

Chapter 7. The Austronesian Conquest of the Sea — Upwind

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This chapter discusses the history of canoe construction and rig design in the Pacific region — pre-Austronesian, Austronesian, and Southeast Asian early historical. Sailing conditions in the Pacific are described, together with sailing techniques and zones of traditionally-remembered interisland contact. Austronesian exploration is considered to have favoured sailing into the wind, with a downwind return.

Introduction

The built-up dug-out or planked canoe with an outrigger and sail has been the principal technology for survival and colonization for the sea-going peoples who spread over Island Southeast Asia and far over the Pacific for at least the past few thousand years. We deduce this from the present and presumed past distributions and structures of the canoes. With the ability to carry fire, family, dogs, chickens, tuberous roots, growing shoots and seeds by sea, the Austronesians eventually occupied the Pacific Islands, travelling into Melanesia about 3500 years ago and onwards into Polynesia. I propose to deal with two questions, whether it was in fact a problem for the early Austronesian colonists to travel against the prevailing winds and currents, and how much we can infer about their vessels.

The Southeast Asian Archipelago, An Easy First Step

The relatively shallow waters of the continental Sunda Shelf of Southeast Asia end at a line drawn through the Straits of Lombok, northwards through the Straits of Makassar, between the island of Palawan and the remainder of the Philippines, then south of Taiwan. To the east of this line are deep water channels that have always isolated the islands of Sulawesi, the Philippines, Timor and other islands of the Moluccas. Further east we come to the shallow Sahul Shelf between New Guinea and the north coast of Australia, once a land bridge for marsupials and also for humans. Whereas land mammals and freshwater fishes were restricted by these narrow seas, humans spread from the Sunda to the Sahul Shelf at least 50,000 years ago when sea-levels were lower than now and sea-crossings were perhaps shorter as a result of the build-up of glacial ice sheets. Even so, people must have crossed at least 70 km of open sea in order to reach Sahul. We may infer that they used bamboo rafts because these are an easily constructed form of transport and they could be made with the crude stone tools

then available. There is no problem about movement over these relatively enclosed seas because the winds and currents reverse every season with the monsoons.

Movements into the Pacific

From 5000 years ago, Island Southeast Asia was progressively colonized by people who spoke languages in the Austronesian family. These people spread southwards through the Philippines and Moluccas and eastwards into the Pacific. They made pottery and fine elbow-hafted and polished adzes. They kept pigs, dogs and chickens, but their chief characteristic was a mastery of the sea and a predisposition to spread from island to island with maritime cultures. By at least 2000 BC, according to comparative reconstructions, their technology must have included the making of pottery, bark cloth, dug-out canoes, mat sails, ropes, fishing gear and anchors. What little evidence we have, based upon the widespread construction methods of Neolithic boats, suggests that they already had a boatbuilding technology based upon lashings, protruding pierced lugs, and a hollowed base for the hull with added planks. At this stage, however, they must have adopted their own unique triangular sail and the outrigger construction. Along the margins of the large Melanesian islands they were not able to replace the local populations as they eventually did in Indonesia. Passing through Melanesia they left a distinctive incised pottery, called Lapita ware (Spriggs 1984, and this volume; Allen and White 1989). From Melanesian coastlands, about 3000 years ago, they colonized onwards to Tonga and Samoa and continued to develop their maritime cultures. By about 2500 years ago they were ready to make even longer sea voyages, with more substantial cargoes, possibly because they had by that time perfected the *double canoe*. They carried the large and varied cargoes essential for colonization, including dog, chicken, bamboo, banana, sugar cane, taro, yams, plant medicines and poisons, many fruits and tree seeds.

Travelling eastwards against the prevailing winds and currents, the Polynesians reached the Marquesas by about 200 BC. By about AD 500 they had colonized Hawaii and Easter Island, New Zealand by AD 1200, and eventually almost all of the habitable islands of the central and eastern Pacific. The golden age of occupation of new island groups was recorded in the folk memories and myths that were later written down by the earliest missionaries. Moreover, different schools of navigators in recent times kept open communication by sea within their own island groups by knowing the positions of many islands and the take-off points and shortest sea routes from one group of islands to another (Lewis 1972).

The curious fact is that, although the Austronesians carried out of Asia many cultural features of possible origin in central and southern China, such as making bark cloth, tattooing, certain decorative patterns, pottery making, adze styles,

domestic pig, dog and chicken, house and granary designs and many useful plants, there is no trace of Chinese boat technology in Austronesian boats, or vice-versa. Similarly, there is little trace of the Pacific boats among the relatives of the Austronesians in Mainland Southeast Asia. This supports the idea that those details of the boat designs that are characteristic of the Austronesians were adopted in the islands at or after the time that they left Mainland Asia. After all, the combination of outrigger and Oceanic triangular sail is not suitable for lakes or rivers. The peculiarities of the single-outrigger canoes of Melanesia, Micronesia and Polynesia very likely had their origin in pre-Austronesian times in what are now Indonesia and the Philippines.

