

THE STORY OF PACIFIC SAILING CANOES AND THEIR RIGS

Adrian Horridge

ABSTRACT

A revised survey of outrigger canoe rigs leads to the new conclusion that the primitive rig that made possible the Austronesian conquest of the Pacific was the mastless rig with a two-boom triangular sail supported on a loose prop, as survived in Madura and western Polynesia. It is proposed that the triangular sail spread across the Indian Ocean and became the lateen, which spread further to the Mediterranean and eventually to Portugal by the fourteenth century. New historical findings suggest that this Western lateen rig with a fixed mast, copied from a Portuguese caravel lost in 1526, influenced sailing practice in eastern Polynesia.

Keywords: Pacific rigs, outrigger canoes, Austronesian, colonists.

THE BEGINNING

The first colonists from Indonesia certainly reached Australia more than fifty thousand years ago, but stone tools suitable to make dug-out canoes have not been found older than about twenty thousand years. Therefore the best guess is that the earliest sea crossings as far as the Solomon Islands were made with rafts.¹ Of sailing rigs developed in those remote times we know nothing. However, a survey of the widespread sailing rafts still in use, mainly on rivers, in historic times, reveals a variety of rigs. The *tak pai* of Taiwan (Nishimura 1925) had a square sail, the balsa rafts of the Peruvian coasts (Johnstone 1980: 224-28) used a two-boom triangular sail: the bamboo rafts (Ghe Bè) of Haiphong Bay, Vietnam (Pietri 1949: 89) used a canvas lug sail or the low rounded junk sail of the southern Chinese: rafts in Fiji (Haddon and Hornell 1936, i: 330) and Mangareva (Gambier Is.) (*ibid*: 91-94) had the local mastless two-boom triangular sail (Figure 52). How long the raft rigs had been in use no-one can now say, but, like much of the agriculture, housebuilding, and other crafts, they could have been developed in the Eastern Archipelago over a long period² before the coming of the Austronesian-speaking peoples from the mainland of South China about four thousand years ago.

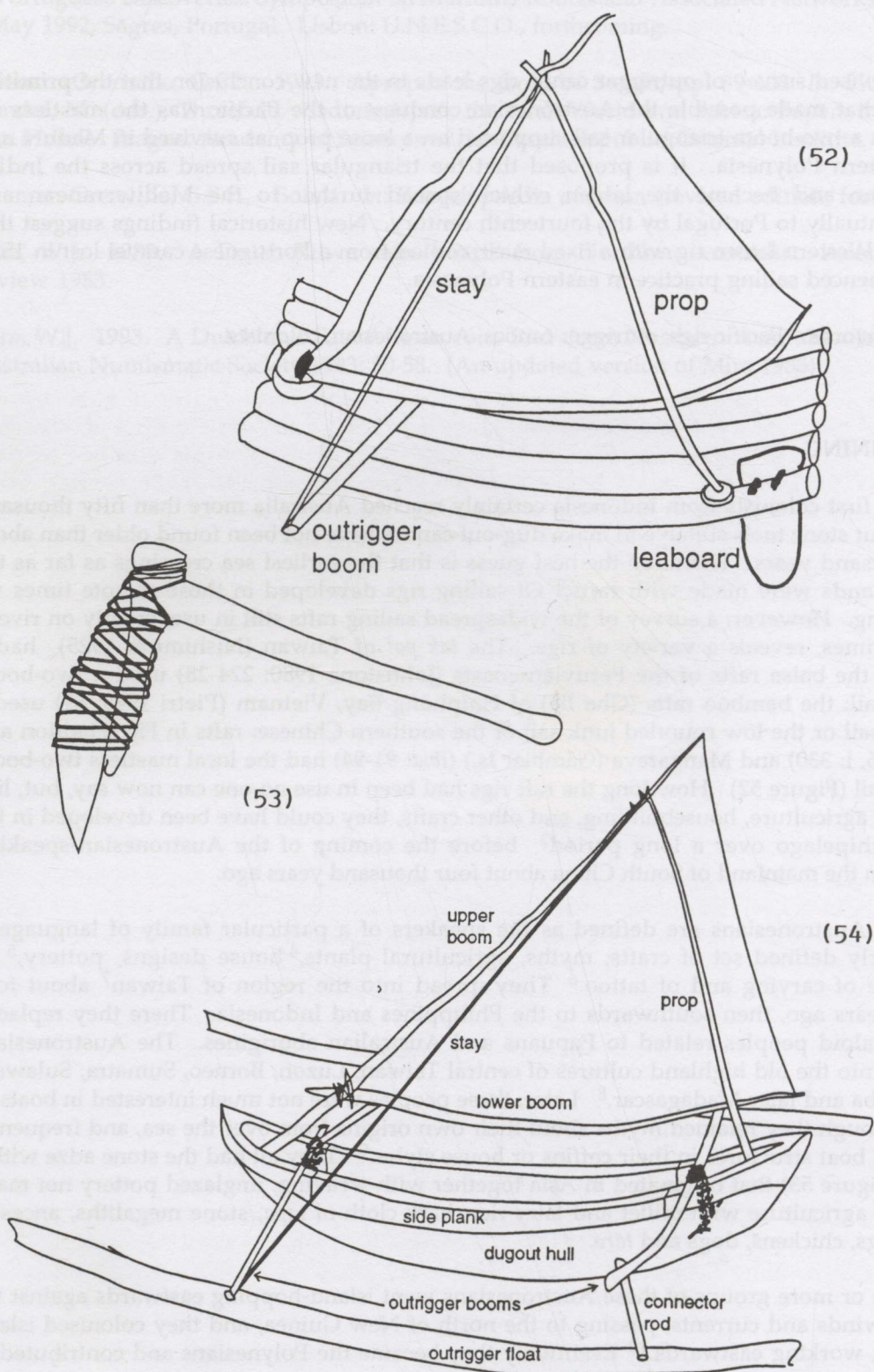
The Austronesians are defined as the speakers of a particular family of languages,³ with a clearly defined set of crafts, myths, agricultural plants,⁴ house designs, pottery,⁵ an artistic style of carving and of tattoo.⁶ They spread into the region of Taiwan⁷ about four thousand years ago, then southwards to the Philippines and Indonesia. There they replaced older Australoid peoples related to Papuans and Australian aborigines. The Austronesians diversified into the old highland cultures of central Taiwan, Luzon, Borneo, Sumatra, Sulawesi, Flores, Sumba and later Madagascar.⁸ Later, these 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.⁹ They all had the stone adze with a bent haft (Figure 53) that originated in Asia together with weaving, unglazed pottery not made on a wheel, agriculture with millet and later rice, bark cloth of *tapa*, stone megaliths, ancestor worship, pigs, chickens, dogs and *taro*.

