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Palaeogeography and voyage modeling indicates early human colonization of Australia was likely from Timor-Roti

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ABSTRACT

Anatomically Modern Humans (AMHs) dispersed rapidly through island southeast Asia (Sunda and Wallacea) and into Sahul (Australia, New Guinea and the Aru Islands), before 50,000 years ago. Multiple routes have been proposed for this dispersal and all involve at least one multi-day maritime voyage approaching 100 km. Here we use new regional-scale bathymetry data, palaeoenvironmental reconstruction, an assessment of vertical land movements and drift modeling to assess the potential for an initial entry into northwest Australia from southern Wallacea (Timor-Roti). From ~70,000 until ~10,000 years ago, a chain of habitable, resource-rich islands were emergent off the coast of northwest Australia (now mostly submerged). These were visible from high points close to the coast on Timor-Roti and as close as 87 km. Drift models suggest the probability of accidental arrival on these islands from Timor-Roti was low at any time. However, purposeful voyages in the summer monsoon season were very likely to be successful over 4–7 days. Genomic data suggests the colonizing population size was >72–100 individuals, thereby indicating deliberate colonization. This is arguably the most dramatic early demonstration of the advanced cognitive abilities and technological capabilities of AMHs, but one that could leave little material imprint in the archaeological record beyond the evidence that colonization occurred.

1. Introduction

By around 50,000 calendar years ago (50 ka; Bulbeck, 2007; Allen and O'Connell, 2008; Hamm et al., 2016; Tobler et al., 2017) and potentially by as early as 65 ka (Clarkson et al., 2017), Anatomically Modern Humans (AMHs) had rapidly dispersed through the continent of Sunda (modern island southeast Asia exposed as a single landmass due to lowered sea level) and crossed the isolated islands of Wallacea into the continent of Sahul - Australia and New Guinea, also joined during lowered sea level (Lambeck and Chappell, 2001; Williams et al., 2018). The genetic evidence suggests that Sahul was colonized from Wallacea in one 'event' constrained by genetic clocks to a range consistent with the majority of the archaeological evidence for the timing of colonization (Hudjashov et al., 2007; Malaspinas et al., 2016; Tobler et al., 2017). Once established in Sahul, dispersing populations rapidly occupied the coasts and interior (O'Connell and Allen, 2015; Bird et al., 2016). The populations in northern Sahul (modern New Guinea) were isolated from those in southern Sahul (modern Australia) soon after arrival (by at least 35 ka; Malaspinas et al., 2016; or much earlier, Tobler et al., 2017), and once colonization was complete gene flow between different settled regions across Sahul reduced rapidly and dramatically thereafter (Tobler et al., 2017).

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The route by which AMHs traversed Wallacea and arrived in Sahul has been debated for decades. Birdsell (1977) provided the first assessment of possible routes, these being divided broadly into a 'southern route' through the Lesser Sunda island arc into northwest Australia and a 'northern route' via Sulawesi and numerous islands east into western New Guinea. Butlin (1993) recognized the role of changing sea level in controlling the distribution of land and hence island inter-visibility, target sizes and distances. An assessment of the regional bathymetry led him to conclude that the southern route, from Timor or Roti to reefs off the continental shelf of northwestern Australia that would be exposed as islands at lowered sea level (the modern 'Sahul Banks'), made the southern route the more likely. He also stressed the role of the carrying capacity of islands and the stress of demographic packing set against glacio-eustatic sea-level fluctuations as a colonizing prime mover. In order to arrive at a point from which the final water crossing to Sahul could be undertaken, a minimum of five water crossings (including across Wallace's Line) were required, even at times of lowest sea level. Crossing to Sahul by any route required at least one crossing approaching 100 km, this generally being the final crossing onto Sahul itself. While knowledge of palaeoenvironments and chronologies of the occupation of Wallacea and Sahul have improved, there has been, as yet, no clear resolution of the debate (O'Connor, 2007; O'Connell and Allen, 2015; Kealy et al., 2016, 2017).

Either route requires a feat of maritime voyaging, and demonstrates that by 50 ka, AMHs in Sahul shared sophisticated behavioural capacities to plan, coordinate and execute major marine voyages across open water. There is no direct evidence regarding the nature or capability of the watercraft that were used in the many marine crossings required to found a viable AMH population on Sahul. However, as the craft were most likely constructed from wood and fibre, it is not surprising that direct evidence has not survived. Indeed the fact that the crossings were made has been used as evidence that such craft must have existed (Balme, 2013). The migration demonstrates the earliest construction and use of watercraft anywhere in the world and is an important time-stamp for evidence of technological innovation, abstract thinking, planning ability, advanced cognition and complex language use (Davidson and Noble, 1992; Bulbeck, 2007; Allen and O'Connell, 2008; Balme et al., 2009; O'Connor et al., 2011).

