

# Geological complexity, biogeographical realms and early human adaptations in Island Southeast Asia

## Outline

In this chapter, we delve into the landscapes of Island Southeast Asia, a region distinguished by its geological diversity and biogeographical complexity. Comprising thousands of islands spanning from the Indochinese Peninsula to Australia, this vast archipelago has played a pivotal role in shaping the course of human prehistory and adaptation. We explore the geological foundations of the region, including the Sunda Shelf and Sahul Shelf, and examine the biogeographical boundaries that have influenced its unique biodiversity. Furthermore, we delve into the history of human populations in Island Southeast Asia, shedding light on their migrations, adaptations, and the emergence of modern behaviors within this dynamic and ecologically diverse environment.

## 1.1. Southeast Asian landscapes

### 1.1.1. *Geology, geography and biogeography*

Island Southeast Asia constitutes the world's largest archipelago, comprising an estimated 25,000 sizable islands of varying dimensions, the most prominent among them being Borneo, divided between territories belonging to Indonesia, Malaysia and Brunei, and Sumatra, Sulawesi, and Java in Indonesia, in addition to Luzon and Mindanao in the Philippines. These islands, characterized by extensive coastlines, are interspersed with maritime regions encompassing both shallow and exceedingly deep seas, spanning over an expansive expanse exceeding two million square kilometers. They extend across the global expanse linking the Indian and Pacific Oceans, stretching from the Indochinese Peninsula to New Guinea and Australia, presently encompassing the territories of the Philippines, Indonesia (with the exception of Western New Guinea), Timor-Leste, Brunei, East Malaysia, Singapore, and the Andaman and Nicobar Islands. The archipelago can be categorized into four distinct groupings: to the west, the Andaman and Nicobar Islands; in the northeast, Borneo, Sulawesi, and the Philippines; at the central and southern regions, the Malay archipelago encompassing the Sunda Islands (Sumatra, Java, Bali, Lombok, Sumbawa, Flores, Sumba, and Timor); and to the east, the Moluccas, which include, from north to south, the Morotai and Halmahera islands, the Sula and Obi groups, the Buru and Seram islands, the Aru archipelago, the Tanimbar archipelago, and the island of Wetar, comprising the larger islands, in addition to the smaller Kisar Island (Figure 1.1).