One or more groups of these Austronesians went island-hopping eastwards against the prevailing winds and currents, passing to the north of New Guinea, and they colonised island after island, working eastwards.¹⁰ Eventually they became the Polynesians and contributed to

Figure 52: Primitive sailing raft with two-boom triangular sail

Figure 53: Adze with bent haft

Figure 54: Double outrigger with two-boom triangular sail

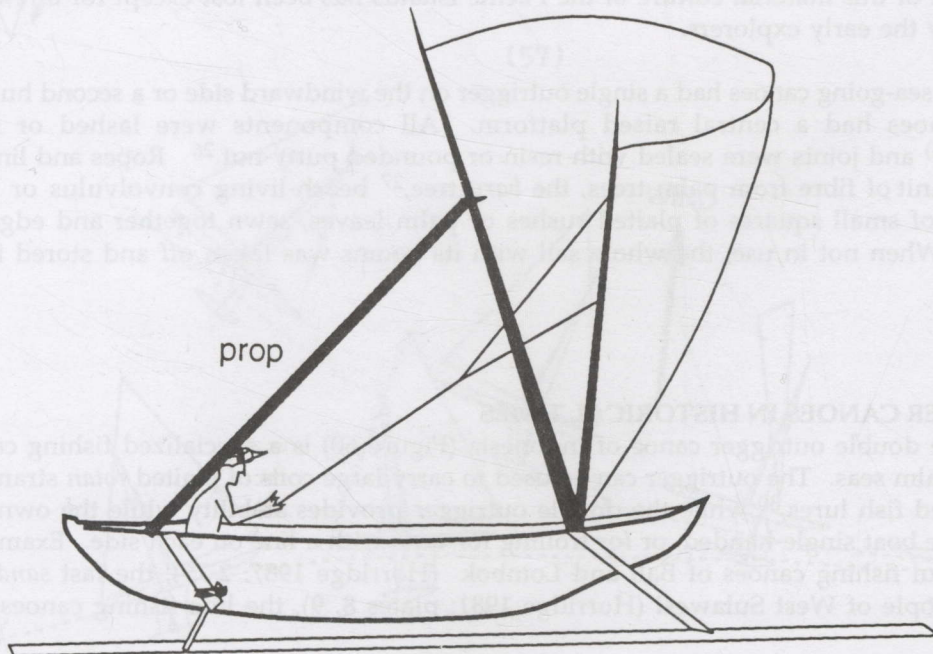


the stock of the Melanesians and the Micronesians. Their distribution is identified with that of the dug-out canoe with outriggers (Figures 54, 57, 64). They relied on large canoes for their over-water migrations. All branches of these migrations took with them the two-boom triangular sail with the mastless rig with no pulley and no fixed rudder (see below). The shallow draft and all the design details are adapted to the conditions of sailing over reefs in warm seas with no harbours. Eventually they reached the islands of the Eastern Pacific, and even visited coastal Central and South America, as inferred from the spread of the coconut and a breed of chicken that lays blue eggs (Langdon 1989) and they carried back into their Pacific cultures the sweet potato, a variety of cotton and possibly a few other plants.

Travelling eastwards through the region of monsoon winds was easy, and the first major hurdle was the stretch of 900kms. (550 miles) of open water between Vanuatu (New Hebrides) and Fiji. For this they probably had to wait for the development of the double canoe, large examples of which could carry one hundred people or several tons of cargo.¹¹ They also developed techniques for making nutritious dried food for survival at sea,¹² ways of carrying fire, seeds and living shoots¹³ out of contact with sea-water, and numerous techniques for fishing, plaiting, sewing and making string.¹⁴

The rig of their sailing canoes was the two-boom triangular sail (Figures 52, 54, 55) supported on a prop which was used to push up the sail, which was then held up by a stay to the outrigger boom on the windward side. The two supporting booms of the sail distributed the load over the weak material. The sail was pushed up with a prop which pivoted freely on its lower end, so that bending forces were avoided, rather than pulled up on a halyard, which requires much stronger rope and a pulley. The pulley was unknown in the Pacific until the arrival of the western explorers.¹⁵ The sail pivots on its tack (the lower forward corner) and tilts forward to steer the craft downwind (Figure 55) or backward to go upwind. Although large steering oars were used, they were never mounted on pivots, as in Arab, Chinese, Indian or Western cultures.

Figure 55: Position of the two-boom triangular sail going downwind



The design of the rig in historical times followed some simple rules. The sail of matting¹⁶ was weak and heavy when wet. Therefore, loads along the edges of the sail were distributed by the wooden or bamboo booms laced or sewn to it. The pole that held up the sail was pivoted freely at its base so that there was no bending load on it.¹⁷ 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 wind on the sail easily lifted the outrigger and spilled the wind. The booms of the sail had flexible ends to assist in spilling a gust. The sail was pulled well down fore-and aft to go into the wind (Figures 52, 54 and on the left in Figure 56), and was tilted forwards and across the boat to go downwind (Figure 55 and on the right in Figure 56). To tack, the bows were pointed downwind and the sail allowed to swing right round the front as the sheet was carried round the front to the other side (Figure 56).

Alternatively, the tack of the sail could be lifted and carried to the other end of the hull (Figure 57), as was done on the single outriggers of the Marianas, the Carolines, Fiji, Tonga, and the double canoes of Fiji and Tonga,¹⁸ all of which were reversible end for end. These are general features common to most of the area of the mastless rig on the map (Figure 58).

Also held in common in historical times were many details of the hull design. The hull was hollowed from a single log¹⁹ except where large trees were not available, in which case planks were carefully carved from driftwood, fitted and sewn together. The main hull usually had the sides raised by an additional plank on each side, and forked stem and stern pieces were added at the ends. This five-part canoe²⁰ was almost identical in design from Madagascar, through Indonesia and the Pacific to Tahiti and Hawai'i.

Next, the outrigger booms must be lashed down very firmly. This was done by leaving projecting lugs²¹ on the inside of the hull, to which were attached flexible ribs or small cross bars (called spreaders) fitted inside the hull (Figure 59). The lashings were of non-extensible *rotan* or other vines which tightened up when wet. Inshore fishing canoes had the outrigger booms lashed over an open hull but some offshore travelling canoes had the hull sealed²² and the superstructure raised above the waves on a waterproof rectangular box which acted as a hatch so that goods could be kept dry within the hull. A platform extended as far as the outrigger booms. Exact designs varied²³ but the same principles were constantly observed, and there is a variety of evidence that the principles were embodied in myths and ceremonies.²⁴ Sadly, most of this material culture of the Pacific Islands has been lost except for a few canoes collected by the early explorers.

All sea-going canoes had a single outrigger on the windward side or a second hull.²⁵ Big double canoes had a central raised platform. All components were lashed or stitched together,⁽¹⁴⁾ and joints were sealed with resin or pounded putty-nut.²⁶ Ropes and lines were plaited sennit of fibre from palm trees, the *baru* tree,²⁷ beach-living convolvulus or vines.²⁸ Sails were of small squares of plaited rushes or palm leaves, sewn together and edged with boltrope. When not in use, the whole sail with its booms was taken off and stored in a dry place.²⁹

