Canoes of the Grand Ocean

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Chapter V

Origins and Relationships of Pacific Canoes and Rigs

by
Adrian Horridge*

Although the origins of the basic structures and rigs are lost in the prehistoric past, a survey of a wide variety of examples and their known history shows that Pacific outrigger canoes were originally as homogeneous as the Austronesian people, but later they were influenced by readily recognizable introduced technology. The earliest transport was probably a raft of large bamboo stems, with a rig consisting of a two-boom triangular plaited mat sail supported on a loose prop, as survived into modern times in several places. The canoe hull evolved from a dug-out tree trunk, to which side planks and stem and stern pieces were sewn. The interaction between the raft and the dug-out produced the outrigger canoes and the double canoes that made possible the Austronesian conquest of the Pacific. Outrigger booms placed across the hull of the enlarged canoe were lashed down to pierced lugs that were left projecting in the bottom of the hull. When large trees were not available, this technique could bind together a plank boat made of drift wood. Limited by beliefs in magic and ancestors, besides engineering constraints, designs were extremely conservative, but the spread of cultivated seeds and roots was rapid and widespread and the social organizations became diversified.

In the west Pacific, the influence of the Chinese was negligible, but from the Indian Ocean the stern rudder, the mast fixed in a thwart and the tilted rectangular cloth sail spread eastwards before 800 AD. From about 200 BC, the Austronesian triangular sail spread westwards across the Indian Ocean and became the lateen, which continued to the Mediterranean and eventually to Portugal by the 14th century. Spanish sailors shipwrecked in the Tuamotus in 1526 AD account for planked hulls with solid stiff ribs, a fixed mast with stays, a fore-and-aft tacking rig, a rudder mounted on a pin, and other European details in eastern Polynesia. Recently, European influences replaced or heavily overlaid the Austronesian designs all over the Pacific.

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The constraints

The Austronesians left no written history of their origins and so our conclusions must be drawn from a wide variety of other evidence. Much of the argument depends on their achievement in transporting people and agriculture over great distances and the natural constraints for a hull or rig to survive at sea. The essential considerations that appear repeatedly throughout this account are the climate and prevailing winds; water temperature; surf, coral reefs or mud; the availability of food and fresh water on coral islands and at sea; availability of timber, fibre and material for tools; design in relation to stresses; strength and fatigue fracture of materials; the compromises relating to the scale effect of the size of the canoes; decay and replacement of parts; and the different requirements for fishing, fighting, exploration, or colonization. These constraints effectively determined the designs of rigs and hulls, the directions and distances sailed, and which designs of hulls, rigs and sails would survive. Each deserves a more comprehensive treatment than is possible here.

A warning

There are several accounts that describe the details, distribution and uses of the outrigger canoes and other indigenous boats of the Pacific region. Dodd (1972) gives a very sympathetic account of Polynesian canoes with excerpts from the original accounts of individual explorers and missionaries, an extensive bibliography, and numerous illustrations. My diagrams illustrate only the principles that I wish to explain. The most comprehensive reference books are by Haddon and Hornell (1975) and Neyret (1974). There you will find most of the factual data about the boats that was collected, without having to search the numerous primary sources. They were compilers, however, and their interpretations of origins and relationships are now highly suspect because they made conclusions from the data that was available at the time, mainly from the boats themselves. Others, notably Needham, Bowen, Doran, also have faulty interpretations of the evolution of the structures and rigs. Still others, notably Best, Buck, Holmes, Horridge, Malinowski, refer to local regions. There are other essential references to special periods or topics, notably Bellwood on the history, Lewis on navigation, Buck and Emory on cultures, Dodd (based on Cook's artists) and Pâris for old illustrations. There are other large and scattered topics where more research is needed, mainly on experimental sailing, ancient weather, local vocabularies for boat parts, and the genetics of domesticated plants, animals and men[1].

[1] In this brief and crowded account, I can do little more than draw attention to the main trends.

The beginning

Java was inhabited by some of the earliest hominids, who were probably not sailors; they came from Africa but we know nothing about their transport. One puzzle is that for 500,000 years early man occupied Java, and presumably much of coastal south east Asia, now flooded, but apparently traveled no further for a long time. The first boats were probably of reed bundles, as used for millennia on the Indian Ocean and surviving into the 19th century in Tasmania, New Zealand and the Chatham Is. There were easy crossings all the way to Australia, especially via New Guinea at times of minimum sea level. The first colonists reached Australia more than 50,000 years ago, and later made bark canoes.

Stone tools suitable to make dug-out canoes have not been found older than about 20,000 years. Therefore the earlier occupation of Australia and Island South East Asia as far as the Solomon Islands was almost certainly made with rafts. Bamboo was abundant in S.E. Asia, can be cut without an adze and is readily bound together with rotan to make large rafts that are seaworthy for months but not years. At least two attempts to sail rafts with the northern current from Asia to America have been almost successful in recent times[2].

Living along the tropical coasts is a healthy life style free from malaria, with abundant food, and anyone can see today that the coastal villages are not short of children. A long period with raft transport allows enough millennia for the first inhabitants to develop tropical gardens, the uses of local plants, pig husbandry, fishing techniques, and other crafts in use today in New Guinea, and to grow in numbers. Then, the great shrinking of the land area of the Sunda Shelf caused progressive flooding of coastal lands[3] that must have forced the pre-Austronesian people to move repeatedly. Until they developed tools to build dug-outs, they must have traveled by raft.

We might ask what made the Austronesians migrate through Island South East Asia, when we know that most of today's Austronesian cultures there are sedentary. First, they were driven from behind by population growth on the mainland of Asia that accompanied the earliest Chinese (Han) agricultural revolution about 8,000 years ago. Secondly, like the Celts who moved into Europe, the Romans into Gaul, or the Vikings to Scotland, they had a technology superior to that of the indigenous inhabitants. They brought agriculture based on millet, rice, taro and other robust foods that could be dried and stored for long periods. As inferred from root words held in common in many branches of their languages, the earliest Austronesians were sufficiently skilled to make pottery, to weave, to transport useful plants, had sufficient astronomy to navigate, and probably were themselves immune to diseases that were lethal to the indigenous islanders. Once under way, they discovered the bonus of discovering pristine islands with sea bird colonies, turtles and dugong that provided easy new food supplies, most of which were soon eaten so they had to move on.

How long rafts had been in use in the region of the Sunda Shelf no-one can now say, but the short and recent time scale of the rapid Austronesian expansion was insufficient for the development of a complete new tropical agriculture and marine technology. Almost certainly, during this period the triangular sail was a mat that was heavy when wet, so it was supported by 2-booms, pushed up with a loose prop because they had no pulley, and the prop was held up with a stay on the windward side. Probably this was not an Austronesian invention, but it was an early solution to the problem of raising a heavy, wet and therefore weak mat sail on a raft. On Mangareva in E. Polynesia, Beechey found a raft with this rig carrying large numbers of people in 1826 (Haddon and Hornell, 1936 vol. 1: 93, fig. 64). The balsa wood rafts of the Peruvian coast were similar and probably of Asiatic or Austronesian origin.

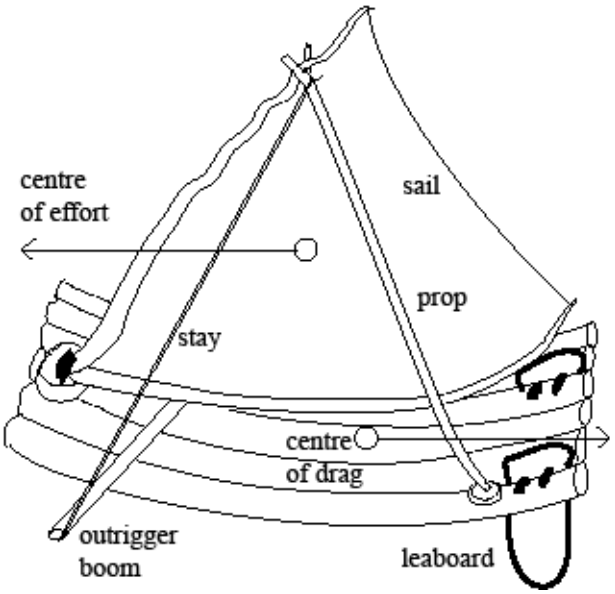


Figure 1. A primitive sailing raft before the stone adze was available to make a dugout canoe. The rig is the two-boom triangular sail supported on a loose prop and held up by a rope on the windward side. The hull could have been of logs or bamboo lashed together. The leaboards adjust the course, which is steady when the centre of effort of the sail is ahead of, and in line with, the centre of drag. Plenty of such rafts have sailed in historic times.

A survey of the sailing rafts in use in historic times reveals a standard construction but a variety of rigs. The

[2] Bisschop (1959) and Tim Severin (1994), the latter with a Vietnamese ghe bè; Piétri (1949:89).
[3] Bellwood (1978:422). Three million square kilometres of land was lost between 14,000 and 7,000 years ago.

hull was slightly curved up at the ends; the poles were lashed with rotan to cross pieces; they were put on a course by vertical dagger boards that were moved to bring the centre of drag behind and in line with the centre of pull of the sail (Fig. 1). The *tak pai* of Taiwan[4] had a square sail (Fig. 23E); the balsa rafts of the Peruvian coasts (Johnstone,1980:224-228) used a two-boom triangular sail: the bamboo rafts (ghe bè) of Haiphong Bay, Vietnam (Piétri 1949:89), used a cotton lug sail (Fig. 23X) or the low rounded junk sail of the southern Chinese. Rafts in Fiji and Santa Cruz (Neyret 1974:48,81; Haddon and Hornell 1936: vol.1:30) and Mangareva (Gambier Is.) (Haddon and Hornell 1936: vol.1:9) had the local mastless two-boom triangular mat sail (Fig. 1).

The Austronesians

Non-Austronesian languages from earlier periods persist in Timor, Papua-New Guinea, parts of Halmahera, and of course Australia[5]. The Austronesians are defined as the speakers of a particular family of languages, with their own set of crafts, myths, taro, beaten tapa bark for cloth, breadfruit, sugar cane, banana, and other agricultural plants[6], house designs, weaving, pottery[7], an artistic style of carving and of tattoo[8], who spread into the region of Taiwan (Bellwood *et al*. 1995: chapt. 5) about 4,000 years ago, then southwards to the Philippines and Indonesia. The most primitive of the surviving Austronesian languages are thought to be those of central Taiwan. They replaced older Australoid peoples related to Papuans and Australian aborigines. Their present distribution is almost identical with that of the outrigger sailing canoe, but not all Austronesian canoes have outriggers.

They carried with them a common theme in Austronesian art that can be traced from the earliest bronze castings (Heine Geldern 1932) of the Zhang dynasty of China, 3,200 years ago, which themselves were based on earlier wood carvings. The double spiral and other motifs can still be seen in the decorations on houses and canoes, on body tattoo and wood carving of the Maoris, and as far east as the Marquesa Is[9]. Their pottery was not made on a wheel but by beating the clay while holding a smooth round stone within the pot. When sand is mixed with the clay, such pots can be used for cooking. The earliest pottery, in the Santa Cruz Is. and Fiji, is dated 1300-1500 BC. These pots were decorated in a simple geometric style, and have been found in a long arc eastwards from the Solomon Is. Examples are still made in the Kai Is (Lat. 6º S; Long. 133º E), but the Polynesians lost the art of making them.