Boat Construction Before the Austronesians

Nothing contradicts the view that excellent sailing rafts and sewn boats existed in the Indo-Malaysian Archipelago long before the Austronesian ancestors are thought to have moved out of Taiwan. The earliest edge-ground axe-like stone tools that could have made a crude dug-out canoe date from more than 20,000 years ago in Australia and 30,000 years ago in Japan. Humans were obliged to cross the sea to reach Australia, perhaps at first on bamboo rafts and later in dug-out canoes. Bamboo rafts are traditional over much of Indonesia and Melanesia as far as Fiji. Other lightweight timbers for rafts, such as *Erythrina* which is still used for outrigger floats, are available on the shoreline. Most of the boatbuilding timbers are also extremely widespread and must have been spread by humans, for only some species have seeds that are viable after floating in sea-water. Also, boat technology and agriculture are interconnected because the production of domestic hybrids depends on transporting parent stocks which would otherwise not be brought together.

Relations with the Indian Ocean

Most likely the earliest trade routes of the Indian Ocean developed about 5000 years ago between the Indus Valley and the Persian Gulf, possibly contemporary with initial Austronesian expansion in Southeast Asia. However, Indian Ocean boatbuilding seems to have contributed nothing to Austronesian designs until effectively historical times. Whether the original Austronesian and Indian Ocean hull was a dug-out log extended upwards by a plank or two, or whether it was built entirely of planks, the seams must have been sewn. It is astonishing how widespread were sewn planks, over Europe, Asia and Oceania, and how long they persisted into modern times, with interesting variants. We can assume that this common heritage extended to Southeast Asia and that the Austronesians also acquired it. In early Egypt, boatbuilders evolved another technique to hold planks edge-to-edge by using flat tenons embedded in slots in the edges of the planks and then locked in with transverse wooden pins. In Mesopotamia and the Indus Valley they used dowels or trenails within carved hardwood planks

which were placed edge-to-edge and then sewn. These additional techniques must have been very ancient but they are linked to the use of bronze tools.

The fixed mast, dowelling techniques,¹ the quarter rudder and the trapezoid sail appear to have spread eastwards into Indonesia from the Indian Ocean during the past 2000 years, since the initiation of trade through the Straits of Malacca. Before the arrival of western explorers these details spread no further than the early trade routes to the Philippines and New Guinea.

Theories that Austronesian rigs were derived from those of the Indian Ocean, or even from Egypt, are mistaken because the Austronesians had left Mainland Asia long before contacts spread eastwards. On the contrary, the westward spread of the Austronesian triangular sail into the Indian Ocean about 200 BC provides us with the probable origin of the Arab triangular lateen sail that spread into Egypt and even into the Mediterranean by late classical times, say AD 200. A thousand years later the Portuguese adopted the lateen on the mizzen masts of their caravels, enabling them to manoeuvre closer to the wind and reach the Pacific.

Although influences from the Indian Ocean were too late to influence the Pacific Austronesians, Sanskrit words and possibly some rigging techniques could have started to spread east of Peninsular Malaysia by 200 BC. Trade routes were also open between Vietnam and eastern Indonesia about 200 BC, as shown by the distribution of the Dong Son bronze drums along the natural sea route dictated by the monsoons in the South China and Java Seas. Recent excavations at Sembiran in Bali have also revealed evidence of drum casting and deposits of South Asian rouletted ware pottery, most likely dated before AD 200 (Ardika and Bellwood 1991). Annual trade between China and India through the Malacca Straits had opened by about 200 BC. Perhaps by that time Austronesian sailors were regularly carrying cloves and cinnamon to India and Sri Lanka, and perhaps even as far as the coast of Africa in boats with outriggers. Certainly they have left numerous traces in canoe design, rigs, outriggers and fishing techniques, and a mention in Greek literature (Christie 1957).

About 1300 years ago or less (Adelaar, this volume), Austronesian-speaking people from Indonesia reached Madagascar and some of the small islands off the east coast of Africa, at that time all apparently uninhabited. Although they later mixed with African Bantu people they preserved their languages and canoe styles. Whether they navigated in both directions in short stages along the coasts of Africa and South Asia, or directly across the Indian Ocean, is unknown, but both routes are probable. Not all the islands of the Indian Ocean were colonized; for example, the Mascarene group (remember how the dodo survived in seclusion there) and the Seychelles were not inhabited when occupied by the French in the seventeenth century, although they were known to explorers and pirates before that. The incomplete coverage suggests that the Malay wanderers did

not regularly cross the central Indian Ocean, where we find none of the folklore of navigation and voyaging that was abundant until recently among Pacific Islanders.

The Austronesian Contribution

Rafts, skin boats, dug-out canoes and particularly sewn boats were all clearly so widespread over Asia when archaeological and historical records began that they must predate the Austronesians. We might try to list the features of characteristic recent Austronesian boats and decide which ones can be considered as uniquely Austronesian.