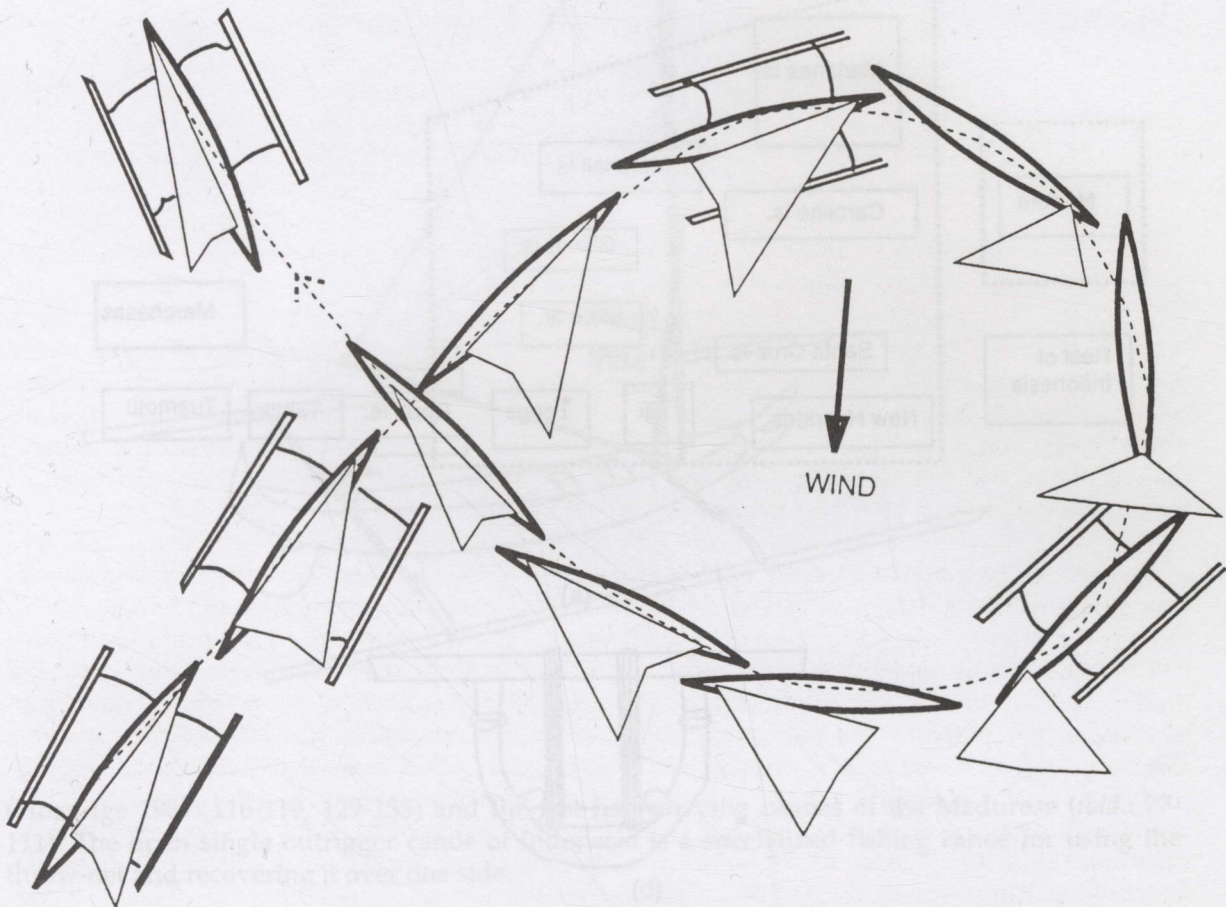
OUTRIGGER CANOES IN HISTORICAL TIMES

The double outrigger canoe of Indonesia (Figure 60) is a specialized fishing canoe for relatively calm seas. The outrigger can be used to carry large coils of plaited *rotan* strands used for anchored fish lures,³⁰ while the double outrigger provides stability while the owner pulls fish into the boat single-handed, or for trolling for tuna with a line on each side. Examples are the colourful fishing canoes of Bali and Lombok (Horridge 1987: 2-75), the fast *sandé* of the Mandar people of West Sulawesi (Horridge 1981: plates 8, 9), the line fishing canoes of Java

Figure 56: Position of sail in relation to wind

Figure 57: The tack of the sail in relation to wind

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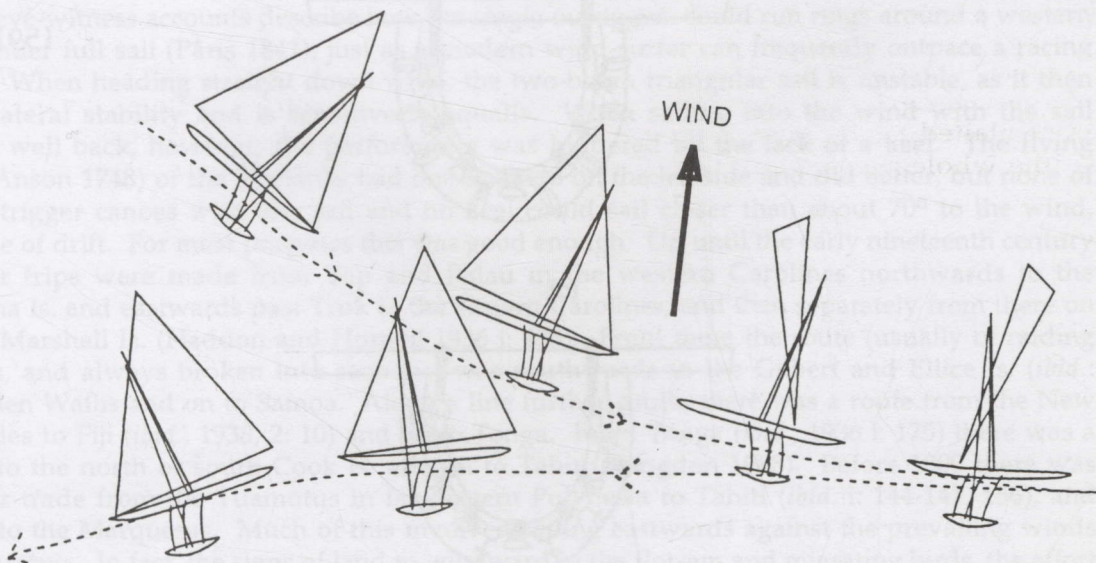


Figure 58: Map of the distributions of the mastless rig in historical times
Figure 59: Attachment of the superstructure to the hull