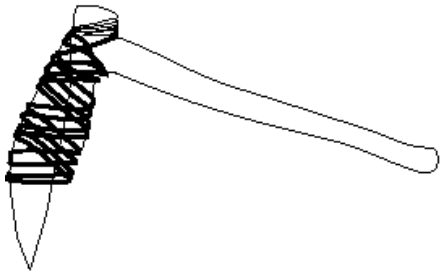


Figure 2. The adze with a bent haft, a suitable tool for making a dug-out canoe and carving flat planks. The binding tightens as it is used.

The Austronesians diversified into the individually isolated and distinct highland cultures of central Taiwan, Luzon, Borneo, Java, Sumatra, Nias, Sulawesi, Flores, and Sumba. The Chams of the Vietnamese coast were Austronesians. Wood from Sumatra drifts naturally to the coast of Madagascar, which was first reached by Indonesians about 200 BC, probably associated with the direct transport of cinnamon to the coast of Africa (Miller 1969: chapt. 8). Later groups followed over a period of 1,000 years.

The Austronesians who moved eastward had a stone tool industry, their adze had a characteristic bent haft (Fig. 2), a style of building houses and rat-proof granaries that originated in Asia, together with weaving, food grinding, unglazed pottery not made on a wheel, agriculture with millet and later rice, bark cloth of *tapa*, large stone megaliths, genealogy and ancestor worship, customs concerning wife giving, pigs, chickens, dogs and taro. Later, the inland Indonesian peoples were not much interested in boats or the sea, although they retained myths about their own origins from over the sea, and frequently they echoed boat structures in their coffins or house styles. Examples are the boat coffins in Sulawesi and Sumba, the council platform like a stone boat at Sangli Dol on the east coast of Tanimbar (Lat. 7º 51' S, Long. 131º 21' E), and the boat terminology for the parts of the house in Sumba. Maritime villages dependent on fishing or trade developed less on coasts that were liable to be inundated by tsunamis, a precaution that has been ignored in modern times.

One or more groups of these Austronesians went island-hopping eastwards against the prevailing winds and currents. Avoiding malaria and lands already occupied, they passed to the north of New Guinea, and colonized

[4] Nishimura (1925). There is a copy in the library, Nat, Marit. Mus. Greenwich, London.

[5] For numerous cultures of S.E Asia and the Archipelago before the Austronesians, see Bellwood (1978: chapt. 3).

[6] See Barrau (1963); Horridge (1985: 2nd Ed.:100, Appendix 1).

[7] Spriggs, M. in Bellwood *et al*., (1995). For dates of Lapita pottery, see Green in Jennings (1979:33).

[8] See http://www.hawaii.gov/hidocs/tattooing.htmlef for references to tattoo.

[9] For Marquesan tattoo patterns, see http://wiki.bmezine.com/index.php/Marquesas Islands.

island after island, working eastwards, making many island bird populations extinct as they went. Eventually they became the Polynesians and also contributed to the stock of Melanesia and Micronesia. Most languages of the Solomon Is. are Austronesian, but dark colour and fuzzy hair are not Polynesian traits. With an interesting exception close to Taiwan and others in the Solomon Is., the Austronesian boats were dug-out canoes with one outrigger on the windward side, or double canoes. The details of the designs were adapted to sailing among shallow reefs in warm seas without harbours. For their over-water migrations they relied on larger outrigger canoes that carried families, fire and agricultural supplies. All branches of these migrations used boats based on the five part hull, the two-boom triangular sail with the mastless tilting rig with no pulley and no fixed rudder (see below), or later modifications of these. Eventually they reached the islands of the Eastern Pacific, and coastal South America[10]. They took with them the Asiatic chicken, and there is considerable discussion as to whether they took a few useful plants to America and brought others back into Polynesia[11].

At first, travelling eastwards through the region of the annually reversing monsoon winds near Asia was easy. The first major hurdle was the stretch of 900 km (550 miles) of open water between Vanuatu (New Hebrides) and Fiji against the prevailing wind. This is exactly the right situation to encourage the bold to experiment with new types of rig and boat, because explorers could see flotsam coming from land upwind and could expect to return home again downwind.

Accounts of raft journeys on the open ocean show that they could no longer use rafts. Most of the cultivated plants had to be carried as shoots or roots because they were propagated vegetatively, but they can be damaged by sea water. To carry families and plants, they probably had to wait for the development of the large double canoe, 30 m long, which could carry 100 people or several tons of cargo[12]. Weaving and pottery were eventually lost because the raw materials were lacking. Plaited pandanus leaves, split rushes or palm leaves, coconut fibre, and beaten *tapa* bark, were substitutes for woven fabric. They also developed techniques for making cooked, fermented and dried breadfruit, a sugary nutritious food that keeps for long periods at sea, ways of carrying fire, seeds and living shoots out of contact with sea-water, and numerous techniques for fishing and sewing (Best 1925: 122 and onwards; Buck 1957; Haddon and Hornell 1975:191). They made rope and string by plaiting sennet. They carried with them the chicken, dog, pig and a long list of plants from Asia that reached Tahiti before 1770, including taro, yam varieties, pandanus varieties, hibiscus, sugar cane varieties, breadfruit, banana varieties, gourds, the *Abrus* bead, fish poisons *Barringtonia* and *Wikstroemia*, the *tapa* tree (*Broussonetia*), ratans, coconut, a *Piper* species for making kava, the Tahitian chestnut (*Inocarpus*), medicinal plants such as *Urenia* and the dapdap tree (*Erythrina variegata*), the oil nut (*Hernandia*) and the putty nut tree (*Parinarium*). Bamboo roots, sago roots, betel nut with associated *Piper betle,* and rami fibre (*Boehmeria*) were transported from Asia as far as Melanesia. All these must be kept out of salt water. Following each step in the eastward colonizations, there must have been many return trips to fetch these plants, and the enormous feat of transportation reveals the quality of the boats.

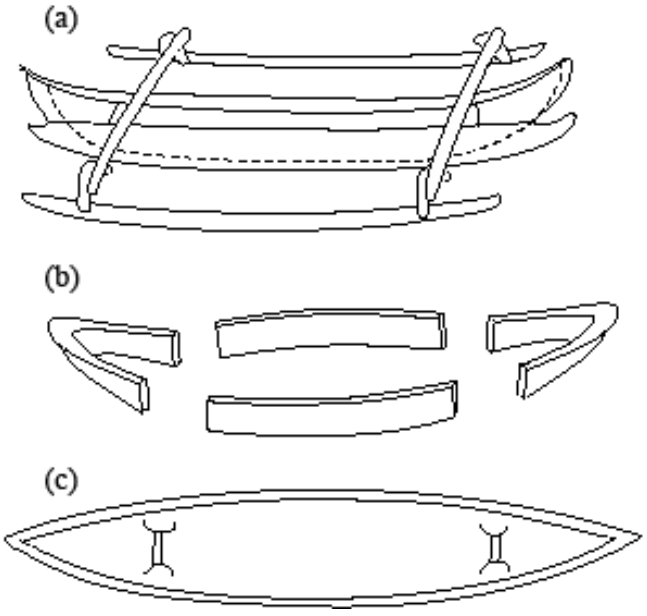


Figure 3. The five part canoe. (a) Double outrigger type. (b) The stem and stern pieces and the two planks. (c) The hull, showing spreaders fitted under lugs.

The 5-part canoe

The designs of the canoe hulls were fundamentally conservative although very diverse in detail. The Austronesian cultures revered the ancestors, or the founders of the village, and they believed people returned in a cycle after death in different flesh and bones. In the same way, the canoes never perished; they were the same canoes as the ancestral ones but made from different trees. There were other factors at work in the preservation

[10] See note 17, and earlier work by Doran and by Jett, S.C. in Riley *et al*. (1971).
[11] Barrau (1963); Bellwood (1978); Langdon (1989). The problems are the sweet potato, maize, and cotton going westwards; the banana, coconut, pottery and adze styles going eastwards, and bottle gourds from Africa. See note 17.
[12] Fijian *ndrua*; See Haddon and Hornell 1975:319.

of designs, the fear of making a fatal change, the fear of being accused of witchcraft to take advantage of neighbours, the secrecy of the boatbuilding guild, and their long detailed training in which every detail of the technology was memorized.

Design by proportions

The base of the dug-out canoe hull was hollowed from a single log, that was built up with planks in various designs in different parts of the Pacific. Where large trees were not available, irregular shaped planks were carefully carved from driftwood, fitted and sewn together.

The main hull had the sides raised by an additional plank on each side, and forked stem and stern pieces were added at the ends. This basic five-part canoe (Fig. 3) was almost identical in design from Madagascar, through Indonesia and the Pacific to Tahiti and Hawai'i. The preferred timber was *Calophyllum inophyllum*[13], a widespread tree that occurs near the shore wherever Austronesian people colonized. Tourists sit in its shade along the beaches of Bali and Fiji. Other timbers were magnolia, jackfruit, breadfruit or several hardwood trees that were abundant in high islands. Outrigger floats were made from the light wood of a common garden tree, *Erythrina*, of which a very widespread species was found in Tahiti by Cook's botanists.

Every step in the construction was bound by traditions that were learned by heart and supported by myths. The dug-out hull or the keel is the female part of the canoe; the forked stem piece is the male part. The two were fitted together in a marriage ceremony that persists today in some Indonesian cultures, especially Balinese (Horridge, 1979), Buginese (Horridge, 1987) and Makassarese, called the *kawinan* ceremony. A tiny piece of gold, or a paper bearing the name of the canoe or ship, is placed in the mortice in the female part before the tenon on the stem part is inserted. Unfortunately, similar ceremonies that must have been customary in Polynesia have been lost or not yet revealed.

In Austronesian cultures the traditional units of measurement were taken from the dimensions of the human body, and related ideas of perfect ratios originated in ancient India. The traditional boats, like the houses, are still built following a system of numbers that give the proportions of every component (Horridge 1987: fig. 8b). The trolling juking of the Straits of Lombok measure 3 fathoms (*depa*) and three hands between the inside of the ends. The *depa* is the span of the arms of the canoe builder, officially 1.7 metres. The thickness of the hull sides and bottom are carefully measured by using a stick as a depth gauge. The internal hull length is divided into 6 equal lengths of x centimetres, which is usually 100 cm in South Bali. The front surface of the mast is placed x cm back from the inside edge of the bows. The length of the mast is 2x+10 cm and the stern outrigger boom is x/2 from the inside end of the stern. This proportional system enables the boatbuilder to build to any desired size, depending on the basic unit. As well as the builder's own body measurements, an appropriate bamboo stick with equally spaced nodes acted as a measuring stick. In Bali, following the small asymmetry in the human body, the forward outrigger boom is always 4 or 5 cm longer on the left side. The total length of the front outrigger boom is equal to the distance between the two booms, and so on for all measurements. There was no concept of hydrodynamic efficiency, but each village has its own style, with slight differences, so there were improvements by trial and error.

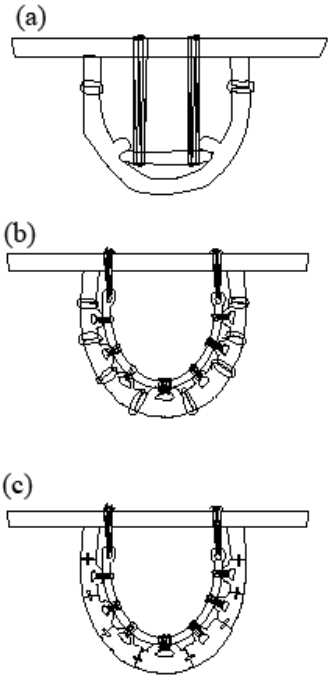


Figure 4. Attachment of the superstructure to the hull. (a) in a 5-part canoe, (b) in a sewn planked canoe, (c) ditto, with dowels between the planks. Dowels were not used until a suitable iron drill became available.

