A response to Anderson. Antiquity. 2013;**87**(337):885-888. DOI: 10.1017/S0003598X00049553

[77] Boulanger C, Hawkins S, Samper Carro SC, Ono R, O'Connor S. Continuity and variability in prehistoric fishing practices by *Homo sapiens* in Island Southeast Asia: New ichthyofaunal data from Asitau Kuru, Timor-Leste. World Archaeology. 2022;**54**(2):288-316. DOI: 10.1080/00438243.2023.2192518

[78] Edyvane K, de Carvalho N, Penny S, Fernandes A, de Cunha CB, Amaral AL, et al. Conservation Values, Issues and Planning in the Nino Konis Santana Marine Park, Timor Leste – Final Report. Dili: Ministry of Agriculture & Fisheries, Government of Timor Leste; 2009

[79] O'Connor S, Robertson G, Aplin KP. Are osseous artefacts a window to perishable material culture? Implications of an unusually complex bone tool from the Late Pleistocene of East Timor. Journal of Human Evolution.

2014;**67**:108-119. DOI: 10.1016/j.jhevol.2013.12.002

[80] Boulanger C, Pawlik A, O'Connor S, Sémah A-M, Reyes MC, Ingicco T. The exploitation of toxic fish from the Terminal Pleistocene in Maritime Southeast Asia: A case study from the Mindoro Archaeological Sites, Philippines. Animals. 2023;**13**(13):2113. DOI: 10.3390/ani13132113

[81] Szabó K, Brumm A, Bellwood P. Shell artefact production at 32,000-28,000 BP in Island Southeast Asia: thinking across media? Current Anthropology. 2007;**48**(5):701-723. DOI: 10.1086/520131

[82] Almeida AD. A contribution to the study of rock paintings in Portuguese Timor. In: Soleim WG II, editor. Archaeology at the Eleventh Pacific Science Congress: Papers Presented at the XI Pacific Science Congress; August–September 1966; Tokyo. Asian and Pacific Archaeology Series 1. Honolulu: Social Science Research Institute, University of Hawai'i; 1967 69-76.

[83] Galipaud JC, Kinaston R, Guillaud D. Aleti Tunu Bibi: Contextualizing a new rock art site in East Timor and the wider Asia-Pacific region. Asian Perspectives. 2016;**55**(2):128-147

[84] Lape PV, O'Connor S, Burningham N. Rock art: A potential source of information about past maritime technology in the South-East Asia-Pacific region. International Journal of Nautical Archaeology. 2007;**36**(2):238-253. DOI: 10.1111/j.1095-9270.2006.00135.x

[85] O'Connor S. Nine new painted rock art sites from East Timor in the context of the Western Pacific region. Asian Perspectives. 2003;**42**(1):96-128

[86] O'Connor S, Oliveira NV. Inter- and intraregional variation in the Austronesian painting tradition: A view from East Timor. Asian Perspectives. 2007;**46**(2):389-403. DOI: 10.1353/asi.2007.0014

[87] O'Connor S, Louys J, Kealy S. First record of painted rock art near Kupang, West Timor, Indonesia, and the origins and distribution of the Austronesian painting tradition. Rock Art Research. 2015;**32**(2):193-201

[88] O'Connor S, Mahirta TD, Ririmasse M, Husni M, Kealy S, Hawkins S, et al. Ideology, ritual performance and its manifestations in the rock art of Timor-Leste and Kisar Island, Island Southeast Asia. Cambridge Archaeological Journal. 2018;**28**(2):225-241. DOI: 10.1017/S0959774317000816

[89] Aubert M, O'Connor S, McCulloch M, Mortimer G, Watchman A, Richer-LaFlèche M. Uranium-series dating rock art in East Timor. Journal of Archaeological Science. 2007;**34**(6):991-996. DOI: 10.1016/j.jas.2006.09.017

[90] García-Diez M, Standish CD, Oliveira NV, O'Connor S. Lene Kici cave art: Possible symbolic evidence associated with palaeolithic human occupation in Timor-Leste. Asian Perspectives. 2021;**60**(1):197-212. DOI: 10.1353/asi.2020.0042