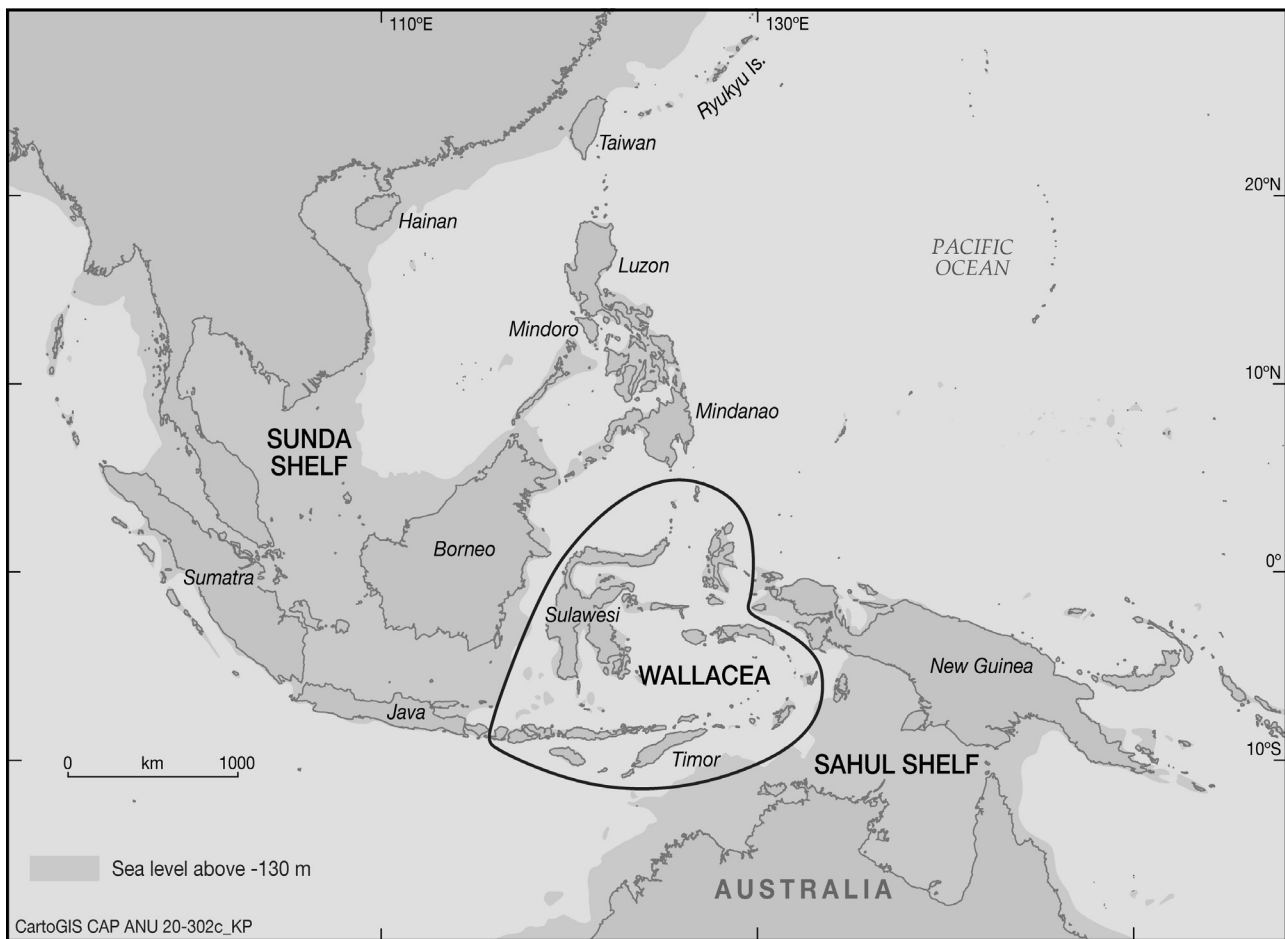
Collectively, these islands are situated within a region marked by significant tectonic convergence involving the

Pacific, Indo-Australian, and Eurasian continental plates. Additionally, the presence of minor oceanic plates, such as the Philippine Plate in the northeast and the smaller Caroline Plate bordering Papua New Guinea to the north, contributes to the complex geological dynamics (Bird, 2003). The entirety of the insular Southeast Asian expanse is an integral component of the Pacific Ring of Fire, a configuration that has given rise to distinctive biogeographic realms closely aligned with major geological formations (Wallace, 1869, "The Malay Archipelago"). Indeed, the absence of historical land connections between certain Southeast Asian islands during periods of reduced sea levels has led to the isolation of various species from these distant landmasses. Consequently, this phenomenon has given rise to the contemporary biogeographical subdivision of the region into three primary zones: the Western biological region of Sunda, the Eastern biological region of Sahul, which corresponds to the easternmost boundary for several Sundanese animal species, and the intermediate Wallacean region lying between the two (Figure 1.1). This Wallacean region represents a biogeographic amalgamation of species from both Sunda and Sahul, with the delineation of biogeographic boundaries having evolved over time, subject to varying interpretations among scholars (Ali et al., 2021).

The primary focus here pertains to marine fauna, and thus, we shall refrain from delving into exhaustive details concerning these biogeographic areas and their associated boundary lines, which have predominantly been established for terrestrial and aerial species. Nevertheless, it is noteworthy that within the realm of biogeography, there remains an ongoing discourse regarding the validity of the term "Wallacea". Some scholars, exemplified by Simpson (1977) and Mayr (1944), contend that Wallacea essentially represents an extreme extension of the Sunda region. Consequently, there exists occasional disagreement among experts as to whether the Philippine archipelago should be included within the purview of Wallacea or categorized differently, a topic that has prompted scholarly discourse (Brown et al., 2013; Lohman et al., 2011).