The traditional method of holding the boat together was to put the hull into compression like an inverted arch by tightening the lashings between a thwart and the flexible ribs lashed to projecting lugs (Horridge, 1982) on the inside of the hull. Small cross bars (called spreaders) were fitted inside the hull in many cultures (Fig. 4). The outrigger booms must be lashed down very firmly. The lashings were of non-extensible rotan or other vines that tightened up when wet. We can now see that the hull of the 5-part canoe lends itself naturally to the design of the outrigger attachments, because the cross piece that clamps down the side planks was extended as the

[13] *Calophyllum*: a genus of tropical trees useful for timber, oil and medicine. See Burkill (1966).

outrigger boom (Figs. 3, 4). The whole structure was readily dismantled for repairs.

Inshore fishing canoes had the outrigger booms lashed over an open hull. Some offshore travelling canoes had the hull sealed with dammar-type resin and with pounded putty nut, which was extremely resistant (Pâris 1843: plates 114, 118). Their superstructures were raised above the waves on a waterproof rectangular box with a hatch so that goods could be kept dry inside. A platform between the outrigger boom and the hull was extended on the leeward side to accommodate passengers, often in a small shelter (Figs 5, 6). Big double canoes also had a central raised platform. Exact designs varied (Haddon and Hornell 1936-38; Neyret 1974) but the same principles were observed over huge areas and time.

In the Pacific generally, all sea-going canoes had a single outrigger on the windward side or a second hull. The second smaller hull was given the same name, *kata* or *katir*, as the outrigger float. The double outrigger canoe (Figs. 7, 8), with both floats in the water at all times, is specialized for inshore fishing, limited in size and not suitable for travelling in the open ocean. Even with superior materials, a modern family-size trimaran is a dangerous boat in a storm. Sewn boats appear to have been the rule until iron tools made it possible to insert strong dowels between the planks, and even then sewing with coir persists in the Indian Ocean. All components were lashed or stitched together, and sewn joints between planks were sealed with resin or the pounded nuts of the putty-nut tree (*Parinarium glaberrimum*). This forms a strong and rigid joint, so the planks do not move relative to each other when it is set. If the planks were fixed to rigid ribs, the seams would open up when the boat was taken out of the water and dried, but flexible lashings allowed for this shrinking.

Figure. 5. A single-outrigger travelling canoe of Satawal, in the Caroline Is., Micronesia. This boat was encountered by the French corvette, the Astrolabe, in 1826 and the print was published by Pâris in 1843 (plate 107). The outrigger is on the far side, beneath a little hut with a square door. The sail is held up by a stay to the wide beam on the lea side, which also supports a plaited shelter.

Figure 6. A thamakau of Lakeba, eastern Fiji Is. In 1826 (Lat. 18ºS; Long. 179ºW). The people were typical Melanesians. The hull is about 1 m deep, and can be kept dry. The man on the left holds a long thin steering paddle. The method of supporting the sail, and the lacing, can be clearly seen. To go about, the tack of the sail is carried to the other end of the boat. Similar craft are still in use (Pâris 1843: plate 117).

Ropes and lines were plaited sennit, of fibre from palm trees, the *baru* tree (*Hibiscus*), or beach morning glory (*Ipomoea pes-caprae*). A seaside shrub (*Wikstroemia foetida*) was used for making fishing nets and fish poison. Sails were of small squares of plaited rushes or split palm leaves, sewn together and edged with a sennet boltrope. They were laced to flexible booms along two edges. Clearly, the sail was a weak component that determined much of the design and dimensions of the whole boat. When not in use, the sail with its booms was taken off and stored in a dry boathouse. There the whole canoe or lashed-lug boat could be disassembled for the

replacement of the lashings, often accompanied by special ceremonies.

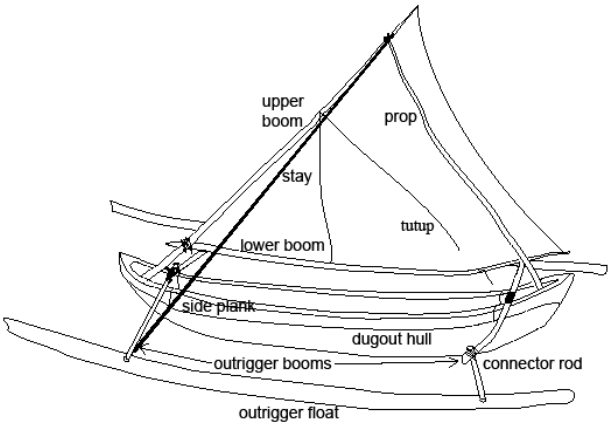


Figure 7. Sketch of a Madurese jukung with the classical mastless rig. Note the position of the two-boom triangular sail when heading into the wind, and the forward extent of the outrigger floats to prevent nose-diving.

The sail was also measured by secret ratios. In Bali, the leech (the free edge) is two thirds of the length along the upper boom and is one hand span more than the length along the lower boom. The exact curves along the edges, to give the sail a shallow belly, are decided by the owner after much discussion. There are many arguments about the correct details and every canoe is identical in each fishing village, but from time to time adjustments are made, and they may adopt a new design from outside, although claiming that it is exactly like that of their ancestors. The belief that the existing canoes were the same canoes as those of the ancestors, but made out of different trees, meant that even if the designs had changed over time, it would not be admitted.

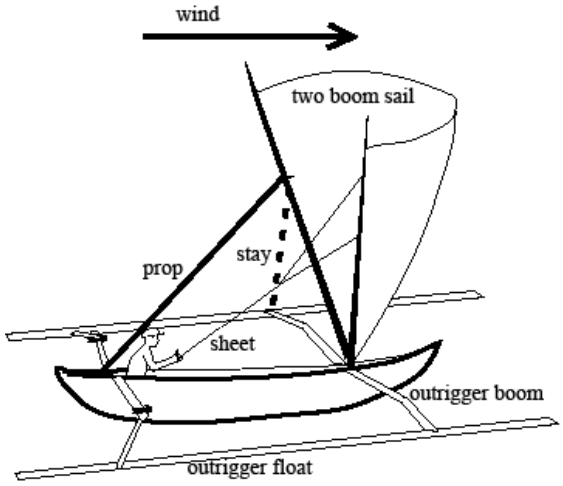


Figure 8. A Madurese jukung sailing downwind. Note the position of the two-boom triangular sail.

Design of the mastless tilting rig

The design of the rig was highly constrained by the strength and elasticity of materials, which were particularly sensitive to wear and fatigue fracture. The design probably originated in Island South-East Asia before the Austronesians arrived, as indicated by its absence from the Asian mainland. The sail was pushed up with a pole, which pivoted freely at its base, removing all bending stresses. It was supported by a rope to the windward outrigger (Figures 7, 8). It was not pulled up on a halyard, which requires a much stronger rope and a pulley, and doubles the load on the mast. The pulley was unknown in Polynesia until the arrival of the European explorers. The doubtful example in Anson (1748) on an illustration of a flying proa that was reproduced by Haddon and Hornell (196: vol. 1:414) was an error[14].

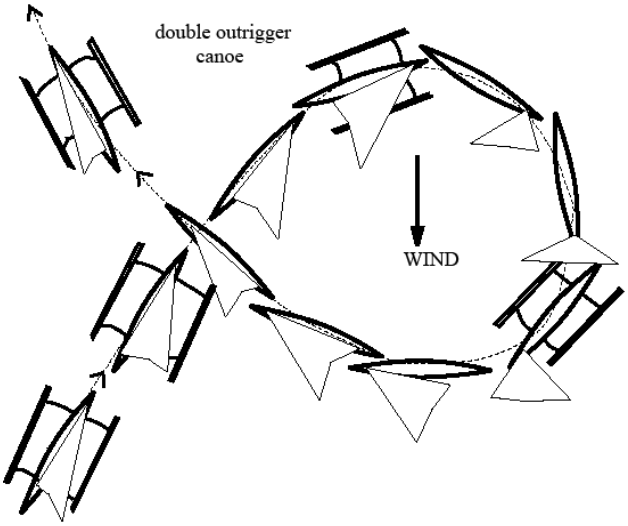


Figure 9. Tacking a double outrigger going upwind. The sail lies in front of the mast and therefore there can be no forestay. To go about, the boat is turned downwind and the sail, together with the sheet, allowed to come right around to the other side over the bows.

The sail was weak and heavy when wet. Therefore loads along the edges of the sail were distributed by lacing or sewing to wooden or bamboo booms that prevented destructive flapping. The stay holding up the sail ran to the outer end of the outrigger boom, so that loading on this stay was minimal. On a single-outrigger canoe a strong gust of wind on the sail easily lifted the outrigger, and the flexible ends of the sail booms assisted in spilling the wind. The sail pivoted on its tack (the lower forward corner) and was pulled back and down to go into the wind, like a modern windsurfer (Figs. 1, 7, and on the left in Fig. 9), but was tilted forwards and across the boat to go downwind (Fig. 8, and on the right in Fig. 9). The sail

[14] Absence of a pulley is negative evidence; no pulley has been found in valid artifacts collected by Cook.

cannot swing over the hull to the other tack because the prop is in the way. To change on to the other tack, the bows were pointed downwind and the sail was allowed to swing right round the front to the other side (Fig. 9), accompanied by the sheet (called "wearing ship").

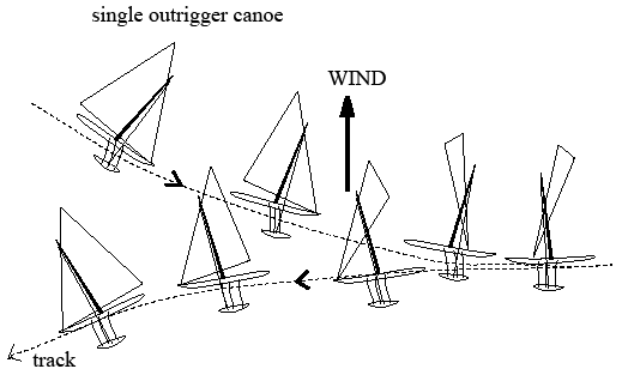


Figure 10. To tack a single outrigger canoe with a two-boom triangular sail, first the sail was closed upwards, then the tack of the sail was carried to the other end of the boat and the sail was opened again. This manoeuvre takes the boat along the dotted track.

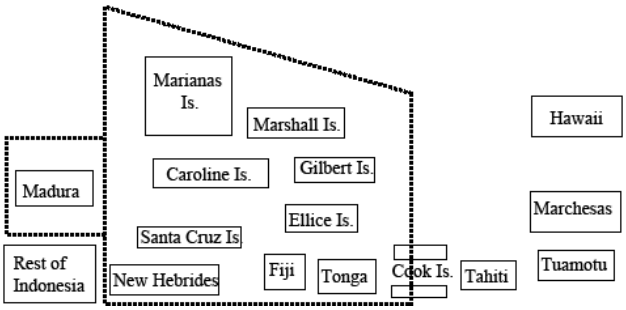


Figure 11. Map of the distributions of the mastless rig in historical times, within the dotted lines.

In many places the tack of the sail was lifted bodily and carried to the other end of the hull (Fig. 10), as was done on the single outriggers of the Marianas, the Carolines, Fiji, Tonga, and the double canoes of Fiji and Tonga, all of which were reversible end for end. To close the sail, the lower boom was raised by a long halyard, called *tutup* in Indonesia, that passed over the upper boom and back to the lower boom (Figs. 5, 14). Sails were closed upwards and lifted off the boat complete with their two booms. These are general features common to most of the area of the mastless rig (Fig. 11). Although large steering paddles were used, they were not mounted on pivots, as in Arab, Chinese, Indian or European cultures.