[91] Standish C, García-Diez M, O'Connor S, Oliveira NV. Hand stencil discoveries at Lene Hara Cave hint at Pleistocene age for the earliest painted art in Timor-Leste. Archaeological Research in Asia. 2020;**22**:100191. DOI: 10.1016/j.ara.2020.100191

[92] Maloney TR, Mahirta O'CS, Reepmeyer C. Specialised lithic technology of terminal Pleistocene maritime peoples of Wallacea. Archaeological Research in Asia. 2018;**16**:78-87. DOI: 10.1016/j.ara.2018.05.003

[93] Shipton C, O'Connor S, Kealy S, Mahirta SIN, Alamsyah N, Ririmasse M. Early ground axe technology in Wallacea: The first excavations on Obi Island. PLoS One. 2020;**15**(8):e0236719. DOI: 10.1371/journal.pone.0236719

[94] Samper Carro SC, O'Connor S, Louys J, Hawkins S, Mahirta M. Human maritime subsistence strategies in the Lesser Sunda Islands during the terminal Pleistocene–early Holocene: New evidence from Alor, Indonesia. Quaternary International. 2016;**416**:64-79. DOI: 10.1016/j.quaint.2015.07.068

[95] Samper Carro SC, Louys J, O'ConnorS.Methodologicalconsiderations for icthyoarchaeology from the Tron Bon Lei sequence, Alor, Indonesia. Archaeological Research in Asia. 2017;**12**:11-22. DOI: 10.1016/j.ara.2017.09.006

[96] Reepmeyer C, O'Connor S, Mahirta KS, Maloney T. Kisar, a small island participant in an extensive maritime obsidian network in the Wallacean Archipelago. Archaeological Research in Asia. 2019;**19**:100139. DOI: 10.1016/j.ara.2019.100139

[97] O'Connor S, Samper Carro SC, Hawkins S, Kealy S, Louys J, Wood R. Fishing in life and death: Pleistocene fish-hooks from a burial context on Alor Islandm, Indonesia. Antiquity. 2017;**91**(360):1451-1468. DOI: 10.15184/aqy.2017.186

[98] O'Connor S, Reepmeyer C, Mahirta LMC, Piotto E. Communities of practice in a Mritime World: Shared Shell Technology and Obsidian Exchange in the Lesser Sunda Islands, Wallacea. In: Bellina B, Blench R, Galipaud J-C, editors. Sea Nomads of Southeast Asia, from the Past to the Present. Singapore: NUS Press; 2021. pp. 28-50. DOI: 10.2307/j.ctv2gjx12g.6

[99] Samper-Carro SC, O'Connor S, Mahirta KS, Shipton C. Talking Dead: New burials from Tron Bon Lei (Alor Island, Indonesia) inform on the evolution of mortuary practices from the terminal Pleistocene to the Holocene in Southeast Asia. PLoS One. 2022;**17**(8):e0267635. DOI: 10.1371/journal.pone.0267635

[100] O'Connor S, Mahirta KS, Boulanger C, Maloney T, Hawkins S, Langley MC, et al. Kisar and the archaeology of small islands in the Wallacean Archipelago. The Journal of Island and Coastal Archaeology. 2019;**14**(2):198-225. DOI: 10.1080/15564894.2018.1443171

[101] Reepmeyer C, O'Connor S, Mahirta MT, Kealy S. Late Pleistocene/early Holocene maritime interaction in Southeastern Indonesia – Timor Leste. Journal of Archaeological Science. 2016;7**6**:21-30. DOI: 10.1016/j.jas.2016.10.007

[102] Reepmeyer C, O'Connor S, Brockwell S. Long-term obsidian use at the Jerimalai rock shelter in East Timor. Archaeology in Oceania. 2011;**46**(2):85-91. DOI: 10.1002/j.1834-4453.2011.tb00102.x