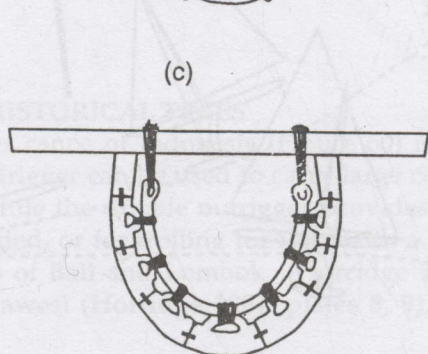
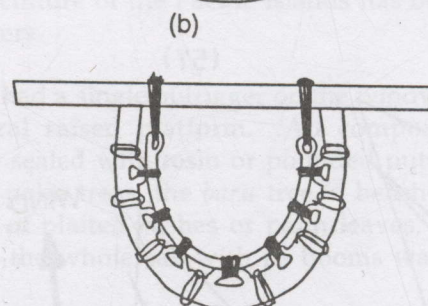
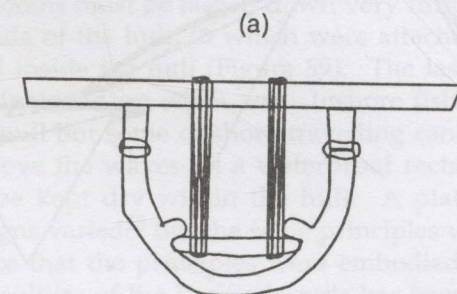
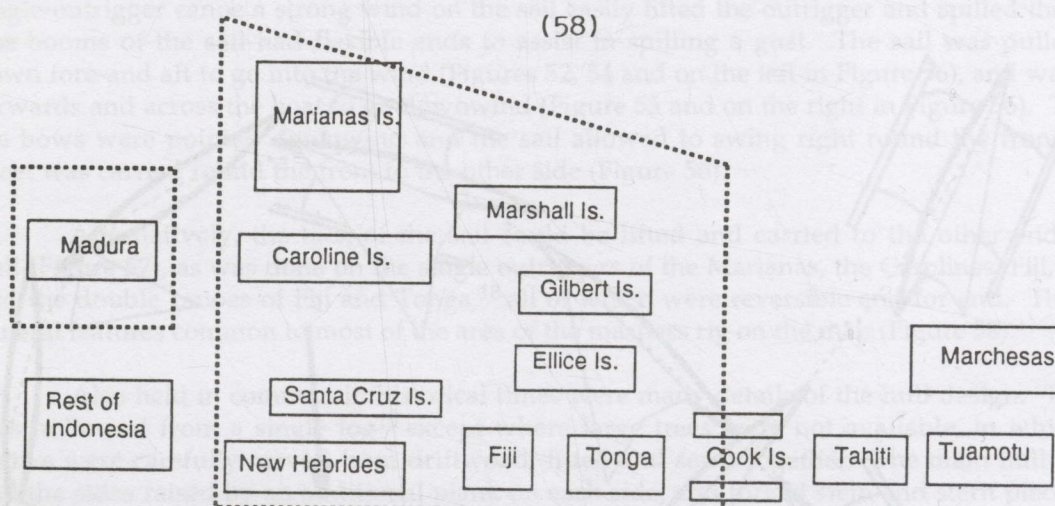
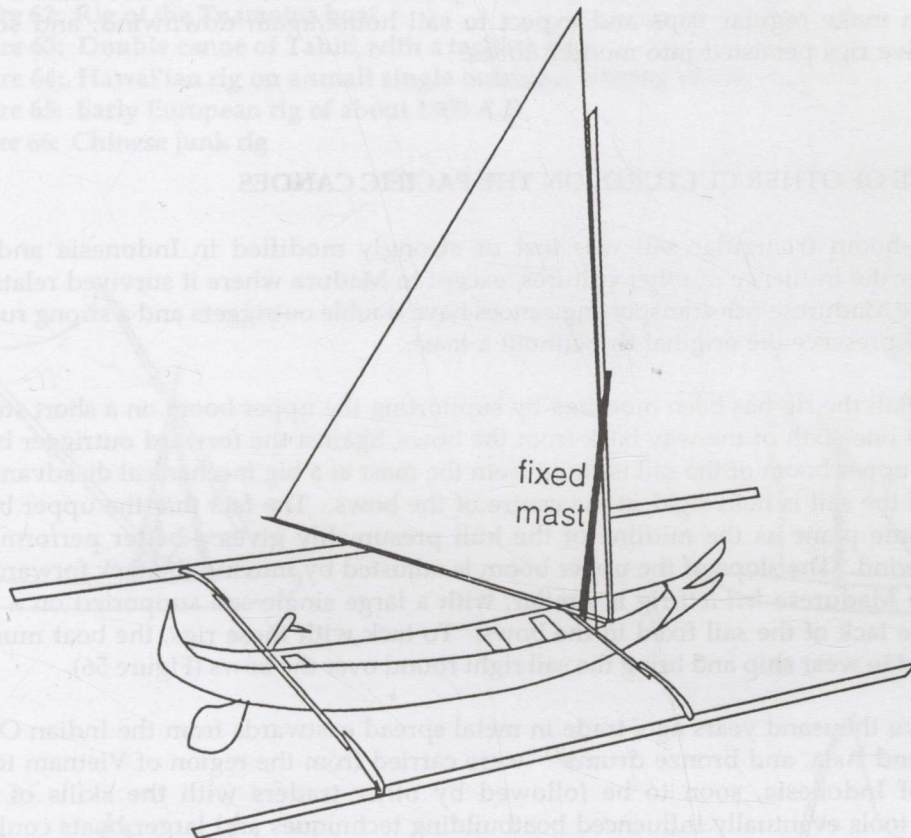


Figure 60: Balinese double outrigger trolling canoe



(Horridge 1987: 116-119, 129-135) and the fast fish-carrying canoes of the Madurese (*ibid.*: 77-111). The open single outrigger canoe of Indonesia is a specialized fishing canoe for using the throw-net and recovering it over one side.

Performance depends on the exact rig, and was superb with the wind on the quarter. Many eye-witness accounts describe how the single outriggers could run rings around a western ship under full sail (Pâris 1841), 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 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) of the Marianas had one flat side on the lea side and did better, but none of the outrigger canoes with one sail and no keel could sail closer than about 70° to the wind, because of drift. For most purposes this was good enough. Up until the early nineteenth century regular trips were made from Yap and Palau in the western Carolines northwards to the Mariana Is. and eastwards past Truk to the eastern Carolines, and then separately from there on to the Marshall Is. (Haddon and Hornell 1936 i: 438). From there the route (usually of raiding parties, and always broken into sections) was southwards to the Gilbert and Ellice Is. (*ibid.*: 440) then Wallis and on to Samoa. Along a line further south, there was a route from the New Hebrides to Fiji (*ibid.*, 1938, 2: 10) and on to Tonga. From Tonga (*ibid.*, 1936 i: 175) there was a route to the north or south Cook Is. and on to Tahiti (Langdon 1988). Before 1800 there was regular trade from the Tuamotus in far Eastern Polynesia to Tahiti (*ibid.* i: 144-147, 156), 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 effort of getting upwind and the high probability of getting back home if in difficulties, have contributed to the development of boats and rigs by many peoples, notably the Vikings, the Portuguese and the English.

Sailing north or south is relatively straightforward in the Pacific. The Polynesians also had the opportunity every few years of sailing eastwards with favourable winds.³¹ In the Archipelago east of Asia, the winds are dominated by the monsoons, and reverse twice a year. Sailors there can make regular trips and expect to sail home again downwind, and so the relatively primitive rigs persisted into modern times.

THE INFLUENCE OF OTHER CULTURES ON THE PACIFIC CANOES

The two-boom triangular sail was lost or strongly modified in Indonesia and the Philippines under the influence of other cultures, except in Madura where it survived relatively unchanged.³² The Madurese fish-transporting canoes have double outriggers and a strong rudder support, but they preserve the original rig without a mast.

Around Bali the rig has been modified by supporting the upper boom on a short stubby mast which is set one-sixth of the way back from the bows, against the forward outrigger boom (Figure 60). The upper boom of the sail is slung from the mast at a big mechanical disadvantage, while the tack of the sail is held rigid in the centre of the bows. The fact that the upper boom is held in the same plane as the midline of the hull presumably gives a better performance when sailing upwind. The slope of the upper boom is adjusted by moving the tack forwards or backwards. The Madurese *leti-leti* rig is similar, with a large single sail supported on a very stiff mast and the tack of the sail fixed in the bows. To tack with these rigs, the boat must be turned downwind to wear ship and bring the sail right round over the bows (Figure 56).