Ceremonies

The canoes were the most important possessions of the Austronesian maritime cultures, requiring great expense in time to make and maintain, and demanding remarkable expertise to sail and navigate safely. It was important that the numerous spirits of the timber trees, the fish and the sea were placated by ceremonies and offerings so that the canoes and their crews would return safely. Therefore, as for objects of significance in all cultures, activity around them was accompanied by ceremonies that were religious in nature and magical in practice. There is a variety of evidence that everywhere the details of construction were embodied in myths and ceremonies[15]. Malinowski (1922: chapt. 5) describes the ceremonies at each stage during the building of a canoe. The lashings were renewed with great ceremony before every voyage. Horridge (1979) describes the surviving ceremonies in the building of an Indonesian prahu and those for Balinese canoes (Horridge 1987:66-72); Ellis (1831) those of Tahiti, and others are reported in Haddon and Hornell (1975). Sadly, most of this pre-contact material culture of the Pacific Islands has been lost.

Outrigger canoes in historical times

The double outrigger canoe of Madagascar, Malaysia, Philippines and Indonesia (Figs. 7, 8, 9) is a specialized fishing canoe for relatively calm seas. The design limits the size because the leeward outrigger digs into the water, but large versions are used for carrying cows (Horridge 1987:21) or schoolchildren (Horridge 1985: plate 7) in Indonesia. A common form of fishing is to leave a float anchored on a long length of rotan into which palm leaves have been fixed, and then each day put a net around the fish sheltering among the fronds. The outrigger booms carry the large coils of plaited rotan on the canoe. The double outrigger provides stability when the owner pulls fish into the boat single-handed, or for trolling for tuna with a line on each side. Examples are the colourful 1 or 2 man fishing *jukung* of Bali and Lombock (Horridge 1987), the fast *pangkur* of the Mandar people of West Sulawesi (Horridge 1985: plate 9), the line fishing canoes of Java (Horridge 1987:119 and onwards) and the fast fish transports of the Madurese (Horridge 1987:81-115.). In contrast, in these areas the single outrigger canoe is very small and specialized for inshore fishing by one man with the throw-net, and recovering the loaded net over the uncluttered side.

Performance of the oceanic single outriggers depended on the exact rig, and was superb with the wind on the quarter. Many eye-witness accounts describe how they could run rings around a European ship under full sail (1843), just as a modern wind-surfer can frequently outpace a racing yacht. When heading straight down wind, the two-boom triangular sail is unstable, as it then

[15] For example, Best (1925), Buck (1957), Malinowski (1922), Ellis (1834).

lacks lateral stability and is sensitive to squalls. When sailing into the wind with the sail pulled well back, however, the performance was hindered by the lack of a keel. The flying proa (Anson 1748; Haddon and Hornell 1936: vol. 1:412-421) of the Marianas did better with a flat lea side on the hull, but none of the outrigger canoes with one sail and no keel could sail closer than about 70º to the wind, because of drift. For most purposes this was good enough.

Long distances were traveled. Until the early nineteenth century regular trips were made from Yap and Palau in the western Carolines northwards to the Marianas Is. and eastwards past Truk to the eastern Carolines, and then separately from there on to the Marshall Is. (Haddon and Hornell 1936: vol. 1:439). From there the route (usually of raiding parties, and always broken into sections) was southwards to the Gilbert and Ellice Is. (Haddon and Hornell 1936: vol.1:440; vol. 2:43) then to Wallis Is. and on to Samoa. Along a line further south, there was a route from the New Hebrides to Fiji and on to Tonga. From Tonga there was a route to the Cook Is. and on to Tahiti (Haddon and Hornell, 1936: vol. 1). Before 1800 there was regular trade from the Tuamotus in far Eastern Polynesia to Tahiti[16], and north to the Marquesas. Much of this involved sailing eastwards against the prevailing winds and currents. In fact, the signs of land to windward in the flotsam and migrating birds, the necessity of getting upwind and the high probability of getting back home if in difficulties, have contributed to the development of boats and rigs on coasts with onshore prevailing winds, notably the Chams, Vikings, Portuguese and the English.

Sailing north or south is relatively straight-forward in the Pacific. Every few years the Polynesians had the opportunity of sailing long distances eastwards with favourable winds[17]. In Island South East Asia, the winds are dominated by the monsoons, and reverse twice a year. Sailors there can make regular trips and expect to sail home in comfort downwind when the monsoon turns.

The influence of other cultures on Pacific canoes

The original mat sail was heavy, weak and soon rotted, especially when wet. Sails of bamboo slats were limited to the area of Chinese influence. European sails were introduced everywhere when woven cloth became obtainable, often sewn together from long strips of the strong cotton fabric used for mattress covers. Modern canvas followed.

The speed of the change shows that plaited mat sails were a pain to make and use, although they had been a principal influence on the design of the rigs. Rotan lashings were replaced by galvanized fencing wire. Ropes were originally all plaited sennets, so they also were weak and not easily hauled through a deadeye. They were rapidly replaced first by hemp and sisal, then by nylon and later by cheaper polymers. A mast fixed in a thwart with wire stays and a masthead pulley and halyard was introduced, and the new materials allowed the sails to be larger. This, in turn, promoted the transition to other more efficient and more convenient rigs. Even so, the two-boom triangular sail persisted in many island groups.

The mastless rig with a tilting sail was lost or strongly modified in Indonesia and the Philippines under the influence of Buginese traders with the tilted rectangular sail and the early colonists with jibs, staysails and yards. Curiously, the old design survived in Madura relatively unchanged, where it demonstrates how effective these rigs were (Horridge 1987:116-119). Versions of a single outrigger, the Fijian thamakau, are still used in the outer islands of Fiji. The Madurese fast canoes for transporting fresh fish (Horridge 1985: plates 8, 9) have the tilting rig with double outriggers and a strong rudder support. The Madurese jangollan, a heavy cargo boat up to 100 tons, is an modern example with the rig modified by addition of a short stubby mast (Figs. 12 and 13). These are the largest vessels now sailing that are available to give us some impression of how the rig of the large Fijian journeying canoes was handled at sea. They are very steady when heavily loaded. There appear to be no experimental measurements of their sailing performance, and it may soon be too late.

Around Bali, the rig has been modified by supporting the upper boom on a short stubby fixed mast which is set one sixth of the way back from the bows, close to the forward outrigger boom, and firmly wedged in a strong thwart. The upper boom of the sail is slung from the mast at a big mechanical disadvantage (Fig. 14), and the tack of the sail is held rigid in the centre of the bows, so that the upper boom is held in the same plane as the midline of the hull. This arrangement presumably gives a better performance when sailing upwind, but the chief advantage is that the rig looks after itself when the single man crew is otherwise engaged with the fishing. The slope of the upper boom, and therefore the centre of action of the sail, is adjusted to give more weather helm by moving the tack forwards. In some villages there is a special smooth channel in which the tack slides. In Madura and Java, the mast is longer (Horridge 1987: figs. 65-68.). The Madurese leti-leti rig, with a large single sail (Horridge 1985: fig. 12; plates H, J, K.), is similar but has the tack on a fixed pivot in the bows, and the upper boom supported on a very stiff mast. To tack with these rigs, the boat is turned downwind to wear ship and bring the sail right around over the bows (Fig. 9). On large boats, there

[16] Pahi described by Neyret (1974); Haddon and Hornell 196: vol.1: fig. 89; Langdon 1988:180).

[17] Under the influence of changes in the El Niño Current which crosses the Pacific. See Irwin (1992) and the Polynesian Voyaging Society at http://pvs.kcc.hawaii. edu/evolution.html.).

is often a trimming sail (Fig. 23P) in the bows supported on a short mast (Horridge 1986a: fig.15). In several parts of Indonesia, the influence of the Dutch is apparent in the spritsail rig on small boats (Horridge 1985: plate 24).

Figure 12. The mastless rig today. This is a Madurese Janggolan sailing downwind heavily loaded with salt. The main is a two-boom triangular sail supported by a pole to the stern and stays to the beams on each side. The fore sail is similar with a sliding ring on the bowsprit. The vertical pole in the stern is a support for the lowered rig. Note the two huge rudders that act as a keel.

Figure 13. Stern view of the janggolan in figure 12. Note the four stays to the beam on each side, and the way that the shape of the belly of the sail is controlled by the lacing.

Early modernization

Alexander the Great had a fleet on the Indian Ocean, but he must have been using existing boats of Indian or Persian construction, probably derived from the ancient trade between the Persian Gulf, the Indus valley civilization, and Egypt[18]. At that time all Indian Ocean ships were of sewn planks and so far as is known had square or rectangular sails (Fig. 23E, R). The opening of the cinnamon and pepper trade through the Malacca Straits about 200 BC coincided roughly with the introduction of the triangular sail into the Indian Ocean, and the square or rectangular sail (Fig. 15) or the lugsail rig (Fig. 23V, W) from the Indian Ocean into Island South-East Asia. Fixed masts and square sails (Fig. 23E) are depicted on carved murals of the 8-9th centuries on the temples of Borobodur and Ankor Wat. The large ships of the spice trade, up to 300 tons, that the Portuguese found at Malacca in the 16th century had several masts with huge sails of this type (Manguin 1980; Horridge 1985:2).

[18] Ancient Egypt used the rectangular sail hanging on a single yard on a fixed mast, with many controlling sheets. ref. Casson, Chap.2.

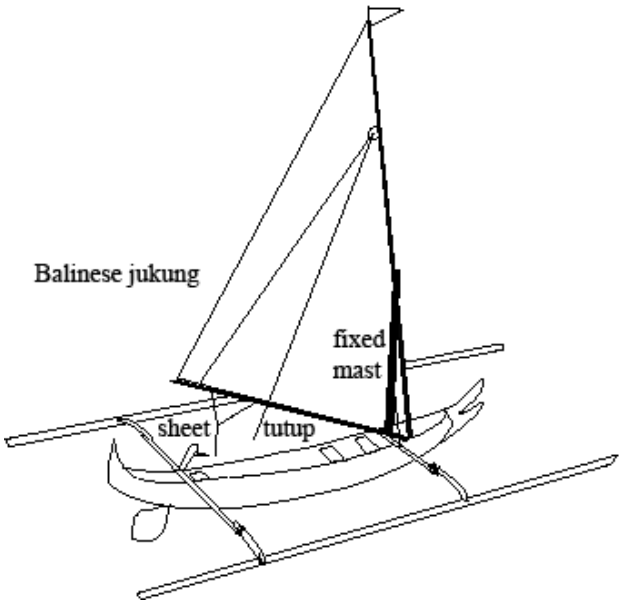


Figure 14. Balinese double outrigger trolling jukung, with a short fixed mast and a two-boom triangular sail. For tacking with this rig, see figure 9.