### 1.1.2. *The Sunda and the Sahul Shelf*

The Sunda Shelf (Figure 1.1) comprises the extruded continental crust that underwent a southward and eastward shift as a consequence of the collision between the Indian Plate and the South Asian continent (Tapponnier et al., 1990). Extending from the Malay Peninsula, spanning from the South China Sea to northern Vietnam, and further encompassing Sumatra, Borneo, and Java, the Sunda Shelf represents a prominent geological feature in



**Figure 1.1. Island Southeast Asia and its biogeographical boundaries, along with continental shelves at -130 meters. Provided by CartoGIS Services, ANU College of Asia and the Pacific, The Australian National University.**

the region. The southern boundary of the Sunda Shelf is defined by the dynamic Indonesian volcanic inner arc, a direct outcome of the subduction process involving the oceanic Indo-Australian plate beneath the continental Eurasian plate (Tregoning et al., 1994). Over geological time, eustatic variations, notably during the Quaternary period and particularly in the Pleistocene epoch (Voris, 2000), led to recurrent exposures of specific areas. These fluctuations facilitated the migration of various fauna, including *Homo erectus* (de Vos & Long, 2001), from the Asian mainland to the contemporary Indonesian archipelago. Indeed, a relatively modest reduction of sea level by 50 meters is sufficient to establish terrestrial connections, effectively forming landbridges between the present-day islands of Sumatra, Java, and Borneo with the Asian continent.

The Sahul platform (Figure 1.1) encompasses the landmasses of New Guinea, Australia, and Tasmania. In its northern region, the platform remains susceptible to ongoing volcanism and seismic activity, while the Australian basement constitutes a remnant of the ancient supercontinent Gondwana (Bird, 2003). Notably, this Australian basement has maintained its isolation from the Asian continent throughout the Quaternary period (Hall, 2002).

### 1.1.3. Wallacea and the Philippines

Wallacea, including the Philippines (Figure 1.1) finds its western boundary adjacent to the Sunda region and its eastern boundary neighboring the Sahul region within the realm of biogeography. Notably, this biogeographic area distinguishes itself from the other two by lacking a unifying geological structural framework. In the northernmost expanse of this region, we encounter the Philippine Islands, situated along the Philippines Mobile Belt. This belt comprises two principal subduction zones: the Philippine Trench in the southern sector and the Manila Trench in the northern segment, positioned at the forefront of the Luzon arc (Galgana et al., 2007). To the south, Wallacea unfolds as a series of diminutive volcanic islands, extending in a westerly to easterly trajectory, commencing with Lombok along the Banda arc and persisting through the Indonesian volcanic arc. Nestled in the center of Wallacea, we find the remnants of Gondwanan and Laurasian continental folded crust, represented by the islands of Sulawesi and the Moluccas archipelago (Hutchison, 2007; Wilson & Moss, 1999). The scope of this research centers on archaeological sites located exclusively within the Wallacean region. These sites encompass both the northern domain, once part of the Philippines, and the southern territory, now encompassing Indonesia and Timor-Leste.

## 1.2. Human prehistory and migration dynamics in Island Southeast Asia

### 1.2.1. Prehistoric human settlements

In the Island Southeast Asian region, significant discoveries of archaic human species have shaped our understanding of the area's prehistoric inhabitants. *Homo erectus*, for instance, was identified on Java approximately 1,800,000 years ago (Swisher et al., 1994). The Indonesian Wallacean island of Flores yielded evidence of *Homo floresiensis* around 700,000 years ago (van den Bergh, et al., 2016). Furthermore, indications of an unknown, likely archaic, human species have been uncovered on Sulawesi, dating back to around 200,000 years ago (van den Bergh et al., 2016) and on Flores, around 900-800,000 years ago (Brumm et al., 2006). Additionally, the Kalinga site (Luzon, Philippines) holds the potential for an as-yet-unknown archaic human species, potentially connected to the 67,000-year-old *Homo luzonensis* found on the same island (Détroit et al., 2019; Mijares et al., 2010). These findings collectively underscore Island Southeast Asia's role as a significant hub for human evolution in island environments, long before the arrival of *Homo sapiens*.