About two thousand years ago, trade in metal spread eastwards from the Indian Ocean and from mainland Asia, and bronze drums³³ were carried from the region of Vietnam to the Eastern limits of Indonesia, soon to be followed by other traders with the skills of iron smithying. Iron tools eventually influenced boatbuilding techniques and larger boats could be made. The curved chisel³⁴ made holes accurate enough for dowels to be inserted between the abutting edges of hardwood planks instead of or as well as stitches and lashings (Figure 59). 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. This was the lashed-lug boat (Horridge 1982), which was the standard planked boat of the East Asian Archipelago for about five hundred years, say A.D. 800 to 1300. In this period traders introduced the tilted rectangular³⁵ or lugsail rig from the Indian Ocean, where square sails must have been known since the times of Alexander the Great or before.³⁶

The latest of these traders and technicians with iron are the Buginese, who reached a little way along the north coast of New Guinea and fished for *trepang* off the north coast of Australia. They hung their quadrilateral tilted rectangular sail on a tripod mast, which was frequently copied on the boats of cultures they encountered. The Bugis are still establishing new colonies in Eastern Indonesia, effectively with the same mixed life-style as traders and exploiters. Their introduced diseases wipe out the local people on isolated islands. Their ancient rig, derived perhaps originally from ancient Egypt³⁷ spread only as far as the trade goods from Asia, that is to the Bismarck Archipelago and the Torres Straits (Haddon and Hornell 1938, 2: 162, 174, 246).

A fascinating series of events led to the modification of the Polynesian rig in the Tuamotus, spreading to Tahiti. As recounted in books by Bob Langdon (e.g. 1988), a Spanish caravelle, the *San Lesmes*, ventured out into the Pacific in 1526, and eventually was wrecked on the island of Amanu, in the Tuamotus. One of the iron cannon was recovered from the reef there in 1929. Some of the crew must have survived, as shown by numerous clues discovered by later explorers, from de Quiros in 1606 onwards. Captain Wallis of the *Dolphin* (*ibid.*: 65) who was the next westerner to visit in 1767, made a sketch of a boat with two fixed masts and two triangular sails (Figure 62) and made a description of a planked boat being constructed *frames first* on a beach. Many other details, notably ribs, straight keel and plank pattern, were

Figure 61: Tripod mast and tilted rectangular rig characteristic of Indonesian trading boats, 8th to 19th centuries

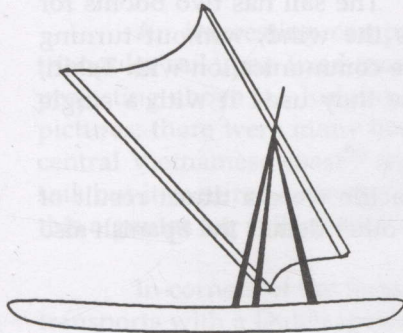
Figure 62: Rig of the Tuamotus boat

Figure 63: Double canoe of Tahiti with a tacking rig

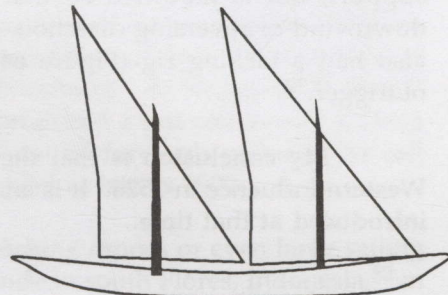
Figure 64: Hawai'ian rig on a small single outrigger fishing canoe

Figure 65: Early European rig of about 1500 A.D.

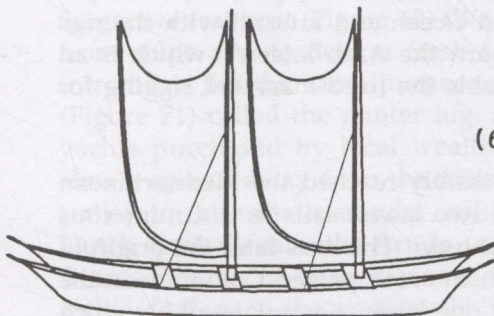
Figure 66: Chinese junk rig



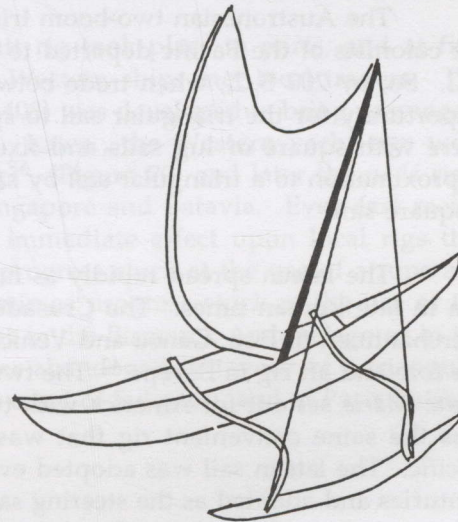
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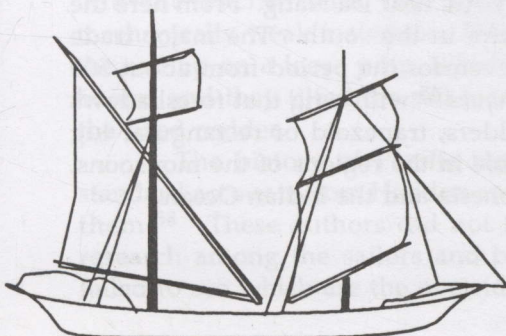
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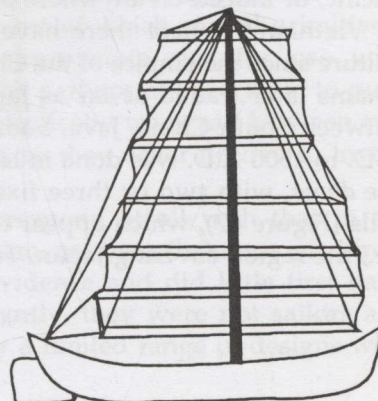
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western in style. Other findings, too numerous to be all coincidences, indicate that the Spanish caravelle had a lasting influence on the local population. The dogs of the Tuamotus had longer hair in more colours than the Polynesian dogs, so were much prized. The explanation is that they were descended from shipwrecked Spanish dogs. For example, when Captain James Cook arrived in Tahiti in 1769, he found that special dog hair was traded from the Tuamotus to Tahiti for the decoration of capes and robes (*ibid.*: 94).

The rigs of the Tahitian canoes (Figure 63) as illustrated by Cook's artist, Sydney Parkinson,³⁸ had *two* curiously vertical sails that are unlike anything elsewhere in the Pacific, with masts that could have been copied from Western fixed masts. The rigs of the canoes of the Tuamotus and Society Is. had stays, unlike the Austronesian rig. The sail has two booms for support, but is modified so that it will tack to and fro across the wind, without turning downwind or reversing direction. The Hawai'ians, who had some communication with Tahiti, also had a tacking rig (Figure 64), but it is difficult to see how they used it with a single outrigger.³⁹

My conclusion is that the tacking rigs of the Eastern Pacific were a direct result of Western influence in 1526. It is an interesting question how many other details the Spanish also introduced at that time.

THE TRIANGULAR RIG SPREAD WESTWARDS

The Austronesian two-boom triangular sail and mastless rig must have evolved before the colonists of the Pacific departed to become the Micronesians and Polynesians, before 2000 B.C. So, by 200 B.C., when trade between Arabia, India and China developed, there was an opportunity for the triangular sail to spread into the Indian Ocean and interact with the rigs there with square or lug sails and fixed masts. So was born the Arab lateen⁴⁰ which is an approximation to a triangular sail by sailors who had available the fixed mast and rigging for a square sail.