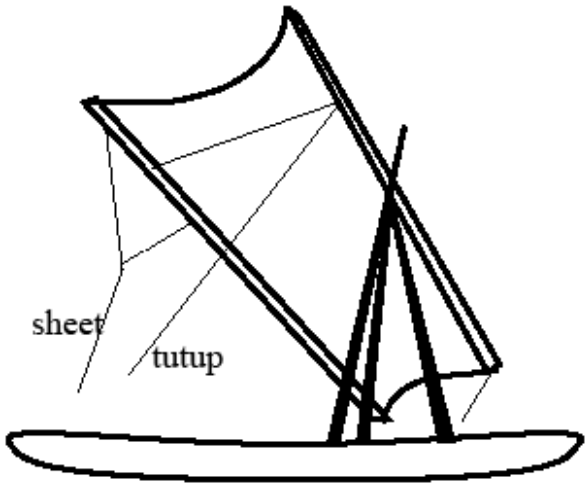


Figure 15. The tripod mast and tilted rectangular rig that was characteristic of the Indonesian trading boats from the 8th to the 19th centuries, and still persists today where there was Makassarese influence.

The Chinese rigs and boat building designs had negligible influence on the Pacific, or indeed anywhere outside China, but the Austronesians, with their language, customs and maritime tradition colonized the coasts of Vietnam and even the Mergui Archipelago on the west coast of Burma. Chinese rigs meet Austronesian rigs on the island of Hainan and the border with Vietnam[19]. In the eighth century AD, the Austronesian maritime empire of the Chams was based on the port of Hoy An, near Da Nang, and their sewn boats and triangular sails persisted until recently along this coast. From there they traded as far as Japan in the north and Sumatra in the south.

Trade in metal spread eastwards from the Indian Ocean and from mainland Asia. Bronze drums Bellwood (1978:180-191,222) were carried from the region of Vietnam to the Eastern limits of Indonesia 2,000 years ago, soon to be followed by iron smiths and other traders. Iron tools, and their names, together with some Sanskrit words, spread with traders from mainland Asia by at least the 5th century AD. Iron was smelted in large quantities in Borneo and Sulawesi in the 10-12th centuries. Iron metal for foundry work by local smiths was traded along the coasts of New Guinea and to the eastern edge of the Philippines.

The iron tools eventually influenced the boat building techniques and larger boats were made by adding planks in a set pattern that was constant for centuries, with a name for every plank. The curved chisel[20] made round holes accurate enough for hardwood dowels to be inserted between the abutting edges of the planks instead of, or as well as, stitches and lashings (figure 4c). The dowels resist sheer stresses between the adjacent planks and overcome the main problem in building larger boats with many rows of planks. As before, the hull was held together by flexible ribs lashed down to projecting lugs on the planks, in a way that could be easily dismantled. This was the lashed-lug boat (Horridge 1982), which is known to be the standard planked boat of the East Asian Archipelago and the basis of power for the numerous sultanates of the Archipelago for about 1,000 years up to about AD 1800. Usually with outriggers, and with numerous men rowing or paddling, the kora-kora was a ship of war that could go directly into the wind across shallow reefs, and could be picked up and carried inland for safety. Many isolated areas, such as the Kai, Aru, Tanimbar, Solor, Sangir islands, kept this design into colonial times. Pirates with these vessels were finally defeated only when the steam gunboats arrived.

From about 1500 AD onwards, Buginese traders from South Sulawesi reached along the coast of New Guinea as far east as Biak in the north and the Aru Is. in the south, and later they fished for trepang off the north coast of Australia. They hung their traditional quadrilateral tilted rectangular sail on a fixed tripod mast (Fig. 23Q), which was frequently copied on the boats of cultures they encountered throughout central Indonesia, but their rig spread only as far as the trade goods from Asia, that is to

[19] Vietnam rigs in Piétri (1949). Ref to southern limit of Chinese rigs in the end-map in Paris P. (1955).

[20] The curved chisel, sharpened on the inner surface to act as a drill, was mentioned by Fr. Alcina in 1668 as a *lokob* (Horridge, 1982). It was the prized tool of the prahu builders of S. Sulawesi (Horridge, 1979).

the Bismarck Archipelago and the Torres Straits. The Buginese are still moving by sea and establishing new colonies in Eastern Indonesia, with a mixed life-style as traders and exploiters. Their introduced diseases wipe out the local people on isolated islands. They build houses on the beach and later take over the land, as any tourist can see on the north coast of Bali.

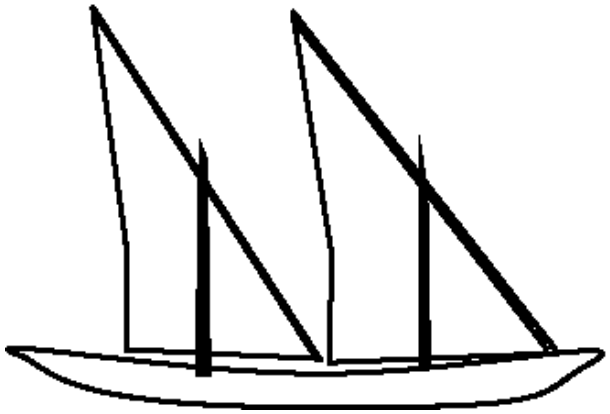


Figure 16. Rig of the Tuamotuan double canoe, from a drawing by Capt. Wallis in 1767. Similar rigs were introduced by the Portuguese to many parts of their trading empire, notably the coasts of Brazil (Pâris 1843: plate 131; Bellec 1993).

European introductions into E Polynesia

A fascinating series of events appears to have led to the early introduction of a European boatbuilding technique and tacking rig in far eastern Polynesia, spreading from the Tuamotus to Tahiti. As recounted in books by Bob Langdon[21], a Spanish caravelle of the Loaisa expedition, the San Lesmes, ventured far out into the Pacific in 1526, and eventually was wrecked on the island of Amanu, in the Tuamotus. One of its iron cannon was recovered from the reef there in 1929. Some of the Basque crew survived and had children, as shown by recently surveyed genes and numerous clues discovered by later explorers, from de Quiros in 1606 onwards. Captain Wallis of the Dolphin[22] who was the next European to visit Amanu in 1767, made a drawing of a boat with two masts and two triangular sails (Fig. 16) and described a large planked boat being constructed *frames first* on a beach. Many details, notably ribs, stays, straight keel and plank pattern, were European in style.

Other findings, too numerous to be all coincidences, indicate that the crew of the San Lesmes had a lasting influence on the local population. The fishing net knots and the creation myths were European. Many of the earliest explorers noted the dress fashions and European appearance of the chiefs. The shipwrecked Spanish dogs of the Tuamotus had longer hair in more colours than the Polynesian dogs. When Capt. James Cook arrived in Tahiti in 1769, he found that prized dog hair was traded from the Tuamotus to Tahiti for the decoration of capes and robes.

In 1767, Capt Wallis brought back from Nukutavake in the Tuamotu Archipelago the hull of a small canoe 3.8 m long (Haddon and Hornell 1936: fig.45) with no sign of the lashed lug or 5-part canoe designs. Later explorers described large double canoes with two masts called *pahi*, up to 30 m long, made of sewn planks fixed to shaped ribs with wooden pegs, with a keel and surmounted by a gunwale. Several of these double canoes, with distinctly European details in the construction, were sketched in the 18th and early 19th centuries. They were symmetrical and could sail either way by turning round the sails. The steering oar pivoted on a wooden pin. In Cook's time they ran a regular service between Tahiti and the Tuamotus via Ana'a and Mehetia, transporting labourers and goods of all kinds.

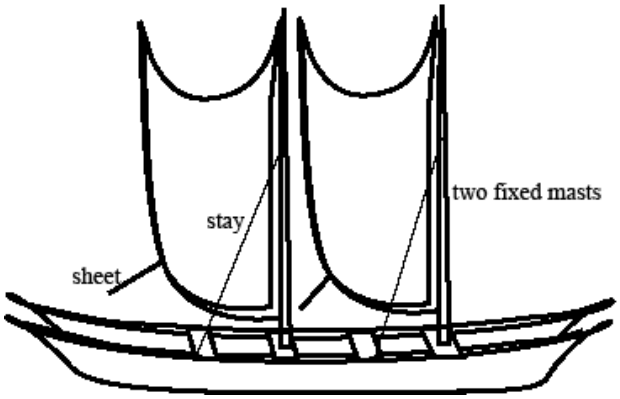


Figure 17. Double canoes of Tahiti with a tacking rig. These copies of paintings by Lt George Tobin (with Bligh on the Providence) and others by Cook's artists, suggest that the masts could be tipped forwards or back to trim the direction of sailing, but the sail pressed against the stays when sailing downwind. They look inadequate for long sea voyages.

The rigs of the Tahitian single outrigger and double canoes were well illustrated by the artists Parkinson, Henry Roberts and Webber, who traveled with Cook, and by Tobin with Bligh[23]. They had one or two curious

[21] Langdon (1975, 1988). A splendid ripple on the world of scholarship; very educational.

[22] See Langdon (1975), plate 20, for a copy of Wallis'sketch (from the National Library of Australia). Abstracts of Wallis' journal (unpublished copy in Public Record Office, London), were published in Hawkesworth (1773).

[23] *Pahi* double canoe in Dodd (1972:94). All Cooks artists and Lt George Tobin (with Bligh on the *Providence*) illustrated the

vertical tacking sails, often called the 'Oceanic Spritsail'. The masts were of bamboo, supported by four stays of twisted hibiscus bark on each side, with fore and aft stays in some examples. The tall sails were each supported by a long curving boom along the trailing edge, and were slung behind the mast so that they tacked in the European way. To my eye, they look unseaworthy. This rig differed in principle from those outside Eastern Polynesia because the sail was behind the mast. There was no obvious way to control weather helm, and the relatively short stiff mast required about 8 stays that must have greatly increased the loading on it. The sail extended far above the top of the mast, with a sharp leading edge for greater efficiency (Fig. 17). When sailing down wind, the sail pressed against the stays, hardly a recipe for safety in the open sea. All of Cook's artists illustrated the sails hoisted on both masts at the same time on the double canoes. None of these details were to be expected in eastern Polynesia.

Further consideration of plaited mat sails suggests that they would disintegrate if allowed to flutter or flap for long. They were laced to thin flexible booms and cut away at the leach. This would account for the curious thin boom along the trailing edge of the Tahitian rig, as a solution to the problem of making a tacking rig with a plaited mat sail (Fig. 17). We know that long distance journeying stopped. My own view is that their mat sails and sennet ropes were too weak to support a tacking rig for distant travel, so they had cut off their options.

Discussions in my own previous works omitted these European influences. Based on the varied and detailed revelations, one must conclude that the triangular tacking sails of the far eastern Pacific, and many other curious details, are strong evidence of Spanish intrusions 250 years before other explorers appeared. The broader significance of these findings is that we cannot infer that the rigs and all the other peculiarities of the tacking canoes were the most ancient by the "age distribution method" i.e., the idea that the oldest went the furthest.

The San Lesmes was not the only ship to disappear in Polynesia before 1770. William Ellis (1834, chapter 16) recorded three accounts of foreigners landing at Kealakekua on Hawai'i before Cook. New evidence appeared in the late 1950's of Spanish castaways from a galleon lost in the 1570's, that would explain the pale complexions, helmets, short mantles and iron daggers noted by Cook. The burial casket of a deified chief deposited in a cave about A D 1600 contained a 2 m piece of European sail cloth and a iron tool like a chisel[24]. Ancient laid ropes that could be Spanish flotsam have also been found. The Hawaiians, who had some early communication with Tahiti, also had a tacking rig (Fig. 18) with a single outrigger[25].