The basis of all Austronesian boats, beyond the simple dug-out and the raft, is the lashed-lug construction technique, in which projecting perforated lugs are left in the dug-out base of the hull and on the additional planks which are sewn on to its sides (Figure 1). Thwarts and flexible ribs are lashed down to these lugs, so further compressing the planks added to the hull. The same lashing technique holds down the transverse booms for the outrigger and may well have originated for that purpose. The ends are each closed by a stem and stern piece carved from a fork which runs a little way along the sides of the hull. Early Austronesian boats did not necessarily have outriggers; excellent fishing boats and especially war-canoes with a single hull persist ethnographically in Botel Tobago and as the *mon* of the Solomons. This lashed-lug technique spread into the Pacific, sometimes with stitches through holes in the planks or through projections from the planks, and sometimes strengthened by bindings between projections on the inside of the planks. The seams could be packed with absorbent fibre that expanded when wet, sometimes the plank edges were polished to a perfect fit by rubbing them together, and sometimes the seams were overlaid by padded laths under the stitches. Until the curved metal chisel or other tools became available for drilling straight dowel holes, the joints were sewn and sealed with resin. This technique is widespread from Hawaii to Madagascar and throughout Micronesia, Polynesia and Indonesia. It was modified in only two ways; (a) by modernization; (b) by a different, probably very ancient, tradition of long thin canoes without outriggers in which men often stand to propel the boat along, e.g. Asian dragon boats, Asmat canoes and the boats incised on the sides of Dong Son drums.

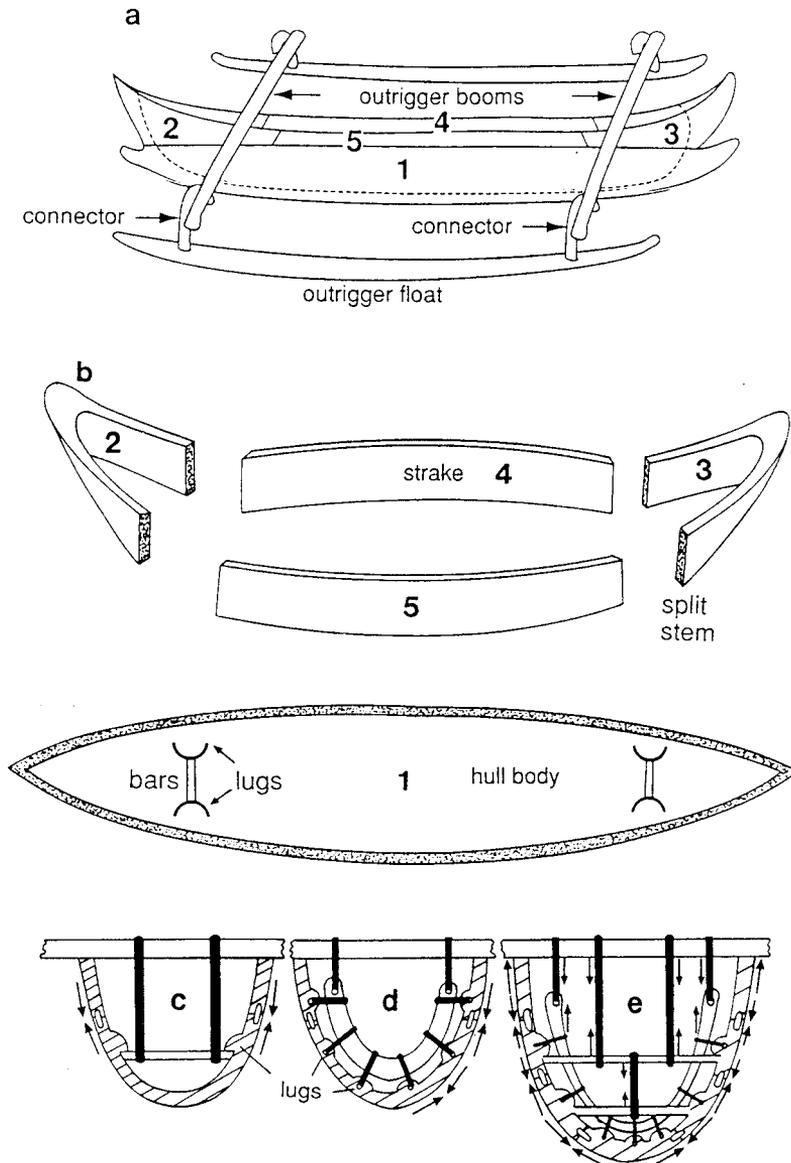


Figure 1. Basic construction of the Austronesian lashed-lug built-up outrigger canoe.

(a) The 5-part canoe; (b) exploded view of the upper hull; (c) (d) and (e) sections of hulls of increasing complexity.

(c) Downward compression; (d) arch compression; (e) combined downward and flexible rib construction. The details and variations on these themes were different for different island groups.

(The drawings are based on modern Indonesian canoes — the use of dowels is not a prehistoric feature, as indicated in the text.)