The history and migration patterns of our species in Island Southeast Asia continue to be subjects of ongoing debate. Fossil evidence from Zhirendong in Southern China, dated to 100,000 years BP, (Liu et al., 2010), direct dating of human remains to 74,000 years BP in Sumatra (Westaway et al., 2017), and the unearthing of early human occupation at Madjedbebe in Australia (Clarkson et al., 2017) all suggest the dispersal of *Homo sapiens* through the Philippines and the Wallacean region between 100,000 and 65,000 years BP. Notably, in the Philippines, a tibia fragment discovered in Tabon Cave, Palawan, dates back to approximately 47,000 ± 11,000/-7,000 years BP (Détroit et al., 2004). In Wallacea, the oldest human remains, a tooth found at Liang Bua on Flores, has been dated to 46,000 years ago (Callaway, 2016), while the earliest traces of *Homo sapiens*' settlement are at Laili Cave, Timor-Leste, dating to around 44,600 years BP (Hawkins et al., 2017). Additional findings, such as Holocene fossils from Wajak (Storm, 1995) and the Gunung Sewu sites (Simanjuntak, 2002) in Indonesia, provide evidence of hunter-gatherer populations in Island Southeast Asia from the end of the Pleistocene to the mid-Holocene. These populations are morphologically described as "Australo-Melanesian" (Widianto & Noerwidi, 2023), but our knowledge of their subsistence strategies and symbolic behavior remains limited (Habgood & Franklin, 2008).

Around 5,000 years BP, populations speaking languages related to the Austronesian family, engaging in a subsistence mode combining agriculture and animal breeding, began to migrate into Wallacea (Bellwood, 2013, 1997). These groups likely originated from South China, traversed to Taiwan (Hung & Carson, 2014; Melton et al., 1998), and then journeyed from Taiwan to the northern Philippines (Piper et al., 2009; Bellwood, 1997). They swiftly colonized

the islands, influencing the existing Australo-Melanesian populations and eventually displacing them (Bellwood, 2011). Known for their exceptional navigational skills, these Austronesian-speaking populations rapidly expanded into the remote Pacific islands between around 3,000 years BP, contributing to the development of the Lapita culture. This culture was marked by the creation of ceramics adorned with anthropomorphic figures (Bellwood, 1997) and an intensive reliance on marine resources, as evidenced by the abundant archaeological sites containing mollusc shells and fish remains (e.g., Ono et al., 2019; Bedford et al., 2007; Bouffandeau et al.; 2018; Butler, 1994; Walter, 1989; Kirch & Dye, 1979).

### 1.2.2. Migration hypotheses and recent least-cost pathway models

Since the 1960s, pioneering zoologists and archaeologists engaged in research within the region have embarked on the endeavor of constructing numerous migration models. Their aim has been to elucidate the intricate dispersal of *Homo sapiens* from continental Asia through the intricate expanse of Wallacea into the Sahul region (Kealy et al., 2016). One noteworthy model, advanced by Birdsell in 1977, emerges prominently. Birdsell's model presented two principal migration routes - a northern trajectory and a southern one. The former traversed from Borneo to the northwestern reaches of Papua, while the latter followed a path from Bali to the northwestern shores of Australia.