Japanese style pottery found on the coast of Peru has been dated at 4,000 to 4,700 years old (Riley et al., 1971). Recently, a catamaran from Japan largely drifted 15,000 km to San Francisco in 51 days, continuing 6,000 km to Ecuador in 27 days. The discovery of DNA tested bones of the Asiatic chicken on the coast of Chili, carbon dated to 1200 AD (Storey *et al.* 2007), together with probable transport of banana and coconut, justified the work of Langdon (1989) and also suggests that someone really reached S. America from somewhere. This calls for a reconsideration of the boats that could span 5,000 km, and new re-enactments with truly antique craft. Clearly, the Tahitian and Hawaiian canoes of 1770 are unlikely candidates, but around 1200 AD they must have had better craft to reach Tahiti and Hawai'i. On the other hand, large Chinese junks were lost in the same system of currents about the same time. Interesting problem.

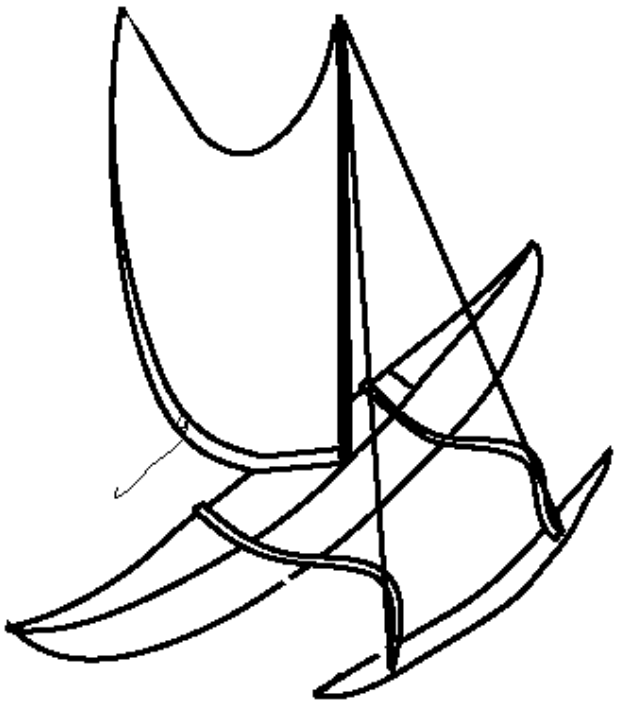


Figure 18. Hawaiian rig on a small single outrigger fishing canoe.

The triangular sail in the Indian Ocean

rigs of Tahitian canoes. For Tobin's journal, see Schreiber (2007).

[24] Reports of the casket are filed in the Bishop Museum Library under the heading 'Spanish problem'. See also Stokes (1930).

[25] Hawaiian tacking rig in Holmes (1981) p.65, and Buck (1957). See also (with reservations) Polynesian Voyaging Society at http://pvs.kcc.hawaii.edu/evolution.html.

About 200 BC trade between Arabia, India, Java and China developed. Cinnamon, cloves, nutmeg and pepper from Indonesia, and sandalwood and whale products from Timor, were shipped to Crivijaya and Malacca by Indonesians, then northwards to China, or westward to the African coast, as indicated by their eventual arrival in small quantities in the Roman Empire from that direction (Miller 1969: chapt. 8). There was an opportunity for the triangular sail to spread into the Indian Ocean and interact with rigs with fixed masts and square sails (Fig. 23E) or lug sails (Fig. 23X). Out of this union was born the Arabic Lateen[26] which is an approximation to a triangular sail by sailors who already had a mast fixed in a thwart, the pulley, rope and rigging for a square sail (Fig. 23E). Actually, the origin of the lateen rig in the Indian Ocean is obscure, as would be expected if it was derived from early Austronesian traders.

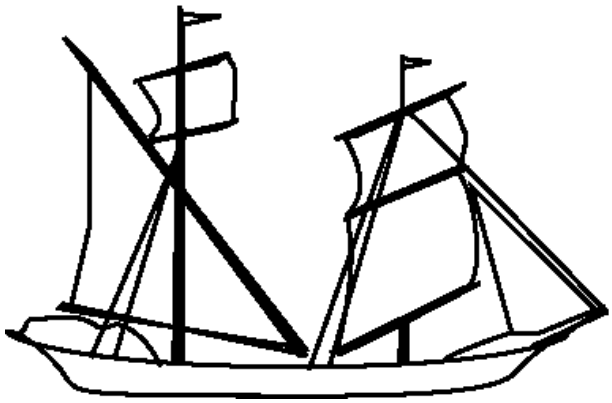


Figure 19. Early European rig of about 1500 AD, with the triangular lateen sail on the mizzen mast.

Austronesian influence is apparent today in many places around the Indian Ocean, with outrigger canoes in Sri Lanka, the west coast of India, and the Comores Is. (East Africa). Madagascar was first occupied by the Austronesian traders that arrived early in the first millennium AD, and their agriculture, house styles and language are still predominant there. The tilted triangular sail, now on a fixed mast, spread rapidly in the area dominated by the monsoons, reaching the Mediterranean in late Roman times (Casson 1971: 268-269)[27]. The triangular sail of the Nile *gaiassa* is of unknown age but not from ancient times BC. The lateen sail was rare in Roman records but common in the eastern Mediterranean. from the 9th century. The Crusader ships in the 13th century had two lateen sails as did numerous merchantmen of Pisa, Genoa and Venice. The ottoman lateen sail was adopted eventually by the Portuguese of the 11-12th centuries, first as the steering sail on the mizzen mast (Fig. 19) and later became a gaff sail (Fig. 22). This was the origin of the fore and aft rig in Europe[28].

The two small caravelles which accompanied Columbus in the Santa Maria set out for America with two masts, each with a large triangular lateen, which was the rig that was later carried by the San Lesmes into the Eastern Pacific. So the triangular sail itself completed the circumnavigation of the world.

Colonial influences

Hull construction

With the arrival of the European colonists and traders in the Pacific, the old rigs were quickly exchanged for new ones, sometimes in a very short time, as rigs are easily seen and copied. In Hawai'i, for example, square sails (Fig. 23E) and topsails were adopted almost at once. In Indonesia and elsewhere, boats with the mainsail in front of the mast and no forestay were fitted with a jib-sail, which had to be taken down every time that the boat went about (Wallace 1869: chapt. 28). The ancient technology with a tilting prop put only the weight of the sail on the hull, but now in a strong wind the stays and large sail generated unbearable stresses, 10 times the weight of the sail, that could pull out stays and push the mast through the bottom of a traditional hull. Therefore the whole technology had to change together; a long straight keel that was angled on to the stem and stern posts, instead of a gradual curve, the use of thick ribs to which the planks were solidly and permanently attached with tree nails, in contrast to the lashed ribs that compressed the hull, the use of thwarts, the transom and stern rudder, and the stepping of the mast on the keel.

Most of the Polynesian boat building and sailing traditions slowly disappeared in the 19th century, but some have been recently revived in modern guise for heroic re-enactments[29]. You should look carefully, however, for modern detail in modern "ancient" boats. Although the copies in nylon and fibreglass may look similar to the traditional ones, they usually have technically significant innovations, and are less likely to be worked to bits by a rolling sea.

An interesting compromise between old and new was the hoisting of a rectangular lug sail (Fig. 23X) or a two-boom triangular sail upon a mast fixed in a thwart, so that one of the booms lies parallel to the mast, but projecting above it, while the other acts as a boom (Fig. 20), as on

[26] See Fig. 23 I. The sail was loose-footed when cloth was used.
[27] For contemporary illustrations, see Bellec 1993. Columbus' caravel rig, ref Landström 1961: 106.

[28] 'The Fore-and-Aft Rig in America' by E. P. Morris (1927) is a collection of rare information.
[29] e.g., Finney, B (1979); Jennings (1979) Chapt. 14. See also Polynesian Voyaging Society at http://pvs.kcc.hawaii.edu/evolution.html.

the English Mirror dinghy. We call this a gunter lug sail (Fig. 23O). Judging from widespread illustrations from Thailand to Tahiti, there were many rigs of this type in the 19th century. At Singapore[30], throughout Indonesia[31], on the central Vietnamese coast[32] and in Micronesia[33], this system produced a fast convenient tacking sail, but it required a strong fixed rudder and a jib for trimming the rudder, because the sail will not tip forwards or back.

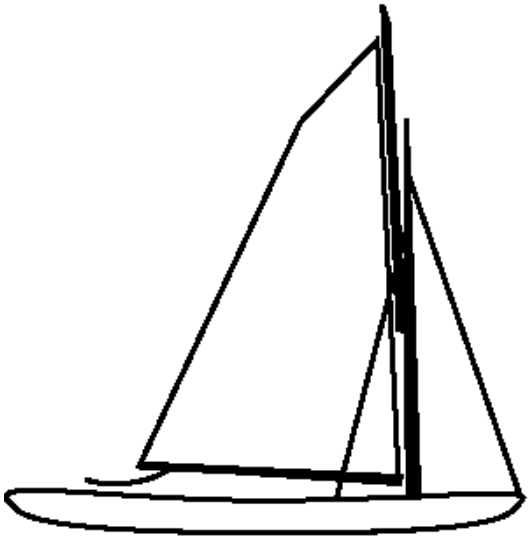


Figure 20. Two-boom triangular sail attached to a fixed mast, as on the 19th century Singapore fast boat. Now called the Gunter-lug sail in England and *layar nadé* in Indonesia (Fig. 23O).

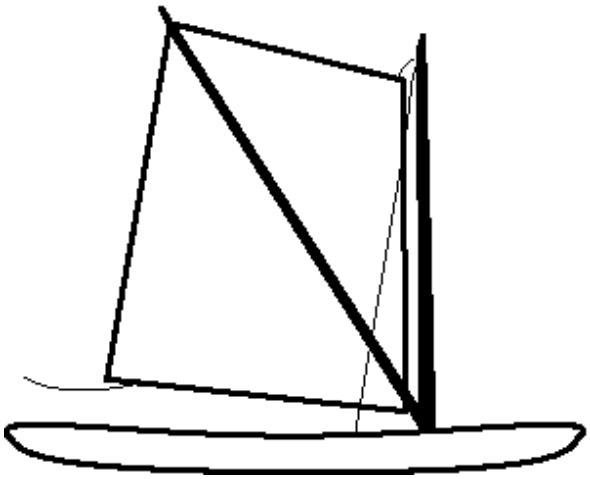


Figure 21. Dutch spritsail.

In corners of the former colonial empires one still finds fishing canoes or even large sailing transports with a Dutch spritsail rig, or a relation (Fig. 21), as found at Ende in south Flores, Indonesia[34] in Jakarta Bay[35], and once common in the eastern Pacific[36]. In Island south-east Asia there are still plenty of small boats with a trapezoid or a European rectangular lug sail (Fig. 23X) suspended on a fixed mast by two halyards ending at different distances from the centre of the upper boom[37] and a lateral rudder that rises conveniently over coral reefs.

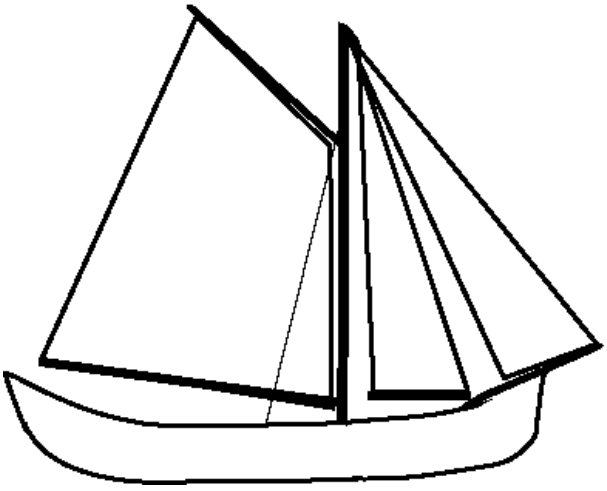


Figure 22. Gaff rigged cutter, still in use in parts of Indonesia.