The lateen spread rapidly as far as Egypt⁴¹ and possibly reached the Mediterranean Sea in late Roman times. The Crusader ships of 1268 had two lateen sails as did numerous merchantmen of Pisa, Genoa and Venice in the thirteenth century. This was later the origin of the fore and aft rig in Europe.⁴² The two small caravelles which accompanied Columbus in the *Santa Maria* set out for America with two masts, each with one large triangular sail,⁴³ which was the same convenient rig that was later introduced by the *San Lesmes* into the Eastern Pacific. The lateen sail was adopted eventually by the Portuguese of the thirteenth-fourteenth centuries and adapted as the steering sail (Figure 65) on the mizzen mast (Landström 1961). So the triangular sail itself completed the circumnavigation of the world.

The Chinese rig (Figure 66) and boatbuilding designs had negligible influence on the Pacific, or indeed on anywhere outside China. Chinese rigs meet Austronesian rigs on the coast of Vietnam,⁴⁴ where there have been many sewn boats and signs of Austronesian maritime culture since the empire of the Chams, based on a port at Hoy An, near Da Nang. From here the Chams later traded as far as Japan in the north and Sumatra in the south. The major trade between South China, Java, Sumatra and South India, however, for the period from about 500 A.D. to 1500 A.D. was done in large planked ships called *jonques*⁴⁵ with a rig that foreshadows the *dhow*, with two or three fixed masts, fixed quarter rudders, trapezoid or rectangular lug sails (Figure 67), which appear to have been the most suitable in the regions of the monsoons, i.e., the region covering Japan, Taiwan, the Philippines, Indonesia and the Indian Ocean.

COLONIAL INFLUENCES

With the arrival of the western colonists and traders, the old rigs were quickly exchanged for new ones in many parts of the Pacific, sometimes in a very short time, as rigs are easily seen and copied. In Hawai'i, for example, square sails and topsails were quickly assimilated. In Indonesia, boats that should have no forestay were fitted with a jib-sail, which had to be taken down every time that the boat went about.⁴⁶ Ancient technology of sails, rigs with plaited sennit and tilting masts are too prone to accident. Contemporary sailcloth generates stresses that pull out stays and destroy a traditional hull. Therefore the whole technology had to change together. Most of the Polynesian sailing traditions were quickly given up, but some have been recently revived in modern guise.⁴⁷

An interesting compromise between old and new was the hoisting of a two-boom triangular sail upon fixed mast, so that one of the booms lies parallel to the mast (Figure 68), but projecting above it. Judging from cave paintings on the Thailand coast and other sources of pictures, there were many boats of this type in the nineteenth century. At Singapore,⁴⁸ Java,⁴⁹ central Vietnamese coast⁵⁰ and in Micronesia,⁵¹ this system produced a fast convenient tacking sail, but it required a strong fixed rudder because the sail will not tip forwards or back. We call this a gunter lug sail, as on the Mirror dinghy. It reached England as late as 1900.

In corners of the former Dutch empire one still finds fishing canoes or even large sailing transports with a Dutch spritsail rig (Figure 69), as found at Ende in south Flores, Indonesia,⁵² in Jakarta Bay,⁵³ and even in the eastern Pacific.⁵⁴ The Malaysian coasts still have plenty of small boats with a lug sail that is a trapezoid or rectangular sail suspended on a fixed mast by two halyards ending at different distances from the centre of the upper boom⁵⁵ (Figure 67).

Even the adoption of the Western fore-and-aft rig took place in parts, and at first imperfectly, starting at major ports and places where Western ships met local traders. The Singapore fast boat (Figure 68) (Warrington Smyth 1929: 408) was developed to bring passengers from ships and to deliver fresh fruit and vegetables. Later, the Western yacht rigs were introduced for the same purpose, speed. The gaff rig⁵⁶ (Figure 70) and later the *nadé* rig⁵⁷ (Figure 71) called the gunter lug, also spread from Singapore and Batavia. Even fast racing yachts purchased by local wealthy colonists had an immediate effect upon local rigs that slowly spread away from the main ports. Sometimes progress stuck 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, as in the Bismarck Archipelago or in the Torres Straits. In some places the square sail was later 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.

CONCLUSION

Making sense of the Pacific rigs is based first upon the limited distribution of the pulley, the fixed mast, the fixed rudder and the square sail, none of which spread primitively into the Pacific with the Polynesians, who had more appropriate rigs for use with mechanically weak materials. They used sennit not rope, which perhaps obliged them to push the sail up on a loose prop, which in turn supported the mechanically weak sail between two booms and they tilted the sail fore-and-aft on its tack to steer, so they never needed to invent the fixed rudder.

The history of Pacific rigs given here does not correspond at all with that in the standard accounts from Haddon and Hornell, Bowen or Needham, or others that are copied from them.⁵⁸ These authors did not take into account all the evidence and did little first hand research among the sailors and boatbuilders. More importantly, they were not sailors and failed to see which are the overriding considerations and why a limited range of designs were

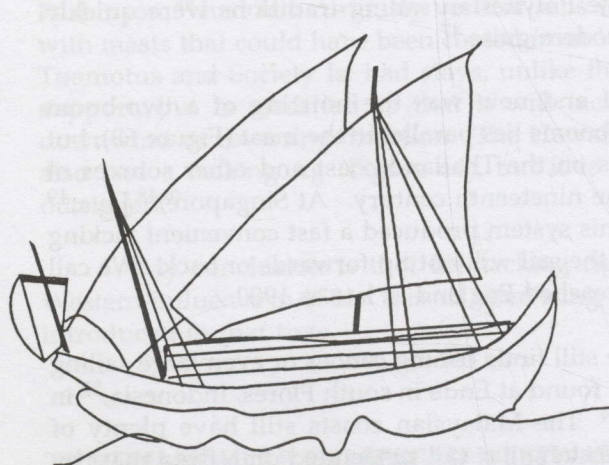
Figure 67: Malaysian trapezoid sails on fixed masts on 16th century local *jonque*

Figure 68: Two-boom triangular sail on a fixed mast, as on Singapore fast boat

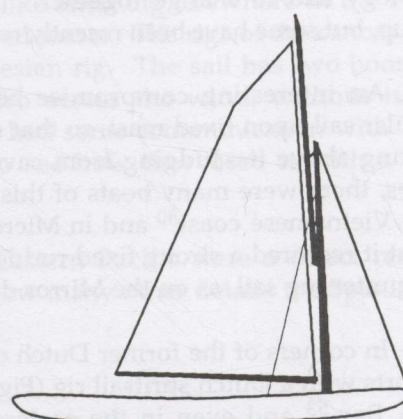
Figure 69: Dutch spritsail

Figure 70: Gaff rigged cutter

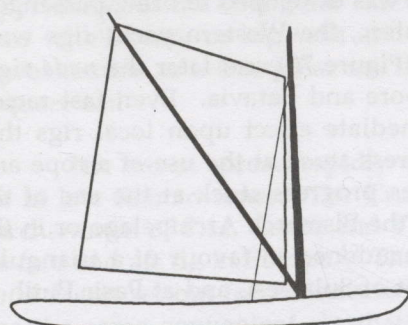
Figure 71: Gunter (*nadé*) rigged cutter; *lambo* in Indonesia