In their comprehensive study, Kealy and colleagues (2018) developed an array of spatial variables to facilitate an in-depth understanding of early human migration routes. These variables encompassed bathymetric data, the distance required for water crossings, intervisibility between islands, topographical steepness, historical paleocurrents, prevailing winds, resource accessibility, and a keen emphasis on the numerous submerged islands that would have surfaced during periods of lowered sea levels (Kealy et al., 2016). This multifaceted dataset was then rigorously compared with existing archaeological records, culminating in the construction of a least-cost pathway model delineating the *Homo sapiens*' dispersal through the Wallacean archipelago. The result of this research pinpointed the most probable route taken by our species in their journey to Sahul—a northern route from Sulawesi to New Guinea's Bird's Head peninsula, lending support to the prevailing northern route theory (Figure 1.2). Bird and colleagues (2019), incorporating demographic models, affirmed that *Homo sapiens* reached Sahul through multiple shorter maritime crossings within Wallacea. Their findings emphasized that the northern route, demanding less in terms of efforts and time, likely facilitated the successful colonization of Sahul by a viable population. In contrast, Norman and co-authors (2018) employed an analytical approach grounded in visual connectivity network analyses, agent-based simulations, and ocean current flow modeling. Their conclusions, however, leaned towards probabilistically favoring the southern pathway. It is worth noting, though, that the colonization