Even the adoption of the European fore-and-aft rig took place in parts, and at first imperfectly, starting at major ports and places where European ships met local traders. The Singapore fast boat (Fig. 19) was developed at the end of the 19th century to bring passengers from ships and to deliver fresh fruit and vegetables to that port. About 1900, the European yacht rigs were introduced for the same purpose, speed. Even fast racing yachts purchased by local wealthy colonists had an immediate effect upon local rigs that slowly spread away from the main ports. The gaff rig[38] was everywhere copied from European schooners (Fig. 22). A careful search for the forebears of the Bugis pinisi of 1960-1980 with two curtain gaff sails and two jibs, suggests that the rig was probably copied from American schooners, which had given up the square topsails in the early 19th century, and instead used gaff topsails. For example the L.A. Dunton, built in 1921, and now preserved at Mystic Seaport, Connecticut, was one of the last of a long line of Cape Cod fishing schooners,

[30] For a scale drawing of a Singapore fast boat see Warington Smyth (1929:408).
[31] History of the lambo and nadé rig (Horridge1985: chapt.18).
[32] The *Ghe Câu* of Phan Rang (Piétri 1949:plate 43).
[33] Micronesian modern rig (Knox-Mawer and Carmichael 1968:40d).
[34] Endé rig in Burningham (1990: fig. 10).
[35] Jakarta Bay rig. (Horridge 1985: plate 24).
[36] Spritsail in the Leeward Is. (Haddon and Hornell 1936:vol.1: fig. 84).
[37] Some illustrations in Warington-Smyth, Chapt. 11.
[38] Gaff rig lambo See Horridge *The Prahu,* figure 32. The lambo gaff rig was that of the English pearling boats of early 20th century.

traders and whalers, with almost exactly the rig adopted in South Sulawesi by about 1930.

Sometimes progress stopped at the use of a rope and pulley to raise the triangular sail, as in Madura, sometimes progress stuck at the use of the Dutch spritsail, as in the Aru Is. or at the square sail (Fig. 23E), as in the Bismarck Archipelago and Torres Straits. Later the nadé rig (Horridge 1985: fig. 33) (Fig. 23O) called the gunter lug in Europe, also spread from Hong Kong, Singapore and Batavia. In some places the tilted rectangular sail was abandoned in favour of a triangular tacking sail, as in the southern Philippines, on the west coast of Sulawesi, and at Pasir Putih in Eastern Java. At the end of the 19th century, there was a hotch-potch of colonial influences superimposed on the declining indigenous traditions, quite difficult to unravel.

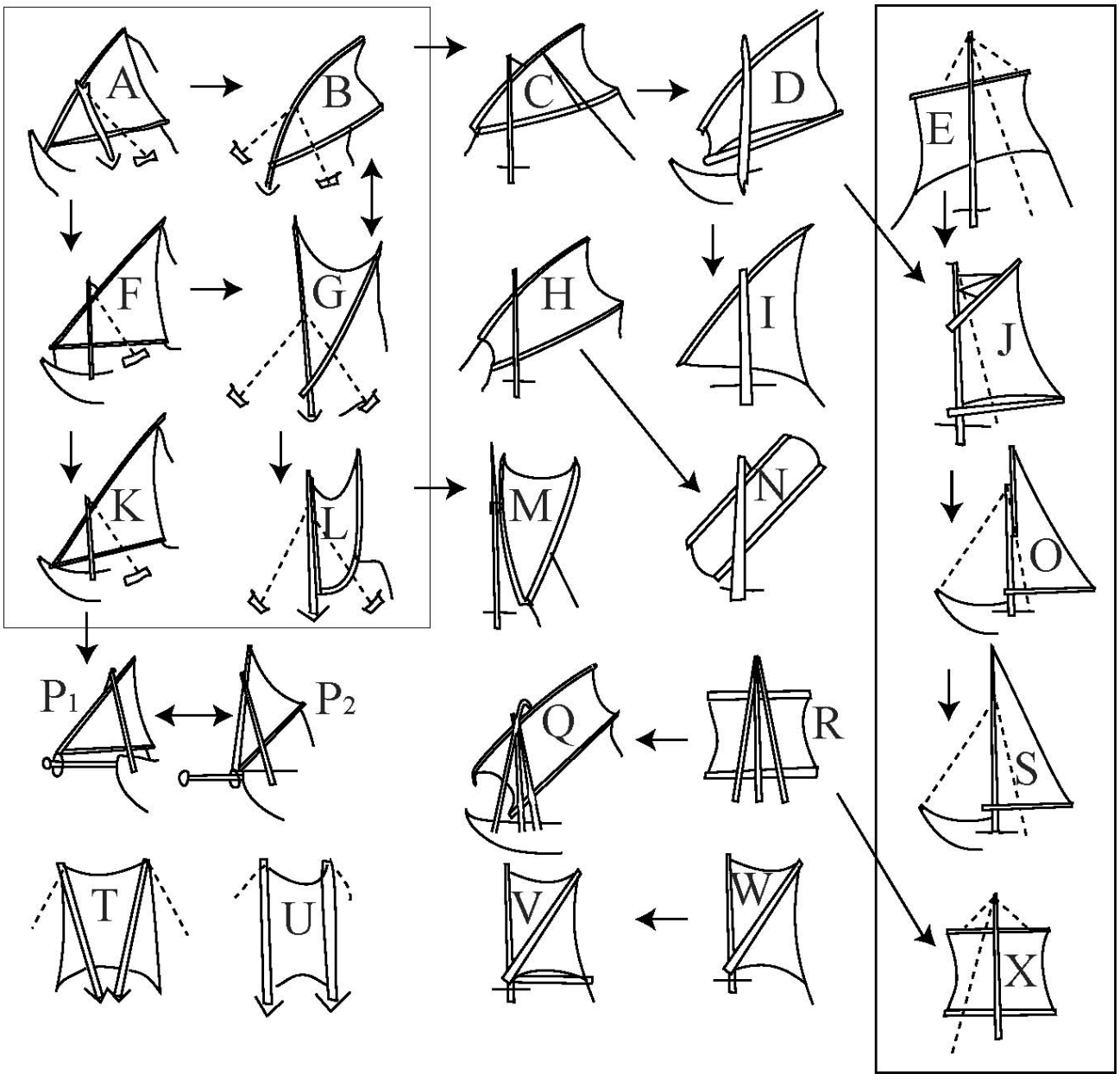


Figure 23. Sail types, with arrows suggesting relationships. In each case, the first name given here is preferred because it refers to the shape or place and carries no overtones of previous theories. In the box on the left are the tilting mastless rigs; in the box on the right are the European rigs.

A, Madurese jukung rig; Primitive Oceanic Lateen of Haddon and Hornell (1936); Crane Sprit of Doran (1981). Suitable for rafts or outrigger canoes without pulley. Ancient Peruvian Balsa rafts.
B, Polynesian Oceanic Rig; Simple Oceanic Spritsail of Haddon and Hornell (1936); Oceanic Spritsail of Bowen (1953) and Doran (1981). The main boom stands on a notch, supported by stays.
C, Two-boomed triangular sail on a fixed mast. Mechanically similar to **K.**
D, Indian Ocean Loose-footed Lugsail; Trapezoid Lateen.
E, Square sail; Ancient Egypt, Mediterranean.
F, Old Micronesian Rig; True Oceanic Lateen (Haddon and Hornell 1936; Crane Sprit of Doran (1981).
G, As in **B** but going downwind. Marquesan Claw Sail (Lewis 1972).
H, Tilted Rectangular Sail probably from the Indian Ocean to Indonesia, or Trapezoid Sail (Coramandel Coast). Common S.E. Asia, also near New Guinea; (Haddon and Hornell 1936: vol. 2:162, 174, 246).
I, Arab or Mediterranean Triangular Lateen.
J, Gaff Rig, 18th century English and American; 19th century in Indonesia.
K, Balinese Jukung Rig; Madurese Leti Rig. The upper boom is fixed at the head of a short mast and the tack is fixed in the bows.
L, Hawai'I Rig; Boom Spritsail (Haddon and Hornell 1936); Oceanic Spritsail (Doran 1981; Holmes 1981); Society Island Spritsail (Bowen 1953).
M, New Guinea Crab Claw; Crab Claw Spritsail (Bowen 1953).
N, Tilted Elliptical Sail on fixed mast. New Guinea.
O, Gunter Lug Sail; entirely modern, English origin in the West Pacific.
P, Madurese Foresail in two positions. The upper boom is on a short mast. A ring on the tack slides along the bowsprit. Copied from the Dutch.
Q, Tilted Rectangular Sail on a tripod mast. Introduced into Java before the 8th century. Still used by Buginese, Makassarese and others, called *Layar Tanja*.
R, Square Sail on Tripod Mast. A suitable rig for reed boats that were once widespread. Ancient Egypt, Sumeria, Indus Valley cultures.
S, Leg of Mutton Sail or Bermuda Rig.
T, Indian Ocean Double Spritsail; Proto-Oceanic Spritsail (Bowen 1953). Sri Lanka, India, Madagascar. Possibly a recent adaptation for hauling a trawl downwind.
U, Melanesian Spritsail. Relationships unknown.
V, Boomed Spritsail. Dutch.
W, Loose-footed Spritsail. In Java called *layar suduk* (dagger rig). Common in Indonesia from the Dutch influence.
X, Lug Sail. Related to **E**. Ancient Middle East, Indian Ocean, Scandinavia. Now world-wide.

Conclusion

Making sense of the Pacific rigs is based first upon the absence of the pulley, the mast fixed in a thwart, stays, the fixed rudder and the square sail (Fig. 23E), none of which spread primitively into the Pacific. The Polynesians had a more appropriate rig for use with mechanically weak materials. They used sennet and pushed the sail up on a loose prop, which in turn supported the mechanically weak mat sail that was laced to booms on two sides. They tilted or rotated the sail on its tack to steer like a windsurfer, so they never needed to invent the fixed rudder or the jib sail. The Austronesian rig later contributed to the development of sailing upwind worldwide, and was itself modified and then replaced (Fig. 23) when tougher and stronger materials made possible larger and faster designs.

The great variety of Pacific canoes was rather exhaustively described by Haddon and Hornell (1936) and by Neyret (1974). However, the evolution of Pacific hulls and the relationships between the rigs suggested by these authors, or Bowen (1953) or Needham (1971), or others that copied from them, does not correspond at all with that given here. They did little first hand research among sailors, and were unaware of the recent evidence. More importantly, they were not engineers, sailors or boat builders and failed to elucidate the over-riding constraints that governed the limited range of designs and size of boats in the Pacific before the European explorers arrived. The mechanically weak mat sails limited the rig and the size. The over-riding consideration in the hull design was the need to avoid fatigue fractures and relieve the sheer stresses caused by flexing and twisting in the waves. Canoe superstructures were built with lashings so that they could accommodate stress concentrations. The planks were sewn edge to edge and the flexible ribs lashed to lugs kept the planks pressed together like an inverted arch in compression. You have to get away from the European ideas that the square sail (Fig. 23E), fixed mast and rudder are primitive and that sails were made of sail cloth. The best introduction to an understanding of Pacific rigs is to learn the art of windsurfing with a tilting mast and study the performance of the rigs currently in use by the Madurese (Figs. 7, 12, 13), then consider the engineering uses of the relatively weak natural materials that were available, and the limited options that allowed a safe design with the best compromise of speed and permissible size.