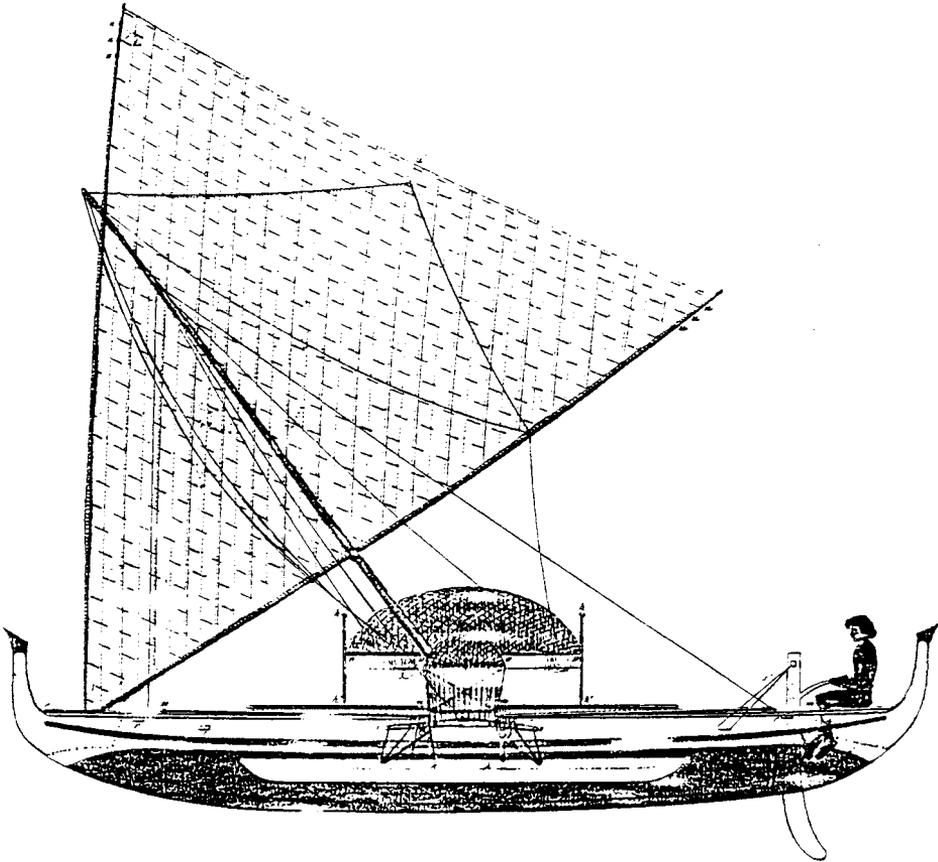


Figure 2. The rig of a single-outrigger travelling canoe of Satawal, Caroline Islands, from Pâris (1841).

The combination of single outrigger and triangular sail pushed up by a tilting pole (Horridge 1986:86) was unique to the Austronesians. The outrigger boom is connected to the float by vertical and oblique connector rods (Figure 1) that are hammered into the soft timber float. Together with the rig and the way of sailing a single-outrigger canoe with the outrigger float to windward, we observe that the Austronesians had a sailing machine with a combination of features that, once perfected, would always have to be built and sailed in the same way. The two-boom triangular sail (see Figure 2) is also unique to the Austronesians in its Austronesian form. This sail pivots on its point, can be tilted fore and aft to steer the boat (as on a windsurfer), is spread transversely across the boat to go downwind, and when the sheet is pulled in and towards the stern the boat is almost self-steering fairly close to the wind. There was therefore no need to invent the fixed rudder, and the sail can be pushed up with a movable prop so there was no need to invent the pulley or the fixed mast with fixed shrouds and stays. In fact, the rig does not allow shrouds and is therefore totally different in

principle from the rigs with fixed mast that might have spread eastwards much later from the Indian Ocean.

When we ask why the outrigger canoe plus tilting sail technology was evolved, there are so many interacting factors that the only quick answer seems to be that there was no other solution to all the simultaneous challenges that had to be met. This answer itself is sufficient to explain the remarkably conservative copying of the successful designs for generation after generation. Some of the numerous technical factors which make the technology appropriate are as follows:

1. Available natural materials are wood, which is good in compression, and plaited fibres such as rotan or palm fibre sennit which are good in tension.
2. Cellulose-based materials are essentially weak for construction and therefore loads must be distributed, avoiding stress concentrations. This consideration governed the whole design.
3. Cellulose-based materials rot and the whole boat has to be dismantled for replacement of parts and sometimes for drying out when temporarily not in use.
4. At sea the main engineering problem is to avoid fatigue fractures caused by the working of the waves and wind, especially if the outrigger is in the water. The solution was to use fibrous materials and to make the structure flexible, more like a basket chair than a rigid four-legged table.
5. As with an eggshell, the double curvature of the hull gives an unexpected bonus in strength and stiffness.
6. Without a pulley (which they did not have) the size of the sail is limited by its weight when wet and by the strength of the pole that pushes it up. To maximize the compression strength of the pole, it was free to pivot on its end so that lateral forces were all transferred to the stay in tension and there were no bending forces on the pole.
7. Planks swell in width when wet and the lashing fibre shrinks, so the lashed-lug construction tightened up at sea; compressing the planks together.

The basic principles of sewn and lashed-lug construction are remarkably homogeneous across the whole Austronesian range, except for subsequent influences that have spread eastwards from the Indian Ocean and as a result of the introduction of metal tools and pulleys into Indonesia and the Philippines in historic times. A significant detail is that traditional Pacific canoes had sewn seams with the internal lugs often taking the form of a raised ridge along the whole seam. In the Southeast Asian Archipelago sewing was replaced over the past 2000 years by edge-to-edge planking with internal dowels. Another detail is that Pacific traditional canoes have several short straight sticks hammered into the outrigger float to connect it to the outrigger boom. In contrast, in Indonesia several later designs of connector were adapted to the use of giant

bamboo for the floats. In the Southeast Asian Archipelago, except for Madura, the triangular rig gave way to the trapezoid sail on a fixed mast and this meant also the adoption of the fixed quarter rudder. The limit of spread of these technological changes corresponds well to the limit of spread of metal tools and other goods by traders from Asia. The conclusion is that there was little opportunity or reason for technological change in the Pacific after the basic design was taken east of Indonesia.