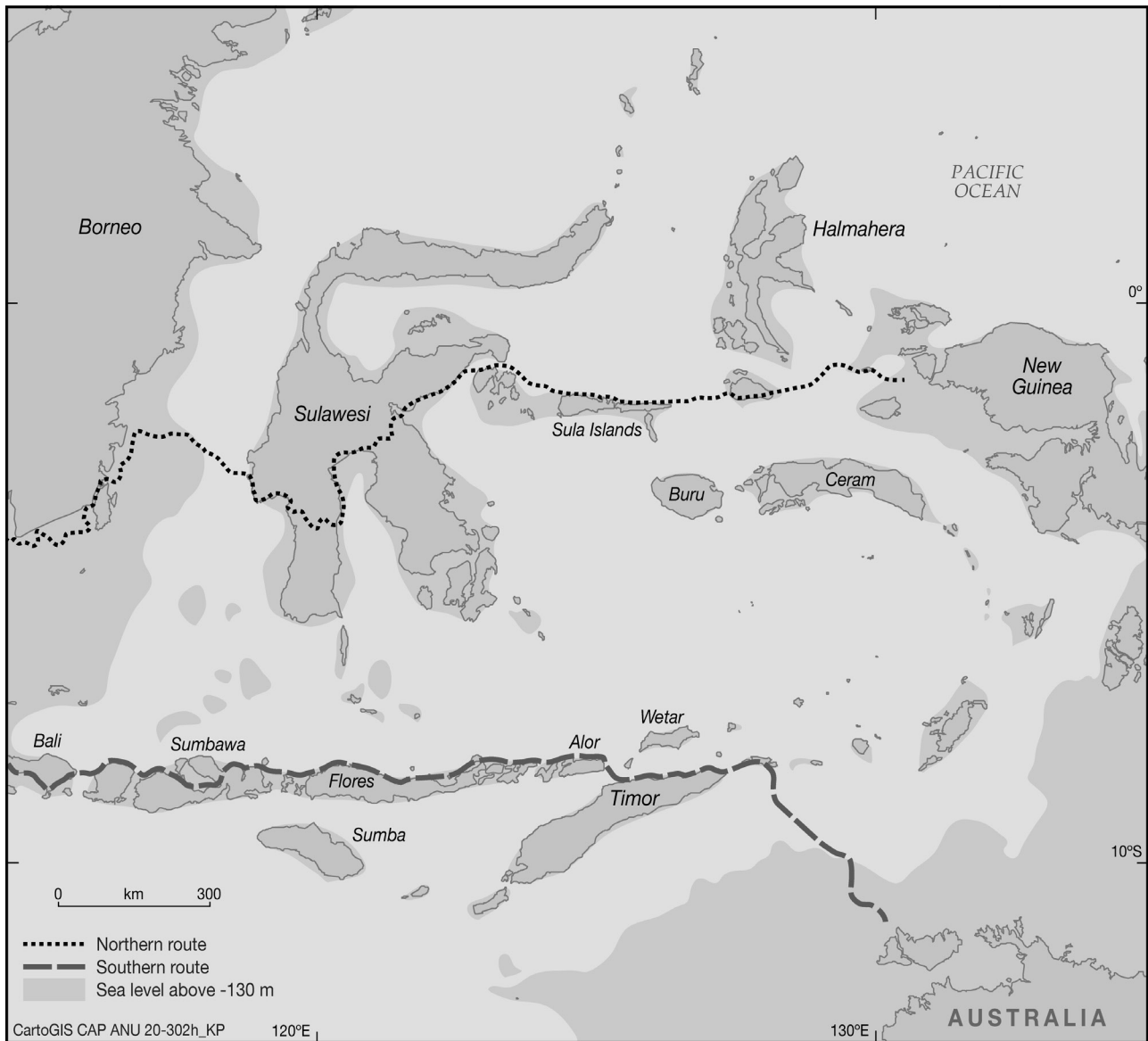


Figure 1.2. Least-cost pathway model routes from Sunda to Sahul, following Kealy et al. (2018). Provided by CartoGIS Services, ANU College of Asia and the Pacific, The Australian National University.

of the Wallacean region by *Homo sapiens*, followed by their migration to Sahul, likely unfolded through a series of multiple colonization events. The existence of various migration pathways serves to better elucidate the cultural, archaeological, and historical complexities that pervade this region.

### 1.3. Human cultural adaptation in Island Southeast Asia

#### 1.3.1. Towards a new definition of “modern behavior”?

The concept of “modern human behavior” is a pivotal aspect related to the emergence of *Homo sapiens* in the archaeological record. This theory, currently the subject of debate, which delineates the timing of the advent of modern culture, is founded upon a set of traits, often regarded as a “package” of cultural innovations (d’Errico et al., 2012b; D’Errico, 2003; Habgood & Franklin,

2008). It implies the replacement of “archaic” populations by modern hominids endowed with cognitive advantages (Henshilwood & Marean, 2003). These enhanced cognitive abilities were particularly valuable for cultural adaptation to new and, at times, challenging environments such as tropical rainforests (Roberts & Stewart, 2018), but also coastal and insular settings demanding sophisticated technology for resource exploitation, including fishing gear and hunting weapons (e.g., Boulanger et al., 2019; Boulanger, 2015; Wedage et al., 2019a; Roberts et al., 2017b, 2015b, a; Rabett & Piper, 2012; van Niekerk, 2011; Ingicco, 2010; Marean et al., 2007; Walter et al., 2000). These capabilities also played a fundamental role in the development of symbolic behavior, encompassing practices like burial rituals and the use of body adornments, mineral pigments, and shell beads (Habgood & Franklin, 2008; Bouzouggar et al., 2007; d’Errico et al., 2005; Mellars, 1989). These traits appear to have emerged concurrently, either through rapid or gradual



processes, around 80,000 years ago in archaeological sites across South and North Africa and the Near East (e.g., d’Errico et al., 2022). In these regions, art associated with sophisticated bone tools thrived before gradually vanishing from the archaeological record between 70,000 and 50,000 years ago (d’Errico et al., 2012b). This abrupt shift might have been influenced by various factors, including climatic events, population fluctuations, or alterations in the mechanisms of cultural transmission (d’Errico et al., 2012b; d’Errico & Stringer, 2011).