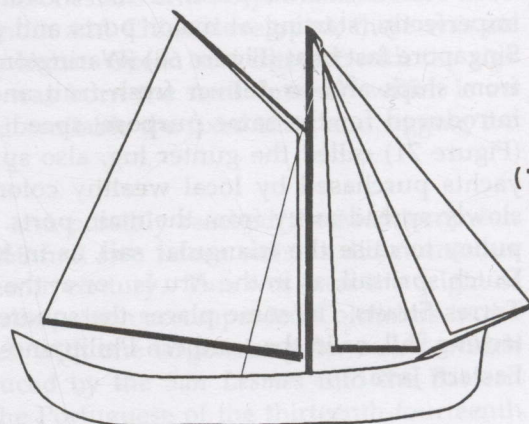
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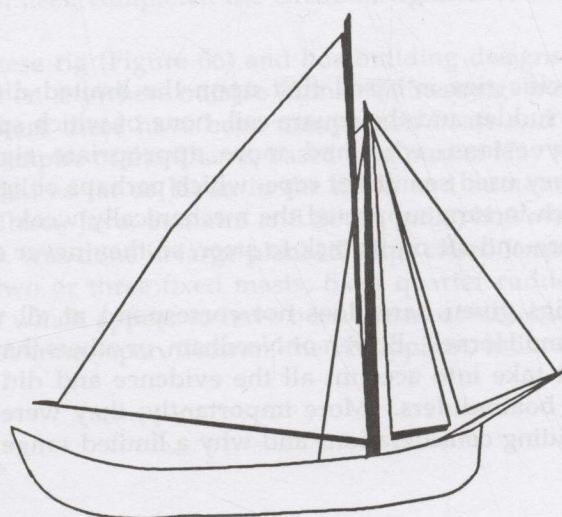
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present in the Pacific when the Western explorers arrived. You have to get away from the Western ideas that the square sail, fixed mast and rudder are primitive in the Pacific and that sails were invented only once. The best introductions to an understanding of Pacific rigs are the study of rigs currently in use by the Madurese, by learning the art of windsurfing with a tilting mast, by consideration of the optimum use of the limited materials that were available, and by working out what sensible sailors would do with the means available to them.

NOTES

1. There were easy crossings all the way to Australia, and to New Guinea at times of minimum sea level. One puzzle is that *Homo* occupied Java, and presumably much of coastal South-East Asia for 500,000 years, but there is evidence of only 50-80,000 years of occupation of Australia. The great shrinking of the land area of the islands (the Sunda Shelf) caused progressive flooding of coastal lands and forced people to move repeatedly (by raft?) until they developed tools to build dug-outs.
2. The timescale for Austronesian expansion is much too short and recent for the development of tropical agriculture. For numerous cultures of South-East Asia and the Archipelago before the Austronesians, see Bellwood (1978, chap. 3).
3. Non-Austronesian languages from earlier periods persist in Timor, Papua-New Guinea and parts of Halmahera. Austronesians also spread to the Cham region of the Vietnamese coast.
4. *Taro*, *tapa* for bark cloth, breadfruit, sugar cane, banana.
5. Pottery not made on a wheel but by beating while holding a stone within the pot. When sand is mixed with the clay, such pots can be used for cooking. They were decorated in a simple geometric style; examples are still made in the Kai Is. Lapita pottery has been found in a long arc from the Solomon Is. to the far Eastern Pacific, but the Polynesians lost the art of making it. The earliest, in Santa Cruz Is. and Fiji, is dated 1300-1500 B.C. See Green, in Jennings (1979: 33).
6. A common theme in Pacific art styles can be traced from the earliest bronzes of China (Zhang dynasty), which were based on earlier wood carving, into the tattoo and wood carving motifs of the Maoris and as far east as the Marquesas Is.
7. The most primitive of their surviving languages are thought to be the three of central Taiwan.
8. Madagascar was first reached by Indonesians probably about 200 B.C., but later migrations followed, perhaps over a period of one thousand years. Wood from Sumatra drifts to the coast of Madagascar.
9. Examples are boat coffins in Sulawesi and Sumba, the stone boat of Sangli Dol (Lat. 7° 51' S, Long. 131° 21' E) on the east coast of Tanimbar, and the boat terminology for the parts of the house in Sumba.
10. Melanesian languages are Austronesian, but dark colour and fuzzy hair are not Austronesian traits.
11. This is exactly the right situation to encourage experiment with new types of rig and boat, because bold explorers could see flotsam coming from land upwind and could expect to return home again downwind.

12. Fermented breadfruit, cooked and dried, makes a sugary food that keeps for long periods (Pâris 1841).
13. Most of the cultivated plants had to be carried as shoots because they were propagated vegetatively.
14. The Polynesians made rope and string by plaiting not by twisting.
15. The example suggested in Anson (1748) on an illustration of a flying *proa*, and reproduced by Haddon and Hornell (1936 i: 414) was an error.
16. Small squares of woven rushes or palm fibre about 50cms. in size were sewn together to make sails.
17. The chief design feature of sophisticated mechanical structures is to avoid concentrations of stress, especially when the materials are weak. Many canoe structures were built like basket chairs to avoid stress concentrations.
18. The sail cannot swing over the hull to the other tack because the prop is in the way.
19. Canoe hulls were carved from trunks of jackfruit, breadfruit or several hardwood trees that were abundant in high islands.
20. The hull of a five-part canoe is the female hollow body. 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 Bali. The Bugis and Makassarese boat builders have a similar *kawinan* ceremony when the stem is joined to the keel in a new traditional hull. See Horridge (1987).
21. The traditional method of holding a boat together was by putting into tension the flexible ribs lashed to projecting lugs on the inside of the hull or planks (figure 59b). See Horridge (1982).
22. See Pâris (1841, plates 114,118). Hulls were sealed with dammar-type resin and with pounded putty nut.
23. Haddon and Hornell (1936) illustrate numerous types.
24. Malinowski (1922, chapter 5) describes the importance of ceremonies during the building of a canoe. The lashings were renewed with great ceremony before every voyage. Horridge (1987: 66-72) describes the surviving ceremonies of Bali.
25. The second smaller hull was given the same name, *kata* or *katir* as the outrigger float. The double outrigger canoe, with both floats in the water at all times, is specialized for inshore fishing and is not suitable for travelling in the open ocean.
26. 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 has persisted in the Indian Ocean to this day.
27. The *baru* tree, *Hibiscus tiliaceus*, has seeds that float and a very wide tropical coastal distribution. The bark makes a strong fibre, also called *baru* in many languages.
28. Many of these plants were transported by canoe.
29. Sails were not lowered; they were closed upwards and lifted off the boat complete with their two booms. This is still done where the two-boom triangular sail is used.