[103] Neri LA, Pawlik AF, Reepmeyer C, Mijares AS, Paz VJ. Mobility of early islanders in the Philippines during the Terminal Pleistocene/Early Holocene boundary: pXRF-analysis of obsidian artefacts. Journal of Archaeological Science. 2015;**61**:149-157. DOI: 10.1016/j.jas.2015.05.005

[104] Fujita H. Early Holocene pearl oyster circular fishhooks and ornaments on Espíritu Santo Island, Baja California Sur. Monographs of the Western North American Naturalist. 2014;**7**(9):129-134

[105] Samper Carro SC, Louys J, O'Connor S. Shape does matter: A

geometric morphometric approach to shape variation in Indo-Pacific fish vertebrae for habitat identification. Journal of Archaeological Science. 2018;**99**:124-134. DOI: 10.1016/j.jas.2018.09.010

[106] Allen MS. Style and function in East Polynesian fish-hooks. Antiquity. 1996;**70**(267):97-116. DOI: 10.1017/S0003598X00082922

[107] Reinman FM. Fishing: An aspect of oceanic economy: An archaeological approach. Fieldiana Anthropology. 1967;**56**(2):95-208

[108] Glover I. Archaeology in Eastern Timor, 1966-67. Terra Australis 11. Canberra: RSPAS, Australian National University; 1986

[109] Oliveira NV. Subsistence Archaeobotany: Food Production and the Agricultural Transition in East Timor. [PhD thesis]. Canberra, The Australian National University; 2008

[110] Mahirta. Human occupation on Roti and Sawu Islands, Nusa Tenggara Timur. [PhD thesis]. Canberra: Australian National University; 2003

[111] Verhoeven T. Eine Mikrolithenkulture in Mittel- und West-Flores. Anthropos. 1953;**48**(H3/4):597-612

[112] Hiscock P, O'Connor S, Balme J, Maloney T. World's earliest ground-edge axe production coincides with human colonisation of Australia. Australian Archaeology. 2016;**82**(1):2-11. DOI: 10.1080/03122417.2016.1164379

[113] Bellwood P, Irwin G, Tanudirjo D. Lithic and other non-ceramic artefacts. In: Bellwood P, editor. The Spice Islands in Prehistory Archaeology in the Northern Moluccas, Indonesia. Terra Australis. Vol. 50. Canberra: ANU Press; 2019. pp. 107-120

[114] Spriggs M. The Island Melanesians. Oxford: Blackwell; 1997

[115] Pawlik AF, Piper PJ. The Philippines from c. 14,000 to 4,000 cal. BP in regional context. Cambridge Archaeological Journal. 2019;**29**(1):1-22. DOI: 10.1017/S0959774318000306

[116] Pawlik AF, Piper PJ, Faylona MG, Padilla SG, Carlos J, Mijares AS, et al. Adaptation and foraging from the terminal Pleistocene to the early Holocene: Excavation at Bubog on Ilin Island. Philippines. Journal of Field Archaeology. 2014;**39**(3):230-247. DOI: 10.1179/0093469014Z.00000000090

[117] Shipton C, O'Connor S, Reepmeyer C, Kealy S, Jankowski N. Shell Adzes, exotic obsidian, and inter-island voyaging in the early and middle Holocene of Wallacea. The Journal of Island and Coastal Archaeology. 2020;**15**(4):525-546. DOI: 10.1080/15564894.2019.1581306

[118] O'Connor S, Oliveira NV, Standish CD, García-Diez M, Kealy S, Shipton C. Faces in the stone: Further finds of anthropomorphic engravings suggest a discrete artistic tradition flourished in Timor-Leste in the terminal Pleistocene. Cambridge Archaeological Journal. 2021;**31**(1):129-142. DOI: 10.1017/S0959774320000323

[119] Malonda JE. Pahatan cadas situs Liang Pu'en Kabupaten Lembata, Nusa Tenggara Timur. [Undergraduate thesis]. Denpasar: Universitas Udayana; 2020

[120] Pargeter J, Faith JT. Lithic miniaturization as adaptive strategy: A case study from Boomplaas Cave, South Africa. Archaeological and Anthropological Sciences. 2020;**12**(9):225. DOI: 10.1007/s12520-020-01176-1