Importantly for the likely routes from Sunda to Sahul, the earliest evidence for exploitation of marine resources by AMHs outside of Africa comes from limestone caves on both sides of the Lydekker Line from the continental Barrow Island on the Northwest Shelf of Australia (Veth et al., 2017) and the uplifted terraces of East Timor (Langley et al., 2016a). Equivalent-aged dietary molluscan remains have also been reported in other ancient limestone contexts from New Ireland (Leavesley and Chappell, 2004) and Niah Cave on Borneo (Barker, 2013). It should also be noted that the AMH population accumulated at the final crossing point also had to be large enough to then establish a genetically viable founder population in Sahul capable of survival and rapid dispersal (Moore, 2001; O'Connell et al., 2010).

While all routes into Sahul imply effective exploitation of coastal resources by AMHs (Bowdler, 1977), the terrestrial environments along the southern route were likely dominated by open savanna woodlands, and potentially joined to similar open terrestrial environments north of the equator and into mainland Southeast Asia via a 'savanna corridor' through what is now the Java Sea (Wurster and Bird, 2016). This would have allowed AMHs with a savannah-adapted skill set to expand south from mainland Asia into Sahul and exploit the savannas that covered most of the interior. Upon arrival in Sahul, colonists were able to penetrate deep into the Australian deserts as indicated by a range of sites from the northwestern deserts including Riwi, *Yurlu Kankala*, *Parnkupirti* and Serpent's Glen now dated to at least 50–45 ka (Veth et al., 2009, 2017; Smith, 2013; Wood et al., 2016). In contrast, the environment along the northern route was largely forested and similar only to the extreme north of Sahul in New Guinea at that time (Russell et al., 2014). Forest cover was likely maintained into the Last Glacial Maximum at latitudes north of central Sulawesi (Martin Calvo and Prentice, 2015). Hence populations moving to Sahul via the northern route would have to move via coastlines, and/or require the capacity to traverse dense forest environments.

Defining the route and nature of the Sahul colonization process is important for inferring the cognitive, linguistic and technological capabilities of AMHs by ~50 ka or earlier. For example, the rapid rate at which colonization of the interior of Sahul subsequently occurred implies considerable technological organization of organic and lithic extractive and maintenance implements.

There has been one early attempt to drift model arrival on Sahul from the eastern tip of Timor (Wild, 1986), a location from which Sahul has never been visible. The model used average currents thought to be broadly representative of January and July as understood in 1947, averaged over a coarse 5° x 5° grid, thus excluding many of the key finer-scale processes that drive voyage pathways (e.g. ocean eddies). That study also assumed the characteristics of a modern vessel of Chinese design with a large sail (achieving 10% windage), and also that voyages were survivable over multiple weeks. Not surprisingly, the study found that, given enough time, some vessels departing in the Austral summer monsoon season would eventually arrive on the northern coast of Sahul, near Darwin, after travelling several weeks and generally more than 500 km. Given our contemporary understandings of technologies available at the time, as well as the meteorology, palaeogeography and oceanography of the region, these simulations cannot now be considered at all realistic.

Here we use daily winds and currents from a data-assimilating model (Schiller, 2012) on a $0.1^\circ \times 0.1^\circ$ grid, running over real historical years with the associated day-to-day variability. We also apply palaeogeographic information derived from new regional-scale bathymetry grid data (100 m-resolution), an understanding of regional sea-level change and vertical land movements in the region, to revisit the issue of the plausibility of accidental or purposeful arrival on Sahul from Timor-Roti.

2. Methods

2.1. Digital elevation model

The new regional-scale bathymetry grid (100 m-resolution) for the northern Australia region (latitude 8° to 18°S; longitude 121° to 133°E) utilized all available bathymetry datasets including multibeam, singlebeam, airborne lidar bathymetry surveys and electronic nautical chart spot depths provided by the Australian Hydrographic Office and Geoscience Australia. Source bathymetry data were edited for noise and adjusted to a consistent WGS84 horizontal datum and approximate mean sea level (MSL) vertical datum. The source bathymetry data were interpolated into a 100 m-resolution Digital Elevation Model (Becker et al., 2009) and merged with 100 m-resolution Shuttle Radar Topographic Model (Farr et al., 2007) land elevation data to produce the final grid (Figs. 1 and 2).

To determine inter-visibility the distance from each point to the horizon at sea level was calculated from:

$$d = 3.57*\mathrm{sqrt}(h) \tag{1}$$

where d equals the distance to the horizon at sea level in km and h

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