30. 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 net the fish sheltering among the fronds each day.
31. Under the influence of changes every few years in the *El Niño* Current which crosses the Pacific.
32. See Horridge (1987, figures 46, 49 and frontispiece).
33. Dong S'on drums, see Bellwood (1978: 222).
34. Iron tools spread with traders from mainland Asia at least by the fifth century A.D. Iron was smelted in large quantities in Borneo in the tenth-twelfth centuries and in Sulawesi. Iron metal for foundry work by local smiths was traded as far as the coasts of New Guinea and the east edge of the Philippines.
35. The fixed tripod mast and tilted rectangular sail were once common throughout central Indonesia.
36. Alexander the Great had a fleet on the Indian Ocean, but he must have been using existing boats of Indian or Persian construction. At that time all Indian Ocean ships had rectangular sails so far as is known. Fixed masts and square sails are depicted on carved murals of the eighth-ninth centuries on the temples of Borobodur and Angkor Wat. For a reference to hints of early lateen sails in Roman times, see Casson (1971: 268-9).
37. Ancient Egypt used the rectangular sail on a fixed mast; ref. Casson (1971: chap.2).
38. Tahitian rigs in Dodd (1972).
39. Hawai'ian tacking rig in Holmes (1981: 65).
40. The origin of the lateen rig in the Indian Ocean is obscure, as would be expected if it was derived from Austronesian traders in South India about the 1st century A.D.
41. The Nile *gaiassa* rig is of unknown age. The lateen sail was common in the Eastern Mediterranean from the ninth century, see Landström (1961: 80 onwards).
42. The lateen on the mizzen mast appeared in 1367, ref. Landström (1961: 91-92).
43. Columbus' caravel rig, ref Landström (1961: 106).
44. Ref. to southern limit of Chinese rigs in Piétri (1949).
45. Refs. to the *jonque* in Manguin (1980).
46. Account in Wallace (1869: chapter 28).
47. Look for modern detail in accounts of modern "ancient" boats, e.g., Finney (1979).
48. For a scale drawing of a Singapore fast boat see Warington Smyth (1929: 408).
49. Canoe rigs of Bali and Java in Horridge (1987).
50. The *Ghe Cáu* of Phan Rang in Piétri (1949: plate 43).
51. Micronesian modern rig in Knox-Mawer and Carmichael (1968: 40d).
52. Ende rig in Burningham (1990, figure 10).

53. Jakarta Bay rig, see Horridge, *The Prah* (1981: plate 24).
54. Sprintsail in the Leeward Is. in Haddon and Hornell (1936 i: figure 84).
55. Some illustrations in Warington Smyth (1929: chap. 11).
56. Gaff rig lambo, see Horridge *The Prah*, (1981: figure 32).
57. *Nadé* rig, (*ibid.*, 1981: figure 33).
58. My fuller discussion in Horridge (1986) omits the data from Langdon about a western rig arriving in the Eastern Pacific in 1526. For R.L. Bowen, see *American Neptune* 13: 81-117; 13: 185-211; 19: 155-199; 19: 274-306. For J. Needham, see *Science and Civilisation in China*, Vol. 4, part 3, Cambridge: Cambridge University Press.

REFERENCES

- Anson, Baron George. 1748. A voyage round the world (1740-44), compiled by Richard Walter. Reprinted (G. Williams, ed.) 1974. Oxford: University Press.
- Bellwood, P. 1978. Man's conquest of the Pacific. Auckland N.Z.: Collins.
- Burningham, N. 1990. Stemless boats of Ende Bay. The Beagle. Records of the N. Terr. Mus. Darwin 7: 105-119.
- Casson, L. 1971. Ships and seamanship in the ancient world. Princeton, N. J.: University Press.
- Dodd, E. 1972. Polynesian seafaring. New York: Dodd, Mead and Co.
- Finney, B. R. 1979. Hokule'a: The way to Tahiti. New York: Dodd, Mead and Co.
- Haddon, A. C. & Hornell, J. 1936-38. Canoes of Oceania. Bishop Museum Special Publication 27, 28, 29. Reprinted as one Vol. 1975. Honolulu, Hawai'i Bishop Museum Press.
- Holmes, T. 1981. The Hawai'ian canoe. Hanalei, Hawai'i: Editions Limited.
- Horridge, G. A. 1981. *The prahu*. 2nd. ed. 1985. Kuala Lumpur: Oxford University Press.
- Horridge, G. A. 1982. The lashed-lug boat of the Eastern Archipelagoes. Greenwich: Monograph 40. Maritime Mus.
- Horridge, G. A. 1986. The evolution of Pacific canoe rigs. *Journal of Pacific History* (21) 83-99.
- Horridge, G. A. 1987. Outrigger Canoes of Bali and Madura, Indonesia. Honolulu: Bishop Museum Press.
- Jennings, J. D. (ed.) 1979. The prehistory of Polynesia. Canberra: Australian National University Press.
- Johnstone, P. 1980. The sea-craft of prehistory. London: Routledge and Kegan Paul.
- Knox-Mawer, J. and Carmichael, P. 1968. A world of islands. London: Collins.
- Landström, B. 1961. (Eng. ed.) The ship. London: Allen and Unwin.
- Langdon, R. 1988. The lost caravel re-explored. Canberra: Brolga Press.

- Langdon, R. 1989. When the blue-egg chickens come home to roost. *Journal of Pacific History*, 24 :164-192.
- Malinowski, B. 1922. *Argonauts of the western Pacific*. London: Routledge and Kegan Paul.
- Manguin, P.-Y. 1980. The Southeast Asian ship: An historical approach. *Journal of Southeast Asian Studies*, 11: 266-276.
- Nishimura, S. 1925. *Ancient rafts of Japan*. Tokyo: Publ. Soc. Naval Architects.
- Pâris, F. E. 1841. *Essai sur la construction navale des peuples extra-Européens*. Paris: Arthus Bertrand.
- Piétrì, J. B. 1949. *Voiliers d'Indochine*. Saigon: S.I.L.I.
- Wallace, A. R. 1869. *The Malay Archipelago*. London: Macmillan.
- Warrington Smyth, H. 1929. *Mast and sail in Europe and Asia*. London: Blackwood.

LEGENDS FOR ILLUSTRATIONS

Figure 52. An idea of 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 lashed logs or bamboo. Plenty of such rafts have sailed in historic times (notes 2-6).

Figure 53. The adze with bent haft, a suitable tool for making a dug-out canoe and carving flat planks. The binding tightens as it is used.

Figure 54. The five part canoe with a two-boom triangular sail. This double outrigger type is still used in Madura for fishing and fast transport of fish.

Figure 55. The position of the two-boom triangular sail when going downwind. Note the forward extent of the outrigger floats to prevent nose-diving.

Figure 56. The sail lies in front of the mast and therefore there can be no forestay. To go about, the boat must be turned downwind and the sail allowed to come right around to the other side over the bows, together with the sheet.

Figure 57. 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 58. Map of the distributions of the mastless rig in historical times.

Figure 59. 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.

Figure 60. Balinese double outrigger trolling canoe, with a short fixed mast and a two-boom triangular sail. For tacking with this rig, see figure 56.

Figure 61. The tripod mast and tilted rectangular rig that is characteristic of the Indonesian trading boats from the eighth to the nineteenth centuries

Figure 62. Rig of the Tuamotus boat from a drawing by Captain Wallis in 1767.

Figure 63. Double canoe of Tahiti with a tacking rig. The drawings of Cook's artists suggest that the masts could be tipped forwards or back to trim the direction of sailing.

Figure 64. Hawai'ian rig on a small single outrigger fishing canoe.

Figure 65. Early European rig of about 1500 A.D., with the triangular lateen sail on the mizzen mast.

Figure 66. Chinese junk rig

Figure 67. Malaysian trapezoid sails on fixed masts on a sixteenth century local *jonque*.

Figure 68. Two-boom triangular sail attached to a fixed mast, as on the Singapore fast boat.

Figure 69. Dutch spritsail.

Figure 70. Gaff rigged cutter, still in use in parts of Indonesia.

Figure 71. Gunter (*nadé*) rigged cutter, called a *lambo* in Indonesia.