There are also social factors. Like a house or fish-trap, a boat is a shared structure from which many gain an advantage. In Austronesian communities, typically, every maritime village has its own boat design and they say that the details of construction have been handed down from their ancestors. The apprentices learn the exact way to build every detail and the conservative attitude is reinforced by memorized chants that must be repeated without error, and by universal belief that any deviation from tradition would cause a disaster at sea. Because the use of them is dangerous, boats are particularly conservative structures and all cultures adhere to their own proven designs. Rigs are more easily copied than hull structures (Horridge 1986). When changes in design are introduced they are not admitted. In consequence, boatbuilding techniques may survive unchanged for 1000 years or may be quickly modified in a single generation, as happens when designs are transferred from elsewhere. There is a negative side to this valuable conservation of the best available designs: inventions that are not immediately needed do not get invented, witness the pulley, the fixed rudder, the keel, the jib sail, the fixed mast or the multiple mast in the Pacific.

Sailing Conditions in the Pacific

Many early accounts describe canoes more than 15 m long carrying 30 to 50 people and a few larger ones carrying more than 100 people. Other reports mention the high speeds of lightly loaded canoes, about 10 knots with the wind on the beam. There are also many mentions of voyages of more than 800 km, and flotillas of many canoes. One of the critical details was the sealed hull, others the warm water, the availability of rain and the use of dried provisions for long journeys. Pâris (1841) mentions that breadfruit was fermented to make it sugary and then baked into hard cakes which kept indefinitely at sea. In the tropical Pacific, the flying fish leap into the boat at night, especially if an oil-nut can be lit to make a light, as modern voyagers describe. If we survey the whole of Polynesia, Micronesia and Melanesia, there are only a few areas that would have been out of reach of exploration with such boats as we know of, equipped as we know they could have been. Recently there have been successful reenactments of several of the voyages described in myths (Finney 1985; Irwin 1989). The difficult laps were on either side of Easter Island and to islands around New

Zealand, and yet people successfully reached even the Chatham Islands in prehistoric times.

Making use of periods of mixed winds (Finney 1985), a month's journey of exploration eastwards between 20°N and 20°S in the Pacific Ocean would easily cover about 1000 km. To be on the safe side a drift back downwind might take two months. Carbohydrate for three months for eight people would weigh about 300 kg, which is not an unreasonable load for a 12 m single-outrigger canoe. Double canoes would carry a tonne with ease, but because of the larger investment in construction labour they were more suitable for carrying family, plants, animals and cargo to places already discovered.

Voyaging was always seasonal, even when not forced by the winds, because the stars are seasonal. Charts of the tropical Pacific prepared for the days of sail show the trade winds blowing fairly strongly but not consistently all the year from the north-east to the north of the equator and from the south-east to the south of the equator. However, from October to June over the whole area of Melanesia and Polynesia to the south of the equator, from New Guinea to the Tuamotus, the winds blow from the north-east about as frequently as they do from the south-east. With normal trade winds the prevailing surface currents average 15 to 25 km per day (Figure 3) and can assist sailing downwind, but are not very significant for a boat that covers 50- 150 km per day. As far east as about Tonga, westerly winds accompany the cyclones in December to March. In Micronesia the winds are more consistently from the east or north-east and cyclones are less predictable. In Cook's account of Tahiti, Tupaia said that his people knew very well how to make use of the westerly winds (Lewis 1972: 297). In Polynesia, westerlies are more likely in December and January. Bearing all this in mind, the obvious time to set out eastwards into the unknown would have been the beginning of December, starting with a westerly wind, and always with the expectation of an easy return home.

Voyages by outrigger canoe would ultimately have been limited by the sea-water surface temperature. Apart from New Zealand, the Austronesian colonization was all within the isotherm of 21°C (70°F) in the warmest season. The Austronesian agricultural crops were mostly limited to this zone, and in New Zealand different storage methods and crops, such as hardy varieties of sweet potato, were used at the limits imposed by cold. The whole culture — plants, housing, dress, boat design and aquatic lifestyle — was adapted to the warm terrestrial climate.