Notably, recent research has unveiled instances of similar behavioral and cultural innovations among other hominids. For example, *Homo neanderthalensis*, found at Vanguard and Gorham’s caves in Gibraltar, exhibited a reliance on marine resources such as mollusks, a few marine mammals, and fish dating back as early as 41,800 years BP (Douka, 2012; Stringer et al., 2008). Similarly, the Iberian Neandertals of Figueira Brava appear to have consistently utilized marine aquatic food resources between 106 and 86 thousand years ago (Zilhão et al., 2020). In 2018, new dating evidence from the Iberian caves of La Pasiega, Maltravieso, and Ardales in Spain pointed to *Homo neanderthalensis*’ origins of rock art dating back to at least 64,800 BP, which is over 20,000 years before *Homo sapiens* arrived in Europe (Hoffmann et al., 2018), although these dates have faced challenges (Aubert et al., 2018). Moreover, paleoenvironmental studies have uncovered early evidence of *Homo erectus* adapting to the tropical rainforest on the island of Java, Indonesia (Sémah & Sémah, 2012). However, this theory remains a subject of ongoing debate (Roberts et al., 2016). *Homo erectus* utilized shells for tool production and the engraving of abstract patterns at Trinil in Java, possibly representing early indications of symbolic behavior (Joordens et al., 2014). It has become evident that the concept of modern behavior no longer solely applies to technological modernization but also extends to the extensive and independent behavioral evolution of populations, some of which were archaic hominins. Southeast Asia appears to hold a pivotal role in the progression of this evolution.

The recent discovery of *Homo sapiens*’ presence in Sumatra, Indonesia, by 80,000 years ago suggests the potential for early adaptation to tropical rainforests by our species (Westaway et al., 2017) even before the first signs of complete acquisition of “modern behavior” in Europe. Additionally, the identification of human occupation at Madjebebe in Northern Australia, dating to 65,000 years BP (Clarkson et al., 2017), indicates that *Homo sapiens* swiftly spread through the Wallacean islands and adapted to coastal environments much earlier than previously assumed. It is evident that the earliest *Homo sapiens* in Island Southeast Asia and Sahul exhibited fully “modern behavior” on their journey to Australia. The origins of marine hunting and gathering in the Indo Pacific region likely trace back to Island Southeast Asia (Kirch & Dye, 1979). Evidence for this transformation extends well into the Pleistocene, although this adaptation appears to have emerged sporadically in archaeological sites widely

separated from each other and characterized by different chronologies (Habgood & Franklin, 2008; Barker et al., 2007). Moreover, cave and rock art constitute significant evidence of symbolic behavior during the European Middle Paleolithic and the African Middle Stone Age (Hoffmann et al., 2018). However, it is only recently that Lubang Jeriji Saléh, a limestone cave in East Kalimantan, Indonesian Borneo, has yielded dates ranging from 52,000 to 40,000 years BP (Aubert et al., 2018), and the earliest hunting scene in a prehistoric site has been dated to 43,900 years BP at Leang Bulu’Sipong 4 in Sulawesi, Indonesia (Aubert et al., 2019). At Niah Cave, Borneo, from approximately 46,000 to 34,000 years ago, there is evidence that *Homo sapiens* exhibited a wide range of strategies to secure subsistence in the tropical rainforest, including the potential collection and processing of toxic plants for consumption (Barker et al., 2007).