References

Anson, Baron George
1748 *A voyage round the world* (1740-44), compiled by Richard Walter. Reprinted (G. Williams, Ed.) 1974 University Press, Oxford.

Bellec, F.
1993 *Nefs, galions et caraques*. Editions Chandeigne, Paris.
Barrau, J. (ed.)
1963 *Plants and the migrations of Pacific Peoples; a symposium*. Honolulu, Bishop Museum Press.
Bellwood, P.
1978 *Man's conquest of the Pacific.* Collins, Auckland N.Z.
Bellwood, P.
1995 "Austronesians Prehistory in Southeast Asia: Homeland, expansion and transformation". In P. Bellwood, J.J. Fox, and D. Tryon, D. (eds.), *The Austronesians: Historical and Comparative Perspectives*. Dept. of Anthropology, Australian National University. Canberra.
Bellwood, P., Fox, J. J. and Tryon, D. (eds.)
1995 *The Austronesians: Historical and Comparative Perspectives*. Dept. of Anthropology, Australian National University. Canberra.
Best, E.
1925 *The Maori Canoe*. Govt. Printer. Wellington, New Zealand.
Bisschop, E. de
1959 *Tahiti Nui*. New York.
Bowen, R. Le Baron
1953 Eastern sail affinities. *American Neptune* 13: 81-113 and 185-214.
Buck, P. E.
1957 *Arts and crafts of Hawaii*. Also in Bishop Mus. Special Publ. 45 Section 6 (1964).
Burkill, I. H.
1966 *A Dictionary of the Economic products of the Malay Peninsular*. Publ. Govt of Malaysia. Kuala Lumpur.
Burningham, N.
1990 *Stemless boats of Ende Bay. The Beagle. Records of the Northern Terr*. Mus., Darwin 7: 105-119.
Casson, L.
1971 *Ships and seamanship in the ancient world*. University Press, Princeton, N. J.
Dodd, E.
1972 *Polynesian seafaring*. Dodd, Mead & Co, New York.
Doran, E.
1981 *Wangka: Austronesian canoe origins*. Texas A & M University Press, College Station.
Ellis, W.
1834 *Polynesian researches*. 2nd Edn. London, Fisher & Jackson.
Green, R.
1979 "Lapita". In J.D. Jennings (ed.), *The prehistory of Polynesia*. ANU Press, Canberra.
Finney, B. R.
1979 *Hokule'a: The way to Tahiti*. Dodd, Mead & Co, New York.
Haddon, A. C. & Hornell, J.
1936-38 *Canoes of Oceania*. Bishop Museum Special Publ. 27, 28, 29. Reprinted as one vol. 1975. Bishop Museum Press, Hololulu, Hawai'i.
Hawkesworth, J.
1773 *An account of the voyages ---Byron, Wallis, Carteret and Cook*. 3 vols. London, Strahan & Cadell.
Heine-Geldern, R.
1932 Urheimat und früheste Wanderungen der Austronesier. *Anthropos* 27: 543-619.
Holmes, T.
1981 *The Hawai'ian canoe*. Editions Limited, Hanalei, Hawai'i.
Horridge, G. A.
1979 *The Konjo boatbuilders and the Bugis prahus of South Sulawesi.* Monogr. 40. Maritime Mus. Greeenwich, London.
1985 *The prahu.* 2nd edn. Oxford University Press, Kuala Lumpur. Page numbers in the notes refer to this (preferred) edition.
1982 *The lashed-lug boat of the Eastern Archipelagoes.* Monogr. 54. Maritime Mus. Greenwich, London.
1986a *Sailing Craft of Indonesia*. Singapore Oxford in Asia.
1986b "The evolution of Pacific canoe rigs". *Journal of Pacific History* 21: 83-99.
1987 *Outrigger canoes of Bali and Madura, Indonesia*. Bishop Museum Press, Honolulu, Hawai'i.
Irwin, G.
1992 *The prehistoric exploration and colonisation of the Pacific*. University Press, Cambridge.
Jennings, J. D. (ed.)
1979 *The prehistory of Polynesia*. ANU Press, Canberra.
Jett, S.
1971 "Diffusion versus independent development". In C.L. Riley, J.C. Kelley, C.W. Pennington, R.L. Rands (eds.), *Man across the sea. Problems of Pre-Columbian Contacts*. Austin. Univ of Texas Press.
Johnstone, P.
1980 *The sea-craft of prehistory*. Routledge & Kegan Paul, London.
Knox-Mawer, J. and Carmichael, P.
1968 *A world of islands*. Collins, London.
Landström, B.
1961 (English Ed.) *The ship*. Allen & Unwin, London.
Langdon, R.
1975 *The lost caravel*. Pacific Publications. Sydney.

1988 *The lost caravel re-explored*. Brolga Press, Canberra.
1989 "When the blue-egg chickens come home to roost". *Journal of Pacific History* 24: 164-192.

Lewis. D.
1972 *We, the navigators*. Canberra. Australian National Univ. Press.

Malinowski, B.
1922 *Argonauts of the western Pacific*. Routledge & Kegan Paul, London.

Manguin, P.-Y.
1980 "The Southeast Asian ship: An historical approach". *Journal of Southeast Asian Studies* 11: 266-276.

Miller, J.I.
1969 *The Spice Trade of the Roman Empire*. Clarendon Press, Oxford.

Nishimura, S.
1925 *Ancient rafts of Japan*. Publ. Soc. Naval Architects, Tokyo.

Morris, E. P.
1927 *The Fore-and-Aft Rig in America*. Newhaven; Yale Univ. Press.

Needham, J. (ed.)
1971 "Civil engineering and Nautics". In *Science and Civilization in China*, vol.4(3). Cambridge University Press.

Neyret, J.
1974 Pirogues Océaniennes. Assoc. des Amis des Musées de la Marine. Paris, France.

Pâris, F. E.
1843 *Essai sur la construction navale des peuples extra-Européens*. Arthus Bertrand, Paris, France.

Paris, P.
1955 *Esquisse d'une ethnographie navale des peuples annamites*. Publ. Mus. Land- en Volkenkunde Prins Hendrik, Rotterdam. N°3(2):1-86.

Piétri, J. B.
1949 *Voiliers d'Indochine*. S.I.L.I., Saigon.

Riley C.L, J.C. Kelley, C.W. Pennington, R.L. Rands
1971 *Man across the Sea. Problems of Pre-Columbian Contacts*. Austin. Univ of Texas Press.

Schreiber, R. (ed.)
2007 *Captain Bligh's second chance. The journal of Lt. G. Tobin*. University of New South Wales Press.

Severin, T.
1994 *The China Voyage*. London. Little, Brown and Co.

Spriggs, M.
1995 "The Lapita Culture and Austronesian prehistory in Oceania". In P. Bellwood, J.J. Fox and D. Tryon (eds.), *The Austronesians: Historical and Comparative Perspectives*. Australian National University, Canberra.

Stokes J.F.G.
1930 *Burial of King Keawe*. Papers of the Hawaiian Historical Society, Honolulu, 17: 63-73.

Storey, A. A, J.M. Ramirez, D. Quiroz, D.V. Burley, D.J. Addison, R. Walter; A.J. Anderson, T. Hunt, J.S. Athens, L. Huynem, E.A. Matisoo-Smith
2007 "Radiocarbon and DNA evidence for a Pre-Columbian introduction of Polynesian chickens to Chile". *Proc. Nat. Acad. Sci. USA* 104(25):10335-10339.

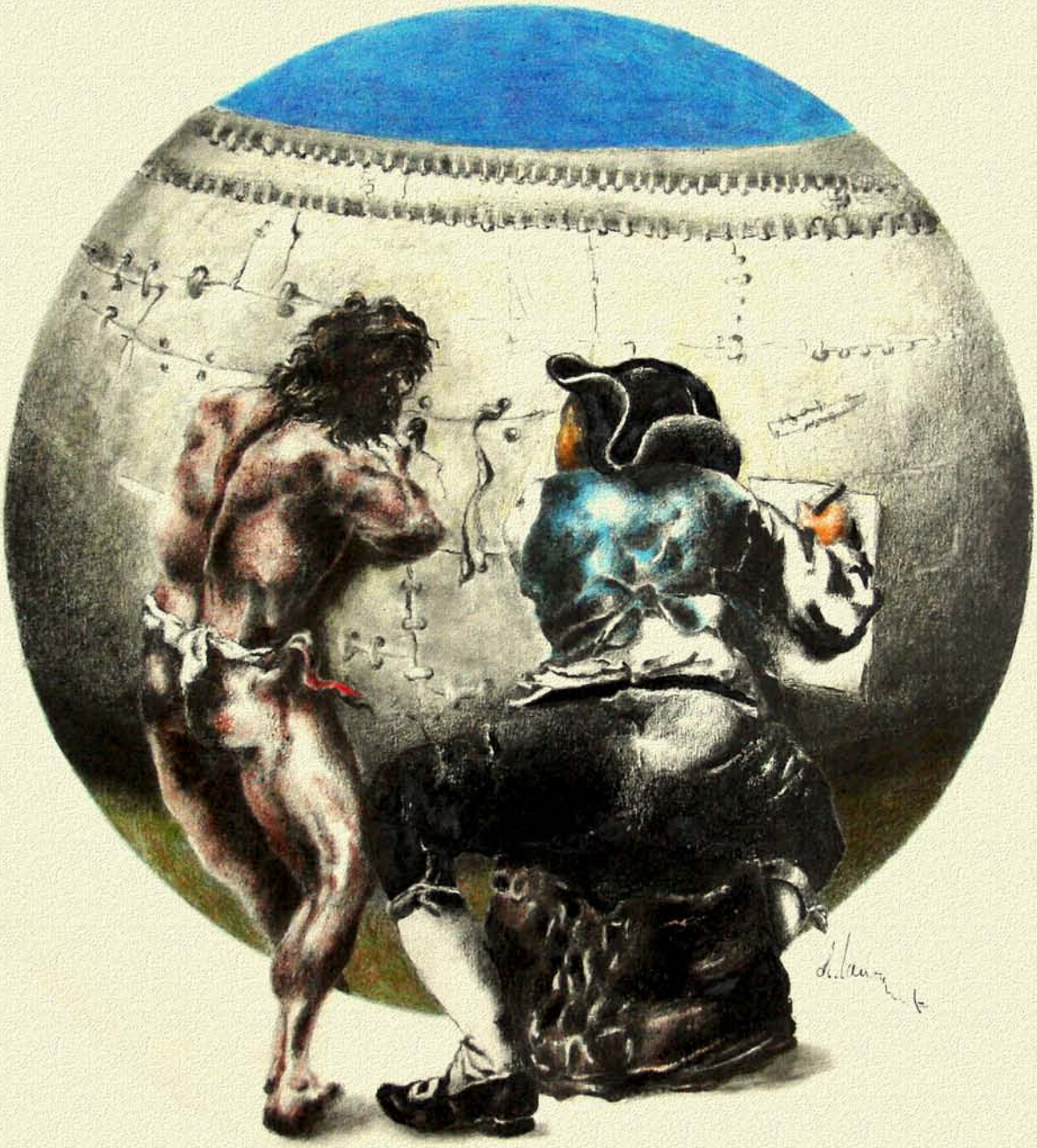
Wallace, A. R.
1869 *The Malay Archipelago*. Macmillan, London.

Warington Smyth, H.
1929 *Mast and sail in Europe and Asia*. Blackwood, London.

Navigators as the principal actors in cross-cultural encounters

Session 1

The many varieties of canoes



Session 2

Paper canoes

Session 3