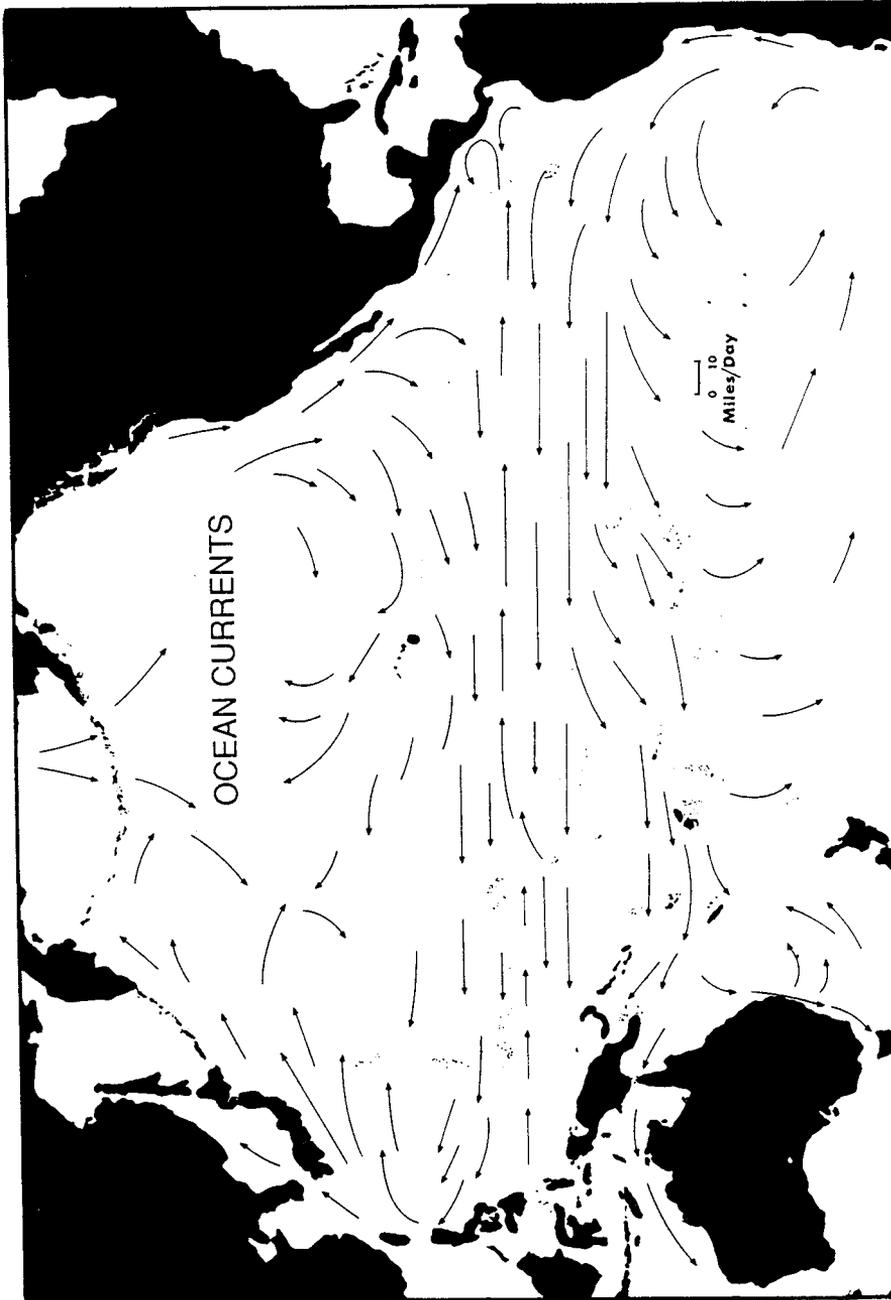


Figure 3. Drift currents in the Pacific with the length of each arrow indicating velocity in nautical miles per day. (1 km approx. = 0.625 nautical mile). Seasonal differences (given by Lewis 1972:102) are small.

Boat size was not a problem, as large canoes of 25 m long could carry 30 or 50 people plus cargo. Speed was not a problem either as the small single outrigger canoes (the flying proas of Micronesia) could do up to 20 knots but were limited to a few weeks sailing. The problem was that such speeds would quickly smash up a large canoe in a heavy sea because the construction materials could not stand the repeated stresses. The upper limit was set by the scale effect acting on the limits of the materials, as for wooden aircraft, windmills and all similar structures. The best compromise seems to have been the travelling canoe of medium size, large enough for one or two families.

The Seaways Were Open, Once Explored

For the end of the 18th century, when the major Western explorations and descriptions had been completed but the local traditions were not destroyed, we have firm accounts from most parts of the Pacific. When these are brought together they reveal an open seaway in a series of separate stages from Indonesia and the Philippines to the extreme east of Polynesia, and north/south to Hawaii and New Zealand. Lewis (1972) pointed out that almost all the Pacific islands can be reached by sea crossings of no more than 500 km, and his analysis of navigation methods shows that planned passages could be much longer. Information about inter-island movement and trade has been summarized from old accounts for each area by Haddon and Hornell (1936-38), along with sizes of boats, performance and numbers of people carried. Many of the same data, and new material, are given by Lewis (1972).