### **1.3.2. The “generalist-specialist niche”**

In the realm of specialized cultural adaptation to marine environments, a striking parallel can be drawn with the evolutionary history of *Homo sapiens*’ adaptation to tropical rainforests in Southern Asia and Island Southeast Asia. Traditionally, tropical rainforests have been characterized by scholars as inhospitable terrains, often deemed as formidable barriers to human migration, as evidenced by the notable “Movius Line” (Roberts & Amano, 2019; Roberts & Petraglia, 2015; Bailey et al., 1989). Some Southeast Asian archaeological sites offer a distinctive perspective on this discourse. One such site of remarkable significance is Fa-Hien, situated in the southwestern region of Sri Lanka, where the earliest *Homo sapiens* fossil in Southern Asia was unearthed. Recently, this site unveiled the earliest evidence of bow-and-arrow technology usage, dating from approximately 48,000 to 4,000 years BP. These artifacts were discovered alongside bone and tooth tools, underscoring the mastery of plant-based resource utilization. Furthermore, a complex array of symbolic artifacts was unearthed, shedding light on the emergence of cultural complexity within the contemporary hunter-gatherer populations (Langley et al., 2020). Notably, these artifacts share striking similarities with bone artifacts discovered in the terminal Pleistocene era at Niah Cave in Borneo (Barton et al., 2009), thus illustrating a remarkable level of technological advancement and the development of cultural intricacies within the hunter-gatherer societies of that period (Piper & Rabett, 2009; Barker et al., 2007). Perera and co-authors (2016) also reported the discovery of bone toolkits dating back to 36,000 years BP, tailored to specialized rainforest exploitation strategies at Batadomba-Iena rock shelter, Sri Lanka. The “microlithic tradition”, as described by Roberts and colleagues (2015a) and Wedage and colleagues (2019b), further illuminates the evolution of a distinct industry that provides valuable insights into a way of life predominantly reliant on rainforest resources, which were previously considered insufficient to satisfy human economic and nutritional needs (Roberts et al., 2015a). These assessments are substantiated by stable isotope and

zooarchaeological analyses, affirming the primary reliance of hunter-gatherer communities on rainforest resources not only in Sri Lanka but also in New Guinea (Roberts et al., 2017a), Java, Sumatra (Indonesia) (Ingicco et al., 2020; Westaway et al., 2017; Amano et al., 2016; Ingicco, 2010), and the Philippines (Boulanger et al., 2019). This firmly establishes a close historical connection between humans and these lush environments (Roberts, 2019; Roberts et al., 2016). Ingicco and co-authors (2020) notably highlighted the intimate relationship between humans and nonhuman primates at Song Terus and Braholo Cave in Java, where primates were both consumed and associated with human burials—a striking parallel to the Tron Bon Lei burials, where human remains were found in association with fishing tools (O'Connor et al., 2017b).

In accordance with the research of Roberts and Stewart (2018), who proposed the theory of the *Homo sapiens* “generalist specialist niche”, it is evident that our species exhibited remarkable adaptability to a wide array of paleoenvironmental niches over time, encompassing diverse landscapes ranging from arid deserts to tropical rainforests. This adaptability, often referred to as “generalist populations” in ecological terms, denotes the capacity to utilize a broad spectrum of resources with a considerable environmental tolerance. Contrariwise, “specialist populations” are marked by a more restricted diet and a narrower environmental tolerance, influenced by factors such as resource scarcity, variances in resource availability among habitats, fitness trade-offs leading to individual-specific behaviors, and the cultural transmission of foraging traditions (Roberts & Stewart, 2018). The archaeological record, especially in the isolated and resource-scarce Wallacean islands, provides valuable insights into human adaptation within challenging environments. Recent stable isotope analyses involving carbon ( $\delta^{13}\text{C}$ ) and oxygen ( $\delta^{18}\text{O}$ ) of human and faunal tooth enamel, derived from late Pleistocene/Holocene archaeological sites across Timor and Alor, have unveiled the varying degrees of reliance among early human colonizers in Wallacea on tropical forest and terrestrial resources versus marine resources (Roberts et al., 2020). The results indicate that the initial human colonizers in this region displayed a specialization in coastal resource utilization. However, after 20,000 years BP, a discernible diversification in human resource utilization patterns across Wallacea began to emerge. While some individuals exhibited continued reliance on coastal resources, as observed at Matja Kuru 2 and possibly Makpan, the majority displayed a broader engagement with interior environments, including closed tropical forest habitats (Roberts et al., 2020). In sum, the study of specialized cultural adaptation to marine environments not only provides an avenue for understanding human history and evolution but also invites intriguing comparisons with *Homo sapiens*’ adaptation to tropical rainforests. The archaeological evidence unearthed in Sri Lanka and Wallacea, in particular, underscores the remarkable versatility and adaptability of our species across diverse ecological niches, painting a complex and dynamic portrait of human cultural evolution.