Let us start with the Palau (Belau) Islands, a group 100 km across, only about six days sailing by local canoe from Mindanao in the Philippines. The long-distance *kaep* canoes for travel within the group were single-outriggers up to 10 m long. Stone money was carried regularly from Palau to Yap, and there is a tradition that *trepan* was taken to Chinese merchants in the Philippines. There were Micronesian colonies on Tobi and Sonsorol, almost in the Moluccas, and traditions of voyages southwards to the coast of New Guinea and of raiding parties coming the other way. All the island groups of Micronesia had regular trade, visits or wars within the main groups, with many traditions of war parties venturing further afield. From Palau there was a continuous route for trade and war through the Carolines past Puluwat, then from Kosrae to Jaluit in the Marshall Islands, then to Tarawa in Kiribati (Gilbert Islands), each stage with a slightly different type of double-ended long-distance single-outrigger canoe (Haddon and Hornell 1936-38, I:439, quoting Hambruch). The Marshall Islanders raided other islands from Kosrae in the west to the Ellice Islands (Tuvalu) in the south (Haddon and Hornell 1936-38, I:439). There was no longer a tradition of exploration, but instead there were extremely well-organized schools of navigators who learned the inter-island routes and the seasons for travel. The large single-outrigger canoes sail more safely into the wind than downwind, but

go fastest and most steadily with the wind on the beam. In the Carolines the *popo* canoes ran regular passenger routes (mainly north and south) over a total range of 3000 km and every year parties of them visited the Marianas (Haddon and Hornell 1936-38, I:438, from an account of the Freycinet voyage). It is an interesting detail that in Micronesia the navigation classes for learning star tracks were conducted on the beaches facing *east* to mark the rise of the stars (Haddon and Hornell 1936-38, I:439).

Another route to the south lay along the island chain past New Ireland and the Solomons to the Santa Cruz islands, to Fiji and on to Tonga. The boats here were more solid single outriggers. From Tonga the route continued into Polynesia to Samoa, thence to Tahiti, from where there were routes in all directions, eastwards to the Tuamotus and thence to the Marquesas, northwards to Hawaii, south to the Cook Islands. From Tonga and Samoa there were traditions of raiding parties to the Santa Cruz islands, carrying Polynesian populations to the Polynesian Outliers such as Tikopia. There is a tradition that many generations ago there were voyages between Tahiti and Hawaii, and between Rarotonga and the Marquesas. Tangi'ia-nui was a great voyager who claimed to be familiar with island groups from Fiji to Easter Island and who ended his life in Rarotonga. Tupaia, the Raiatean high priest friend of Cook, knew of many islands in the Australs, Societies, Cooks, Tuamotus, and westwards as far as Fiji. According to some Maori traditions, Kupe from Tahiti discovered New Zealand about the 10th century. Toi and Whatonga followed 8-10 generations later and then Nuku sailed there via Rarotonga with four canoes. For a while, mainly in the early nineteenth century, until they disappeared, these canoe journeys persisted within the island groups in the central and eastern Pacific, and a few survived into the twentieth century (Lewis 1972).

The voyages we learn about in Polynesian traditional myths were different from those of Micronesia, being less frequent, over longer distances, and related to the original exploration rather than to regular routes. The Polynesian longdistance vessel was the double canoe in which a voyage would be more likely to carry plants, seeds, women and animals, so requiring more time and expense to prepare. The only surviving and regular long-distance inter-island trade that we know of from eighteenth and early nineteenth century accounts of Polynesia occurred in the Societies and Tuamotus in eastern Polynesia and in the Fiji-Tonga-Samoa triangle in western Polynesia.

Thor Heyerdahl, Going Westward

The maps of currents (Figure 3) and winds of the Pacific Ocean show the trade winds that blow from east to west over the area of warm water encompassing most of the Pacific Islands, and steady currents of 8 to 35 km per day that flow in the same direction. Driftwood, rafts and square-rigged ships have been moved on these currents, witness the Kon-Tiki balsa raft (Heyerdahl 1978:185). In 1913,

the *Dagonar*, a derelict sailing ship, took only 170 days to go 8000 km from Peru to the Tuamotus in this current (Hornell 1945). Heyerdahl's basic premise was that early boats *followed* winds and currents, but he thought only of rafts and reed boats. Rafts and reed boats were known world-wide in Neolithic times so people could have drifted eventually to many unlikely places, and perhaps from Peru to Polynesia. Easter Island was known to the Incas and archaeological remains there strongly suggest that some aspects of South American culture and plants spread there, and perhaps into other parts of eastern Polynesia as well (Heyerdahl 1978). Probably the Asiatic chicken was taken to Ecuador via Polynesia, and the South American sweet potato, some cotton, gourds, and other plants travelled westwards by balsa raft into Polynesia. The arguments have raged for years but the evidence for transport in both directions before AD 1500 gets firmer every decade. Drifting downwind on an inefficient boat, however, is an inefficient way to colonize new islands because there is no return (Irwin 1992).

Just drifting in the Kuro Siwo current from Japan to the northwest coast of America takes 3-4 months, and many Japanese fishermen have survived this journey over the past few centuries (Hornell 1945). There are Japanese words in the coastal dialects of the northwest American Indians and ancient planked boats of Austronesian type on the islands off the coast of California. The current continues southwards along the Californian coast almost to the equator. One of the most controversial archaeological records is the discovery of the Valdivia complex on the coast of Ecuador, with pottery dated about 3200 BC resembling that in northeast Asia at that time (Estrada and Meggers 1961). In my view, this Pacific crossing was possible as a way of no return, and therefore unattractive, but some plants, the chicken (Langdon 1989) and craftsmen skills may have travelled this way. As a branch on this line, the current turns westward well out to sea off the coast of Oregon and regularly brought pine logs from the northwest American coast to Hawaii where they were stored and used for building large canoes. Possibly people also went that way occasionally, long before the Austronesians moved into Polynesia.

Rafts were known in the Marianas, Yap, Fiji and Melanesia when Western explorers arrived. There was a persistent tradition of sea-going sailing rafts in Tonga, there were transport rafts in Mangareva, and in New Zealand there were reed boats 18 m long made of bulrushes and flax. Bamboo rafts were commonly used in Japan, Taiwan and Indonesia, some with steering by fore and aft centre boards as in South America. Rafts were Neolithic if not older and perhaps humans are today all members of one species because gene-pools were continually mixed by raft crews.

Exploration Was Upwind

Sufficiency has been said to demonstrate that in the Pacific, *once the way was known*, there were sufficient travellers. Maybe a voyage was not repeated for a century or so, but so long as the route by wave patterns and stars was remembered by the traditions in the schools of navigators, the way was open. It was fear of people, not fear of the sea, that kept the canoes near home.

Let us now consider the exploration of the unknown with the available boats. For much of the year, the winds anywhere in the Pacific came from the direction of unknown islands, so that flotsam would float ashore *proving that more land lay to windward*. The earliest Austronesian colonists in the Pacific were in the situation of the Vikings on the coast of Norway, the Portuguese and later the English and the Dutch, faced by the prevailing south-west winds of the Atlantic. The situation creates a continual stimulus for sailors. In periods when the winds are reversed you can sail out to sea if you are confident that you will be blown back near home, or past home to islands downwind from home. Irwin (1989, 1992) deals with the questions of accessibility and winds in great detail, and stresses that the known art of latitude sailing fits well into a pattern of progressive exploration eastwards with a carefully remembered return at each stage. The only condition is that you have seaworthy boats that sail reasonably well to windward, or even poorly to windward if time is not pressing. You can spend time, maybe centuries, improving your boats and ability to survive at sea. Even in the early exploration phase, colonists must have had fast watertight boats to carry food, plant shoots and seeds.

When we look at the large Micronesian single-outrigger canoes of historical times (see cover photograph), we notice the triangular sail, the outrigger construction, the double-ended arrangement for tacking, the deep well and sealed hulls for safety at sea, and the high speed when travelling light on the best point of sailing. Anson (1740-4), quoted by Haddon and Hornell (1936-38, I:415), noted that the single outriggers of the Marianas were “designed to sail as close as possible to the wind”, and “by the flatness of their lee side they lie much closer to the wind than any other vessel known, and have the advantage of being able to go faster than the wind, like the sails of a windmill.” He gave the speed as 20 knots for a hull of 12 metres. Lewis (1972:269) gives the average performance of a single outrigger as 75°-80° off the trade wind. Pâris (1841) described how the single outriggers of the Carolines sailed best when close to the wind and that otherwise they had difficulty in staying on course, even with the wind on the quarter. Pâris also reported that the double canoe of Tonga (the *kalia*) sailed badly with the wind behind, and the Tongan single outrigger (the *hamatafua*) was difficult to handle with the wind at the side or behind but easy when sailing as close to the wind as possible. Basically the triangular sail pivoted on a universal joint and behaved like that of a windsurfer, self-steering when

balanced on the wind, but the hull sailed closer to the wind than a windsurfer because it gripped the water. The modern windsurfer gives some idea of the performance of a triangular sail on a flat hull; a canoe with the lee side flattened must have been an improvement on a windsurfer, if the materials could withstand the stresses.

Downwind from an undiscovered island there is a scent of land and an interference pattern of the wind-created waves converging behind the island, besides flotsam on the surface, as numerous sailors have described. Therefore Nature assists by providing clues of land on the approach side of the island exactly where they are needed. In contrast, remember how Heyerdahl's Kon-Tiki raft (with a square sail) ended its journey by crashing helplessly on the windward side of a reef. That is not the way to explore or colonize. Sensible seamen approach land upwind and lay-off until they find a calm landing, as you could certainly do in an outrigger canoe with a tilting triangular sail. Those hypothetical younger sons of chiefs, looking for new land, had to sail eastwards because that is the direction their boats would naturally take them on the least foolhardy explorations with expectation of safe return. Let me add that, apart from the early explorers, who saw Pacific craft first-hand, it has been the smallboat sailors, notably Lewis (1972), Finney (1985) and Irwin (1989, 1992), who have the correct interpretation of Pacific sailing and colonization.

Conclusion

The problem of how the Pacific was colonized against prevailing winds and currents is solved if we accept that the earliest path-finders had boats of similar design to the fast, long-distance single-outrigger with a tilting triangular sail, because these boats sail best a little upwind or with the wind on the beam. They must have had these outrigger canoes, otherwise they could never have made exploration probes and then colonized, and exploration is an easier proposition than subsequent colonization. For several reasons, the natural way to go is eastwards with the aid of occasional westerly winds.

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Notes

¹ Dowelling was used for carpentry joins as early as 5000 BC in China (Chang 1986:211, for the Neolithic site of Hemudu), but there is no evidence that the technique was used in boatbuilding.